DOCUMENT RESUME

ED 060 893 LI 003 561

TITLE Hearings Before the General Subcommittee on Education...Ninety-First Congress, First Session on H.R. 8809...April 29 and 30, 1969. National Science Research Data Processing and Information Retrieval System. [Complete Text of the Hearings].
INSTITUTION Congress of the U.S., Washington, D.C. House Committee on Education and Labor.
PUB DATE 69
NOTE 408p.; (1400 References)

EDRS PRICE MF-$0.65 HC-$16.45
DESCRIPTORS Documentation; Federal Legislation; *Information Processing; *Information Retrieval; *Information Systems; *National Programs; *Scientific Research
IDENTIFIERS *Scientific and Technical Information

ABSTRACT

Reported are the hearings held on April 29 and 30, 1969 before the General Subcommittee on Education of the U.S. House of Representatives on H.R. 8809, a bill to amend Title IX of the National Defense Education Act of 1958 to provide for the establishment of a national information retrieval system for scientific and technical information. The purpose of the act is to implement a nationwide storage and retrieval system for scientific research data, using as many existing facilities as possible in order to avoid duplication and to assure quick access to and a constant inventory of, all science research data. [Testimonies by Dr. John Rothman and Mr. Robert November appeared earlier as ED 051 861]. (SJ)

NATIONAL SCIENCE RESEARCH DATA PROCESSING AND INFORMATION RETRIEVAL SYSTEM

HEARINGS

BEFORE THE

GENERAL SUBCOMMITTEE ON EDUCATION

OF THE

COMMITTEE ON EDUCATION AND LABOR

HOUSE OF REPRESENTATIVES

NINETY-FIRST CONGRESS

FIRST SESSION

ON

H.R. 8809

A BILL TO AMEND TITLE IX OF THE NATIONAL DEFENSE EDUCATION ACT OF 1958 TO PROVIDE FOR ESTABLISHMENT OF A NATIONAL SCIENCE RESEARCH DATA PROCESSING AND INFORMATION RETRIEVAL SYSTEM

HEARINGS HELD IN WASHINGTON, D.C.

APRIL 29 AND 30, 1969

Printed for the use of the Committee on Education and Labor

CARL D. PERKINS, *Chairman*

31-464

U.S. GOVERNMENT PRINTING OFFICE
WASHINGTON : 1969

COMMITTEE ON EDUCATION AND LABOR

CARL D. PERKINS, Kentucky, *Chairman*

EDITH GREEN, Oregon
FRANK THOMPSON, JR., New Jersey
JOHN H. DENT, Pennsylvania
ROMAN C. PUCINSKI, Illinois
DOMINICK V. DANIELS, New Jersey
JOHN BRADEMAS, Indiana
JAMES G. O'HARA, Michigan
HUGH L. CAREY, New York
AUGUSTUS F. HAWKINS, California
WILLIAM D. FORD, Michigan
WILLIAM D. HATHAWAY, Maine
PATSY T. MINK, Hawaii
JAMES H. SCHEUER, New York
LLOYD MEEDS, Washington
PHILLIP BURTON, California
JOSEPH M. GAYDOS, Pennsylvania
LOUIS STOKES, Ohio
WILLIAM "BILL" CLAY, Missouri
ADAM C. POWELL, New York

WILLIAM H. AYRES, Ohio
ALBERT H. QUIE, Minnesota
JOHN M. ASHBROOK, Ohio
ALPHONZO BELL, California
OGDEN R. REID, New York
JOHN N. ERLENBORN, Illinois
WILLIAM J. SCHERLE, Iowa
JOHN R. DELLENBACK, Oregon
MARVIN L. ESCH, Michigan
EDWIN D. ESHLEMAN, Pennsylvania
WILLIAM A. STEIGER, Wisconsin
JAMES M. COLLINS, Texas
EARL F. LANDGREBE, Indiana
ORVAL HANSEN, Idaho
EARL B. RUTH, North Carolina

GENERAL SUBCOMMITTEE ON EDUCATION

ROMAN C. PUCINSKI, Illinois, *Chairman*

HUGH L. CAREY, New York
WILLIAM D. FORD, Michigan
LLOYD MEEDS, Washington
JAMES G. O'HARA, Michigan
AUGUSTUS F. HAWKINS, California
WILLIAM D. HATHAWAY, Maine
PATSY T. MINK, Hawaii

ALPHONZO BELL, California
JOHN M. ASHBROOK, Ohio
ALBERT H. QUIE, Minnesota
JOHN R. DELLENBACK, Oregon
EDWIN D. ESHLEMAN, Pennsylvania
EARL B. RUTH, North Carolina

CONTENTS

NATIONAL SCIENCE RESEARCH DATA PROCESSING AND INFORMATION RETRIEVAL SYSTEM

TUESDAY, APRIL 29, 1969

HOUSE OF REPRESENTATIVES,
GENERAL SUBCOMMITTEE ON EDUCATION
OF THE COMMITTEE ON EDUCATION AND LABOR,
Washington, D.C.

The subcommittee met at 10:08 a.m., pursuant to notice, in room 2261, Rayburn House Office Building, Hon. Roman C. Pucinski (chairman of the subcommittee) presiding.

Present: Representatives Pucinski, Bell, and Dellenback.

Staff members present: Allan Kiron, technical adviser; John F. Jennings, subcommittee counsel, Alexandra Kisla, clerk; and Charles W. Radcliffe, minority counsel for education.

(The text of H.R. 8809 follows:)

[H.R. 8809, 91st Cong., first sess.]

A BILL To amend title IX of the National Defense Education Act of 1958 to provide for establishment of A National Science Research Data Processing and Information Retrieval System

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That (a) the first sentence of section 901 of the National Defense Education Act of 1958 is amended by striking out "a Science Information Service" and inserting in lieu thereof the following: ", A National Science Research Data Processing and Information Retrieval System.

"In order to avoid unnecessary and costly duplication in scientific research and to assure quick access to, and a constant inventory of, all science research data, such a nationwide system shall include close voluntary cooperation with, and utilization of, on a contract basis wherever practicable, all existing science research data processing and information retrieval facilities in the United States and its possessions including Government agencies, private and public universities, private and public laboratories and libraries, abstracting societies, professional organizations dealing with specific scientific disciplines and any other facilities dealing with dissemination of scientific research information.

"The purpose of this Act is to implement, not substitute, existing information retrieval facilities. Therefore, it is specifically prohibited under this Act for the National System to establish any Government-owned or operated science research data processing or information retrieval facility where such a facility already exists under either private or public ownership. The National System shall use every voluntary means to arrange for an orderly cataloging, digesting, and translating, with the aid of electronic devices, if necessary, of all scientific research data produced in the United States or available in the United States from other nations and through the national science research data processing and information retrieval system, make such information readily available to any scientist or researcher, either privately, publicly, or self-employed, through an appropriate communications network. The national system shall arrange for appropriate financial payment for all science data provided into the national system by private source."

(b) The center heading of section 901 of such Act is amended to read as shall (1) provide, or arrange for the provision of," and inserting in lieu thereof the following: "System, shall (1) provide".

SEC. 2. The first sentence of section 902(b) of the National Defense Education Act of 1958 is amended by striking out "Science Information Service" and inserting in lieu thereof the following: "National Science Research Data Processing and Information Retrieval System."

SEC. 3. (a) The heading of title IX of the National Defense Education Act of 1958 is amended to read as follows:

"TITLE IX—NATIONAL SCIENCE RESEARCH DATA PROCESSING AND INFORMATION RETRIEVAL SYSTEM"

(b) The center heading of section 901 of such Act is amended to read as follows:

"FUNCTIONS OF THE SYSTEM"

(c) The table of contents of such Act is amended by striking out

"TITLE IX—SCIENCE INFORMATION SERVICE

"Sec. 901. Functions of the service."

and inserting in lieu thereof the following:

"TITLE IX—NATIONAL SCIENCE RESEARCH DATA PROCESSING AND INFORMATION RETRIEVAL SYSTEM

"Sec. 901. Functions of the system."

Mr. PUCINSKI. The meeting will come to order.

I am very happy to see my colleague this morning. We hope as we move along other members of the committee will join us. I think we have six committees going this morning on various subjects, and members may come and go as they try to spend some time with each of the committees.

I am very pleased that we can resume hearings on H.R. 8809.

Six years ago we began hearings calling for the establishment of a national scientific and technical information system.

In the course of those hearings, witness after witness, representing most of the scientific disciplines, presented eloquent and convincing testimony describing the impenetrable paper curtain of scientific and technical information that literally blocks our scientists from effective access to the very information they need.

Many of you here this morning are familiar with the testimony contained in those earlier hearings. Our subcommittee learned, not only of the overwhelming advances in scientific and technical information, but the staggering task of tracing specific information that characterizes any serious scientific work today.

The conclusion of our witnesses was that our most efficient retrieval systems were incapable of handling the torrential flood of information. Enumerating bibliographies of bibliographies, ad infinitum, contributed to the problem. It did not solve it.

As a result, scientists and researchers tied up countless hours, days, weeks, and months of their valuable time searching for material related to their fields. All too often vast sums of private and public funds were poured into developing or perfecting processes which had been discovered years, even decades, earlier.

This deplorable waste of time, talent, and money cannot be justified any longer. The duplication, however unknowing, taking place in laboratories across this Nation is not only grossly inefficient; it is too expensive in human terms.

We need our scientists, researchers, and technical people free to operate in pursuit of ideas or projects that interest them.

And I might add at this point, this whole idea for retrieval systems started several years ago when we had a bitter debate on the floor of the House. At that time there were those who argued that there is too much waste and duplication in our scientific efforts in this country and that we ought to impose limitations on the amount of money that is made available for research.

I am not capable of sitting in judgment on a scientist's effort. I believe we ought to make available to the scientists of this country an information retrieval system so that they may have access to whatever information they need. The scientists would themselves impose the discipline that is necessary to avoid duplication.

I can't think of a scientist who would knowingly duplicate somebody else's work. The purpose of H.R. 8809 is to try to design a system which would make available to scientists information as readily as possible.

The bill we have under discussion today, H.R. 8809, is designed to serve as a coordinating mechanism—not to confine every scrap of scientific information under a single roof—but to seek the information, correlate it with similar or related information, and, through a network of electronic equipment, make that information instantly available to every working scientist in the country.

This bill does not seek to supplant existing retrieval systems—merely to augment their capability on a nationwide basis.

Six years ago the witnesses testifying on this subject repeatedly stressed our technical capacity to develop and operate such a national information system. The hardware and the electronics are easily within the range of our greatly increased skills.

Admittedly, this system will cost money—a lot of money. This is no sport for the meek to implement. Yet the millions of dollars that have already been expended, and are being expended at this very moment, in needless duplication of techniques already developed is unconscionable.

If the success of the past hearings on this subject can be measured by the extensive discussions, interest, and support expressed by the scientific community, then indeed the efforts of this committee have been rewarded beyond my expectations.

I was also gratified to see the emergence of a large group of studies specifically dealing with the concept of a national scientific and technical information system, including the Baker Report of 1958, the Crawford Task Force Study in 1962, the Weinberg Panel in 1963, the System Development Corporation Study in 1965, and the Science Communications Report in 1968. Not to mention the many, many task forces that are studying this problem and that have been at the White House level.

There has never before in the history of our Nation been so much support based on so much study pointing toward so great a promise for so many people.

As Dr. Jerome Wiesner said recently:

> The computer, with its promise of a millionfold increase in man's capacity to handle information, will undoubtedly have the most far-reaching consequences of any contemporary technical development.

And yet we do not have a national information system. While we wait, we are flooded with scientific and technical information at the rate of 65,000 words per minute.

Since our hearings 6 years ago, this rate of increase spawned a total 200 billion words—the equivalent of 25,000 encyclopedia volumes.

It would take the average scientist, reading 24 hours a day, 400 years just to cover the material added during the last 6 years.

I hope today to learn how much progress we have made in the direction of a national information system and what further steps must be taken to insure that this great Nation will reap the incalculable benefits of scientific and technical information.

And I might add that one of the things that have developed since we began hearings on this suggestion has been the meeting in Geneva 3 years ago, I believe, of some 2,300 scientists from all over the world. The meeting attracted scientists from the newly emerging nations of the world, as well as the small nations. They adopted a resolution pleading and urging the development of an information retrieval and dissemination system through which they could participate more readily in scientific development. In my judgment the development of a national information retrieval system could become a keystone of American foreign policy.

We can capture the imagination of scholars around the whole world if we can make available to them the information that has been generated in this country in scientific pursuits. I think this is the way to peace and this is the way to better understanding among nations.

All of these things led us to resume the hearings on this subject.

I am very happy to have our colleague here.

Would you care to add anything to what I have said, Mr. Dellenback?

Mr. DELLENBACK. As you pointed out, I was unfortunately caught, like many of our Members, in a situation where there are three different committees on which I am serving. I am due at all three of those hearings.

But I particularly wanted to be here to hear Dr. Seaborg, whom I have both heard of and have had a chance to meet briefly, and I welcome very much this opportunity.

I will both listen to you and read your testimony carefully. I think the problem is an important one for the world and for America. I am pleased to be in a position where I can have a chance to see if we can make some contribution to this legislation.

Mr. PUCINSKI. Thank you very much.

Our first witness this morning is Dr. Glenn T. Seaborg, Chairman of the Atomic Energy Commission, Nobel laureate, one of the foremost scientists of the world. Dr. Seaborg's credentials are well known to the members of this committee and the American public. He has had experience with the problem of scientific and technical information retrieval and our committee looks forward to hearing Dr. Seaborg's testimony on this subject.

Doctor, I would like to welcome you. Certainly there are few Americans and few people in this world better qualified to discuss this subject than yourself. This committee is privileged to have so distinguished a member of the scientific community resume hearings on this very, very difficult subject.

We have your statement here, Dr. Seaborg. You may proceed in any manner you wish. You can either read your statement or you may put it into the record in its entirety and discuss it.

STATEMENT OF DR. GLENN T. SEABORG, CHAIRMAN, ATOMIC ENERGY COMMISSION; ACCOMPANIED BY EDWARD BRUNENKANT, DIRECTOR, DIVISION OF TECHNICAL INFORMATION, ATOMIC ENERGY COMMISSION

Dr. SEABORG. Thank you, Chairman Pucinski and Congressman Dellenback.

I think perhaps, because it is a rather short statement, that I will read it and that would set the stage for any questions you might have.

I am pleased to appear before this committee to present some views on the proposed legislation to establish a National Science Research Data and Information Retrieval System. I have no hesitation in agreeing, Mr. Chairman, that the problem dealt with in this legislation is one of the major ones confronting modern society. Continued progress in science and technology requires effective communication of the nature and results of research.

This subcommittee has received in prior sessions impressive testimony about the magnitude of the information explosion which lies at the root of the problem.

Only recently I have had a personal experience which dramatized this phenomenon for me. I had occasion last year to publish in the Annual Review of Nuclear Science a review of recent research on the properties and methods of production of the heaviest chemical elements. In preparing this article, I asked our technical information people at Oak Ridge to compile a list of references to work conducted during the last 5 years on elements lying beyond plutonium in the periodic table of the elements. The resulting bibliography contained 579 entries, and in the article which ultimately appeared, I found it necessary to cite 332 references.

Let me at this point introduce my colleague, Mr. Ed. Brunenkant, who is Director of our Division of Technical Information, under which the Oak Ridge group operates.

To continue, when one considers that this is a quite specialized area of science, the magnitude of the information problem which confronts the average scientists and technologist comes into clear focus.

The information problem of scientists is to know what other scientists are doing and have done and what results they have achieved. Having this information enables scientists to give the proper direction to their own work. If they do not have it, they may duplicate each others work or proceed in ignorance of findings which might be helpful.

It seems quite apparent that a central element in any solution of the information problem is the use of electronic computers for retrieving information needed by individual scientific workers. I would caution, however, against considering that the establishment of a gigantic computerized system for identifying original literature within a given scientist's field of interest would constitute a sufficient solution. I think I might best serve the subcommittee by pointing out some other matters which need also to be considered in arriving at a full solution of the problem.

First, as I myself have found out, the original literature in most fields, even quite specialized ones, is now too large to be scanned by the individuals working in it. It is not only too large, but it varies too much in quality and interest. Thus, while a computerized system for retrieving original literature, including abstracts and indexes of the literature, must probably be a part of the ultimate solution, it is only a part. Various other devices must be added if science and the people working in it are to be adequately served.

The technical information system which we have set up at AEC recognizes some of these other needs. For example, we publish review journals in which the work going on in certain subareas of nuclear technology is summarized, analyzed, and evaluated. Such critical reviews of the scientific literature are of great value in enabling scientists and technologists to keep generally informed about developments in their fields without incurring the huge expenditure of time which might be necessary to comb the original literature.

Second, I would like to emphaize the number and variety of special fields that must be considered in establising a national retrieval system. We at the AEC sponsor the operation of over 25 specialized information and data centers at various institutions of learning, which provide data compilations and other publications bringing together new information in various subfields of science and technology for the benefit of specialists in those fields. Through these centers a few highly qualified scientists are able to extract and organize the most pertinent findings from the ponderous mass of original literature and thereby to make it unnecessary for each interested individual to comb the literature personally.

Third, I would enter a plea that in seeking mechanized solutions to this massive information problem we not lose sight of the human aspects of communication. Some of the most significant and stimulating contacts among scientists have always come about in informal person-to-person communications, in exchanges of correspondence, in conversations, at conferences, and the like. There is no true substitute for this type of interchange among professional colleagues and provision must be made for retaining it in information systems of the future.

Fourth, much of the information generated in scientific research must ultimately be made available not only to scientists working in the particular fields, but also to wider audiences which include teachers, students, scientists in related fields, managers, and informed citizens.

Repackaging in more digestible form than that in which the research was first reported is required for these audiences. Here we look to forms such as books, TV programs, films, film strips, articles in less specialized periodicals, and the like. A successfully performing information system should, as part of its function, be able to identify the subject matter which requires such treatment.

Fifth, another matter that should be considered in relation to the proposed legislation is its influence on, or restriction of, other retrieval systems. For example, since the Government is one of the prime producers of research and information, care should be taken to insure that the Government or a Government agency is not prohibited from developing and performing research if need be on scientific data processing and retrieval systems for its own benefit. Some non-Government organizations also have, or are developing, very significant information retrieval systems with the help of some Government support.

So it is also necessary to make sure that these systems continue to be aided individually as well as tied into any national system that may be developed. As one example of such a system I might point out the American Chemical Society's Chemical Abstracts Service Chemical Compound Registry. This computer-based registry, begun in 1960, has already registered more than 1 million chemical compounds and continues to add them at a rate of 4,000 to 5,000 per week. It already works closely with such Government organizations as the National Science Foundation, the National Library of Medicine, and the Food and Drug Administration. I mention these things not to downgrade the need ultimately for a national multidiscipline retrieval system, but to point out some of the complexities that might be involved in bringing such a system into operation. The task of coordinating existing systems will require much work and care.

Sixth, in considering the planning and implementation of the national system your legislation proposes, we must also carefully examine the state of the art—both from an equipment and manpower standpoint. I have had many people point out to me the difficulties involved in setting up a comprehensive data system. Some have stressed the technical problems while others have insisted that the development of our hardware up to date far exceeds our human capability to put it to maximum use. We need a great many more trained people in this field. And apparently the shortage of such personnel may exist for some time. Therefore, I have been told, we must avoid moving too quickly to avoid spreading our human talents and skills too thin.

Seventh, examining a different aspect of the proposal, it should also be borne in mind that the scientific information problem cannot be solved on a purely national basis. The scientific community is international. The nuclear energy field provides a vivid example. For over 20 years, the AEC has been publishing a journal called Nuclear Science Abstracts which indexes and abstracts the current world literature related to nuclear science and its applications. In the early years, the preponderance of entries in this journal understandably referenced work done in the United States, where nuclear energy as a practical phenomenon had its birth. Over the years, however, an increasing percentage of the items have originated in other countries and in 1968 the foreign entries were over 55 percent of the total.

In recognition of the international character of nuclear science, the United States is joining with other coutries in developing, under the aegis of the International Atomic Energy Agency (IAEA) in Vienna, an International Nuclear Information System, the acronym for which is INIS. The Agency's Board of Governors has given formal approval to INIS and we expect it to be partly operational in 1971 and fully operational in 1975.

Under this system each nation will survey its own national scientific literature, identify items which fall within the subject scope of the system, and supply bibliographic descriptions, abstracts and subject indexing terms to the IAEA. The IAEA will merge the data received and make available on magnetic computer tape copies of a complete file which each member state will be able to use in supplying nuclear information services. The IAEA will also supply a periodical categorized listing of all items reported to the system and, on request, micronegative copies of all report literature and abstracts.

The international nature of science also calls attention to the importance of translations in any effective information system.

There is an ever present danger in dealing with broad problems of this kind that they may be segmented and dealt with in piecemeal fashion.

The pending legislation concerns itself with the large data processing and information retrieval facilities which may be central to the information services of the future. But they are not the only institutions involved. I note, for example, that this committe also has before it proposed legislation relating to a National Commission on Libraries. (H.R. 908, 4150, 8306, and 8614.) Libraries are indeed an integral part of the institutional framework involved in the information problem.

In conclusion, Mr. Chairman, I would like to state my opinion that the pending bill is on sound ground in calling for cooperative efforts on the part of existing information facilities rather than for a more centralized system. In the present developmental phase of computerized information systems, this pluralistic approach is the one most likely to produce the experimental breakthroughs on which future progress will depend.

In this connection, we should note that considerable cooperative efforts among information systems are now taking place. The AEC and other science agencies of Government, for example, have for several years been coordinating their information activities through a committee of the Federal Council on Science and Technology. Important steps have been initiated through this Committee on Scientific and Technical Information (COSATI) in the development of new systematic approaches and standards for information work. Individually and through COSATI Government agencies have also achieved a large degree of cooperation and coordination with non-Government information systems, such as those of the American Chemical Society and the American Institute of Physics.

We would trust that any new institutionalized framework will permit this type of voluntary cooperation to continue.

Mr. PUCINSKI. Thank you very much, Dr. Seaborg.

Would you care to add something to that, sir?

Mr. BRUNENKANT. I believe not, Mr. Chairman.

Mr. PUCINSKI. Dr. Seaborg, I am very pleased that you have fortified a good deal of the thinking of this committee. Certainly your testimony dramatizes the magnitude of the problem that we are dealing with. There is no easy solution.

As President Kennedy said many times, "A journey of a thousand miles requires a first step."

It does seem to me that we ought to start moving in some positive direction toward implementing the many things that you have mentioned in your testimony.

For example, you quite properly point out that we can't rely solely on computer technology; we have to have the human factor. No computer generates its own knowledge. A computer assembles the knowledge that is put into it by human beings.

You also mentioned the abstracting societies. I have maintained that one of the secret strengths of America is that we have this excellent network of abstracting societies. I think the Soviet Union would give its scientific eyeteeth to have the sort of network that could do the kind of work that our abstracting societies are doing.

Our bill envisions a contractual agreement with these abstracting societies and certainly it would be foolish for anyone to suggest that we ought either to supplant them or compete with them.

We would anticipate the use of these abstracting societies on a contractual basis, tied into the national information system.

You referred to the international aspect of information retrieval. I have already mentioned that. I was very happy to see the American Chemical Society Chemical Abstract Service has just recently entered into an agreement with its British counterpart and there will be an international exchange between the two countries.

I am very pleased with your testimony because it illustrates the huge task before us. I said earlier today that this is not sport for the meek.

The decade of the 1950's was devoted to the development of nuclear energy, in which you, Dr. Seaborg, played such a very important role; the decade of the 1960's was devoted to space exploration and we hopefully are going to have a man on the moon before this year is over.

It is my judgment that the decade of the 1970's will largely be concerned with trying to put into a more orderly, manageable system, the fantastic scientific genius and progress that has been generated by man.

Your testimony quite properly shows that there is no easy answer. Anyone who presumes that this system can be put together in 6 months really hasn't looked at the problem as you have.

To that extent, Dr. Seaborg, I want to congratulate you for your forthright statement.

Dr. SEABORG. I might mention the magnitude of the problem here by referring to a speech I made in 1966 where I pointed out that at that time there were about 300,000 articles published in some 6,000 scientific and technical journals in the United States alone, and on a worldwide basis a total of about 35,000 journals publishing some 2 million articles a year, written by some 750,000 scientists in about 50 languages. But to dramatize it further, I looked ahead 50 years, and on the basis of extrapolation, suggested that in 50 years from now in the United States alone some 1,300,000 scientists would be publishing annually some 3 million articles in about 60,000 journals, while around the world a total of about 8 million scientists might be writing over 20 million articles in some 350,000 journals, indicating, of course, that long before that time writing in journals will be inadequate and means of storage of information and means for retrieval of information will be necessary and we won't be able to continue by our present methods alone.

Mr. PUCINSKI. That is precisely the thrust of this proposal. It is a tragedy of our times that this knowledge is being generated by the human mind and yet other researchers don't have the time or facilities to be able to take advantage of all this.

I don't think that you could expect any human being, no matter how dedicated, to try to keep up with all of the knowledge being generated; nor is it necessary.

Dr. SEABORG. No.

Mr. PUCINSKI. I don't know of anyone who seriously believes it is necessary for Dr. Seaborg to read all of the journals that are being published.

What we are hoping to achieve is the ultimate development of a retrieval system that will be able to pinpoint for scientists like Dr. Seaborg the very information he needs to complete or implement his own studies. This is one of the things that we have difficulty in communicating.

Mr. Dellenback?

Mr. DELLENBACK. Thank you, Mr. Chairman.

Dr. Seaborg, this is obviously thoughtful and thought provoking testimony. It opens up a lot of questions, all of which we don't have time to pursue this morning.

But I would like to get any further comments that you might make. And there is one point that you touch on at the bottom of page 7 of your testimony where you, in conclusion, indicate that you feel it sound to call for cooperative efforts on the part of existing information facilities rather than for a more centralized system.

I am not sure whether that is the thrust of this bill, although the bill obviously speaks in terms of not duplicating where facilities already exist. I still get the feeling that the bill is thrusting in another direction primarily and I would appreciate any further comments you might make on that.

Dr. SEABORG. As I read the bill, it seems to me that it is consistent with that point of view. What I have in mind is a continued use of the pluralistic system that we have, the abstracting services and correlating services for scientific information, with some kind of a central coordinating system.

It seems to me that that is consistent with the wording of the bill.

Mr. DELLENBACK. Whether it is consistent or not, it is your feeling that this is the most desirable direction?

Dr. SEABORG. Yes, that is what I would recommend; that is right.

Mr. DELLENBACK. And it certainly isn't desirable in your opinion then to try to reach for a national system which takes over and centralizes in the sense of—if it centralizes at all, it centralizes the coordinating efforts that are being made in an individual basis.

Dr. SEABORG. I don't think that is the approach we should use or that it would be the most efficient way of doing it. I do feel though that there is a definite role for the Federal Government in this coordinating system, in this job of coordination.

For example, there would be some responsibilities that might be taken by the Federal Government. One might be to insure that there is at least one copy of every scientific article written anywhere in the world in the United States. I don't mean by that that the Federal Government would be the custodian of that copy, but that they would know where that copy was and be able to retrieve it for any scientist who needed that information and somehow have the information required in order to retrieve it. That is just one example.

Mr. PUCINSKI. Would you yield at that point?

Mr. DELLENBACK. Be glad to.

Mr. PUCINSKI. On the very thing you have been talking about, Dr. Seaborg, we have been looking with great interest at the work of the Soviets at Viniti where they do just that. I agree with your point that we should not have a central library where all of this information is assembled. I think you are right.

Nevertheless the Soviet Union has developed a fantastic operation where every single scientist, ever single Soviet citizen that travels anywhere in the world, is instructed to make sure that if there is a scientific journal or an article in the magazine or article in the newspapers or a paper delivered at a convention, all of this material is gathered from all over the world and forwarded to Viniti. There it is very carefully cataloged and abstracted and filed and ultimately made available to the scientists. It is generally recognized that Viniti today is probably one of the world's great warehouses of scientific information.

But if I may add this. I am glad you developed the point that you did about substitution and the answer that Dr. Seaborg gave you. I would like to call attention to page 2 of the bill which says:

> The purpose of this Act is to implement, not substitute, existing information retrieval facilities. Therefore, it is specifically prohibited under this Act for the National System to establish any Government-owned or operated science research data processing or information retrieval facility where such a facility already exists under either private or public ownership.

We wrote this language to make absolutely certain that there would be no chance of the Federal Government supplanting or removing existing private facilities which now constitute such a very important sector of the scientific community.

Mr. DELLENBACK. Let me ask a question along that line of Dr. Seaborg, Mr. Chairman.

Would you say that all of the processing and retrieval systems, Dr. Seaborg, that are in existence now are uniformally of high quality?

Dr. SEABORG. Well, I suppose that not all of them are, but there are various kinds of abstracting and information retrieval systems, either in operation or planned by the major scientific societies in the United States and those I believe are of high quality. The chemical abstracts of course is unsurpassed.

Mr. DELLENBACK. I don't speak derogation of any of them. I am just talking about this very point that the chairman touched on, that if we find that there is a facility already going under some form or another that this bill would preclude any duplication, even if that facility were really not performing effectively in the field would be part of the information that I have.

Dr. SEABORG. I think that obviously if you made an inventory of all the systems, there would be a variation from high quality to low quality and I would imagine that what you would do in the case of those that were inadequate would be to try to improve them by persuasion. I think that would be feasible, by pointing out where it was deficient and suggesting ways of improving it and helping it financially. I think that would be feasible.

Mr. PUCINSKI. Would the gentleman yield just to make this point?

The bill says, "The national system shall arrange for appropriate financial payment for all science data provide into the national system by private source."

My judgment is that if they are not doing a good job it is because they are plagued like everybody else with lack of funds. My guess is that a transfusion of additional money might bring any private operating agency up to an acceptable standard with the science community.

One factor, I think, is that the scientists, themselves, would be the policemen.

Dr. SEABORG. That, I believe, would perhaps save the situation if the system is inadequate. It is supposed to be serving the scientists and the scientists would be the first to complain and make the required changes or suggest the required improvements be made.

Mr. DELLENBACK. Oversimplifiedly, I would suppose that research takes place in one of three types of facilities: One, purely Government, all the way through; two, private facilities, but financed with Government money; and, three, purely private facilities.

Is the full range of results of research in all three of these fields reduced to scientific papers and thus available to the whole community or do we find that the third field tends not to make its information broadly and generally available?

Dr. SEABORG. Well, in the third field, as you defined, private facilities——

Mr. DELLENBACK. Private industry, for example, I have talked about private facilities handling private moneys.

Dr. SEABORG. Because also there is the category of the universities themselves which, as I listened——

Mr. DELLENBACK. I would think of these as public money, whether they be State moneys or Federal.

Dr. SEABORG. As of the three categories, I wasn't sure that it fell in either of the three. Private industry, where it is working in basic research, publishes information in the traditional manner. But obviously there is a good deal of information that is in the privileged category that has to do with the development of the commercial product that isn't immediately published. But I think usually even that is published in the course of events.

Mr. DELLENBACK. And this is a question, as the others are, I don't know the answer to it and I am asking you for information. If we can, oversimplifiedly, again, separate pure research from applied research, do we find that pure research are made available?

Dr. SEABORG. Yes.

Mr. DELLENBACK. But it is in the applied research that sometimes there is retention?

Dr. SEABORG. There is this delay in publication where a product is in the process of development, in the area of applied research and development, where a product is being developed on a competitive basis to produce a product to be put on the market on a competitive basis, and that is understandable.

Mr. DELLENBACK. One last line. Do you have any estimate of what sort of funds would be called for by this type of concept at this time?

What sort of moneys should we devote to this concept? How much should we authorize if we were to provide for this sort of a move?

Dr. SEABORG. Well, I think that it would have to start modestly in order to get off the ground at all. I hadn't given this much thought. I know that, I suppose, in the Federal Government if we totaled all of the money that goes into information, technical information activities, I suppose it would be in the region of—wouldn't it be more than $100 million?

Mr. BRUNENKANT. I think, Dr. Seaborg, the OST estimate for technical information, and this is rather precisely defined, it excludes technical manuals and other services, the current annual Government expenditures are in the neighborhood of a half billion a year.

Mr. DELLENBACH. I am thinking less of the funds that go into research now, Federal moneys, and if we were to set up a national system of this nature what sort of initial authorizations or appropriations should be called for, one that would not be unrealistic because it would be so large and yet not be so small that it would prove ineffective to accomplish anything meaningful.

Mr. BRUNENKANT. Neither Dr. Seaborg nor I have really given any considered thought to the question. Obviously there are proprietary interests involved or at least corporate interests involved and if you are going to pay for these including waiver of copyright, which is a major problem in terms of computer storage, you are certainly talking in the starting range of $10 million a year, exclusive of hardware.

Mr. DELLENBACK. Does the National Science Foundation have authority to do this sort of thing? Could it move forward with this type of a program under the NSF?

Dr. SEABORG. I don't know. I imagine they could move a good way in this direction.

Mr. DELLENBACH. Without any more enabling legislation?

Mr. PUCINSKI. If the gentleman would yield, I might say Mr. Adkinson would be in a better position to answer that.

Dr. SEABORG. He probably would.

If you get into the cost of the hardware that would depend on its complexity and how much you wanted to do and computer hardware and I would imagine that would build up.

Mr. DELLENBACK. $10 million would be inadequate?

Dr. SEABORG. That wouldn't include much in the way of the apparatus required.

Mr. DELLENBACK. You touched, in your testimony, Dr. Seaborg, on some of that which is already in existence. Are you in a position to say to what extent we already really have an interlocking system. Is it insignificant, are these isolated examples on which you touch or are they illustrative on what is a rather expensive interlocking system?

Dr. SEABORG. We have a certain amount of interlocking capability. There was the SATCOM, I understand that is phasing out; we have the Committee on Scientific and Technical Information of the Federal

Council on Science and Technology COSATI, which is involved with the correlation of scientific information rather widely; we have what is called EDUCOM the system that ties together some 35 to 40 universities in about 20 or 25 States.

Mr. DELLENBACK. So it is more than just a few isolated examples. But there is still a great deal that needs to be done?

Dr. SEABORG. Yes. We have these starting efforts as I have indicated, but they are not broad enough yet to do the whole job.

Mr. DELLENBACK. Thank you very much, Dr. Seaborg.

Thank you, Mr. Chairman.

Mr. PUCINSKI. We had estimates before this committee that we are now spending in this country at all levels in both the Government sector and the private sector, some $17 billion annually on research, all forms of research.

Dr. SEABORG. Federal spending for research and development. I guess some $15 billion of that is in the area of development and applied research and it is $2 billion or so in the area of basic and pure research. Those are rough figures.

Mr. PUCINSKI. When one sees the huge expenditure in this country, $17 billion, one can see the need for some facilities to try and make this research more readily available. And that figure will not remain static.

Dr. Seaborg, you mentioned the National Commission on Libraries bill. I have some serious reservations about the bill in its present form. If it were to deal only with libraries I would have no quarrel with it. But the bill not only deals with libraries but science information retrieval. I am afraid that the National Commission on Libraries and Science Information Retrieval would become just another instrument on top of a lot of other mechanisms now existing in the Government.

I personally think that this whole problem is too vast and needs work and discussion and study to entrust it to a National Commission on Libraries and Information Retrieval. If a national information retrieval system is to be built in this country libraries will have to be tied in; no question about it. Purdue University has one of the finest libraries in the world on the heat elements of metals; and the University of Chicago is now building a $20 million library. Eventually the University of Chicago will be tied in with other libraries and ultimately with an information system.

I agree with you, I think that libraries, the Newberry Library in Chicago and various other libraries around the country——

Dr. SEABORG. Also Crerar.

Mr. PUCINSKI. (continuing). Would become, certainly, an integral part of the cities.

But my experience has been that when you set up a commission the old race for the dollar starts and I think that we tend to duplicate and get in each other's way in trying to get the job done.

Would you have any comment on whether or not we ought to include information retrieval in that library commission or shall we just confine it to interworking arrangements among libraries. I have no objection to that, but I don't like the idea of the proposed National Commission on Libraries moving into the science retrieval field.

Dr. SEABORG. I am not really sufficiently familiar with that library bill to make what I would think would be a sensible comment on that.

Mr. PUCINSKI. Very well.

Dr. Seaborg, as I say, I am very grateful to you for your testimony. When we conclude this particular set of hearings we are going to have a better idea than when we started several years ago of how complicated this proposal is. While this bill calls for the Science Information Service of the National Science Foundation to develop the system, I am not sure that SIS is quite big enough to take on this kind of responsibility. It is entirely possible that an established agency like NASA—which has had a great deal of experience—has the capability to take a hard look at this program.

I want to make one point clear. We envision here a system that, in my judgment, would serve mankind. I am sure that somewhere there are answers pointing to possible cures for cancer. There are unquestionably answers to many of our problems available, but unless scientists can have easy access to this information I am afraid that we are going to continue floundering. I am grateful to you for your testimony.

Mr. DELLENBACK. Are you implying, Mr. Chairman, that the statement I once heard is valid; that anybody who can remain calm in the midst of all this confusion simply does not understand the situation.

Mr. PUCINSKI. That is exactly what we are trying to do.

I would just like to add this one point, because it gets lost. I am a strong believer in letting the scientist be the final judge of his work and its value. If we will leave him free to study he will come up with solutions to man's great problems. All I am seeking to do is to make available to him the product of this colleagues' work. He will then judge whether the information should be developed further or not. I do not want to be one of those who will put restraints on scientific pursuits.

Thank you very much, Dr. Seaborg.

Dr. SEABORG. Thank you, sir.

Mr. PUCINSKI. Our next witness this morning is Burton Adkinson. Dr. Adkinson, won't you come forward?

Dr. Adkinson is the head of the Office of Science Information Service and the gentleman who would be responsible for laying the groundwork for the development of the information retrieval system in this country within the framework of the National Defense Education Act.

We all remember that the Science Information Service was born with the development of the NDEA when in 1954 this country suddenly discovered that we were very far behind in scientific research, particularly in space and something had to be done. Among other things, the bill created the Office of Science Information Service. In proposing a national information retrieval system, it was my view that Dr. Adkinson's shop would probably be the best vehicle for trying to organize the facilities that we have been talking about.

We are pleased to have you before us, again, Dr. Adkinson. You were, I believe, our first witness 6 years ago when we got into this field and, frankly, I am not at all disturbed that we have taken this many years. It would be a great mistake if we tried to plunge into something as big as this and as important as this without thinking it through. I am pleased to have you here this morning to review for us what has transpired in the ensuing years, what new developments have come up, what new thinking has developed in this field, and what can be done to move this concept toward fruition.

Dr. Adkinson, we are very happy to have you here. Your statement will go in the record in its entirety at this point and we will let you proceed in any manner you wish. You can either read the statement or you can summarize it.

(The statement follows:)

STATEMENT OF DR. BURTON W. ADKINSON, HEAD, OFFICE OF SCIENCE INFORMATION SERVICE, NATIONAL SCIENCE FOUNDATION

Mr. Chairman and Members of the Subcommittee, in expressing my appreciation for the opportunity to testify before this Subcommittee, I am going beyond the traditional courtesies. The focus of these hearings has been and continues to be the active, day-by-day concern of myself and the staff of the Office of Science Information Service in the National Science Foundation.

From the beginning the Foundation has had responsibility under Section 3(a)3 of the National Science Foundation Act of 1950, as amended, "to foster the interchange of scientific information among scientists in the United States and foreign countries." In 1958, specificity was added to this mandate by passage of Title IX of the National Defense Education Act, which directed the Foundation "to provide or arrange for the provision of, indexing, abstracting, translating and other services leading to a more effective dissemination of scientific information" and "to undertake programs to develop new or improved methods, including mechanized systems, for making scientific information available." The terms of this mandate serve as a continuing reminder that responsibilities for providing fiscal support to secure a variety of information services is only part of our goal, the easier part. The more difficult part is the one of securing more effective dissemination of scientific information and to ensure improved methods for making scientific information available.

My reason for emphasizing these responsibilities in relation to today's hearings stems from my awareness that this Subcommittee is motivated by the very same concern. I will, therefore, devote myself to an explication of the programs and policies of the National Science Foundation and the Office of Science Information Service in the field of science information, with particular emphasis on developments since 1963, when the Ad Hoc Subcommittee on a National Research Data Processing and Information Retrieval Center held hearings.

REVIEW OF THE PAST SIX YEARS

It would be a mistake to suggest that everything has changed since 1963. There are many similarities in the conditions that confront us today with those identified as forceful influences six years ago. Let me first enumerate some of the similarities:

The field of science information was concerned with the pressure of increasing literature. The expression on everyone's tongue was "the literature explosion." The pressure is equally strong today, although now we have achieved a greater sophistication in an understanding of its essential character. It is not merely a matter of an increase in the number of articles written by scientists and engineers, and an increase in the number of journals and other vehicles for publishing information. More significant is growth, both nationally and internationally, in the number of scientists and engineers active in basic and applied research and development. We have evidence that the average scientist publishes no more today than he did six years ago, or ten or fifty years ago. But more scientists are engaged in the traditional exchange of information—reporting the results of their research and utilizing the published results of the research of their fellow scientists. Along with growth in the volume of publication there is a parallel growth in the need for access to the available literature. The organizations providing information have had to expand their services, their coverage, their capabilities. This expansion is still continuing because the scientific establishment in the United States and in the world outside the United States continues to grow.

Conditions of growth and expansion in the number of scientists, in the literature they produce and require to support their scientific activities, have had ripple-like effects. In 1963 traditional services were already too slow, too cumbersome, too narrow and at the same time too general. These same complaints and corresponding demands for more diversified services, for more rapid service, for more individualized service, are heard today.

The information industry was entering the age of the computer six years ago and managers of information services were under pressure to start utilizing the computer to solve some of these problems. The pressure for computerization or, in more general terms, for exploitation of advanced technological information processing resources is present today.

The ferment in scientific disciplines has not changed. The trend toward increasing specialization is a continuing one with the resulting appearance of new subdisciplines and the merging of older ones. Interdisciplinary research efforts are increasing, particularly as the problems of society have increased in complexity and require the contributions from many fields of science. This ferment continues to impose an incessant pressure on information services for change.

The pressures of 1963 for improved coordination and increased cooperation among information services are unchanged today though there is evidence of change in the response to them.

The demand for more speed and faster service has not changed, although the pressure may be more intense today. This is perhaps not exclusively a result of the volume of information available. More important, I believe, is the fact that the rate of progress and change in science and technology has been increasing so that information tends to become obsolete much more rapidly than it did even six years ago.

There was recognition in 1963 that eventual implementation of the computer technology would require larger and cheaper computer memories to handle the large files inherent in scientific information processing. There was faith that the computer would do anyhting for which man could program it and there was faith in man's ability to program. In 1963, one could foresee computerized translation (it was called "mechanical translation") when memories, speeds, and costs converged. Today we are much less optimistic with this prospect. Six years ago abundant effort was expended in computer experimentation in new methods for indexing, storing, and disseminating information. It is to these efforts that we owe controlled indexing vocabularies, computer-generated permuted or "quick" indexes, systems for selective dissemination of information, and the capability for processing information in machine-readable form so that it can be stored and further manipulated in and by the computer.

There were those farseeing individuals who could project the implications of those activities and realized that eventually there would be a need for an organization of future information systems. Considerable effort was devoted to modeling future systems of systems, networks of systems, centrally controlled monolithic systems, and so forth. The flavor of the arguments of that day can be appreciated when it is remembered that one of the divisive issues was whether the United States should or should not have a centrally managed system for information services. Should we have a system like VINITI, which serves the Soviet Union? When all was said and done, however, in 1963, science information systems were still operated as they always had been—manually. The computer was still a promise; its effective use was still ahead.

The situation in 1969 is radically different. To the modeling efforts of 1963 we owe our present view of evolutionary progress, building upon present strengths and evolving system management and coordination techniques that would enhance such progressive buildup and evolution.

Active efforts to develop large automated information systems dominate the scene. This statement deserves some elaboration. In the field of chemistry, a capability was developed to represent a chemical compound structure in machine-readable form. This capability led, during the six-year period, to the development of a register of chemical compounds and to programs which would tie the register to literature references related to individual compounds, to information about compound names, properties, chemical activities, and other data. This capability coincided in time with an unbelievable increase in chemical literature and a corresponding increase in chemical abstracts. The Chemical Abstracts Service faced an imminent operational crisis. Today, their capability has improved to the point where it permits the American Chemical Society to institute plans for a totally automated information system, including the publication of its journals and the preparation and publication of the *Chemical Abstracts*. Parenthetically, let me indicate that the plans of the American Chemical Society include attention to exchange of information at professional meetings and informal communication as well as to primary and secondary publication programs.

The program in chemistry, as it has developed to date, has many implications for information system programs under development in other fields of science. Such programs are now being pursued for other major disciplines including physics, psychology, biology, the earth sciences, and others.

The significant element that I wish to stress is that today the use of the computer is a present reality in information processing. It is being exploited in its various modes depending upon requirements and calculated benefits. Processing of increasingly large data banks and files takes advantage of the economics of batch processing. Tape and disc memories are utilized; and output utilizes on-line printers and a variety of on-line terminals.

Advances which make the computer a real and present tool for information processing pose the problem of developing connections between information systems as a present concern rather than as a problem for the future. The processors, the operators of information systems, increasingly recognize the need for increased cooperation, for developing of compatibility in machine processing at both input and output phases, because of the economic imperatives associated with the operation of large automated information systems. The user, the scientist or engineer, increasingly wants access to the information regardless of organizational affiliations. The biologist who requires access to information in the field of chemistry, the chemist who needs physical data, the engineer concerned with behavioral information, cannot be constrained by historical divisions among disciplines. Relationships among and between information systems have to be developed to facilitate the most rapid access to data wherever it may be, and efforts to link systems into a functioning network will continue to be necessary.

Another important difference of the past six years concerns the entry of commercial information processors into the field. It is still difficult to assess the implications of this development. In 1963 the field was not one to attract commercial enterprise aside from its traditional function as an outlet for published products. Today this sector recognizes a valid market for information services, a market to which it can make a valid contribution through specially tailored information products and services extending beyond the conventional printed book. The difficulties of assessment stem from the fact that commercial enterprise normally advances risk capital to develop a product with the intention of realizing a profit on the capital. By the very virtue of its former lack of profitability, the field has tended to be dominated by nonprofit services, such as those rendered by government agencies, universities, and professional societies.

A final aspect that I would mention, in terms of a significant difference as between 1963 and 1969, concerns the matter of personnel, talent, and capabilities available to the field of science information. Let me focus on research libraries which provide a significant information resource to this field. In 1963, the major libraries serving science and technology, including Federal libraries and major university libraries like those at Harvard, the University of California, and the University of Chicago, recognized the need to tool up for computer exploitation. They had to meet pressing problems concerned with acquisition, organization, and service of their rapidly expanding collections. Automation programs were being initiated in libraries. They were, however, programs of an embryonic character. Initial efforts in one or another library were devoted to using computers for normal business applications and for some minor inventorying functions. A definite limitation was the fact that librarians were not knowledgeable about computers. Programmers and systems analysts were not a normal complement of the library staff.

Today the situation is radically different. The Library of Congress just recently announced a service which makes its cataloging available in the form of machine-readable tapes. Today there are libraries in this country ready, able, and willing to subscribe to such tape services and to utilize cataloging information in machine-readable form. Most major libraries now have computer programmers. An increasing number are concerned with the prospect of adding computer tapes with many different kinds of information, not at all limited to bibliographic data, to their collections. The American Library Association has formed a new division concerned with library automation. The Special Libraries Association is considering a merger with the American Association for Information Science. This change is one that is not limited merely to the fact that libraries, large and small, are increasingly computer oriented. Their capabilities have developed in this regard as have their human resources. The implication of the relationship of this development to the developments in information services provided through the basic discipline oriented information services will be mentioned later in my testimony.

The differences highlighted between the conditions and the situation of 1963 and of 1969 apply to the field of scientific and technical information in general. The major changes paralleled and in some instances were influenced by support policy changes in the National Science Foundation.

Policies and programs in the earlier period were concerned with support for ongoing operations and services, and with support for research and experimentation designed to prepare the science information community for the time of activation with respect to new developments—particularly developments involving applications of the computer technology.

FOUNDATION SUPPORT IN 1963

The support then provided may be characterized as follows:

Support for translation—This included translations accomplished by professional societies within the United States on the basis of their judgment of needs. Scientific journals, mainly Russian but some Chinese and Japanese, were translated cover-to-cover; a few were published with a selection of the more significant articles in a particular field. The professional societies engaged their own translators in a few instances but relied for the most part on commercial translation organizations for the actual translation as well as the printing and binding of the translated journal. A complementary translation activity at this time consisted of contracts for translation services with organizations in a few foreign countries (Poland, Yugoslavia, Israel) in which excess local currencies had accrued to the credit of the United States under the provision of P.L. 480. The Foundation's appropriations permitted acquiring these currencies, and securing contracted translation and related services to meet requirements of agencies of the Federal Government.

Support for publications—This involved the recurrent requirement for financial assistance to scientists and scientific societies for the publication of monographs, i.e., works of high scientific merit without the profit potential to enlist the interest of commercial publishers. The further requirement for support of scientific journals that needed to pull out of a deficit or whose inauguration was beyond dispute was also involved. However, support for journals played a relatively small role, with the major portion of appropriated funds going to support publication of scientific monographs in a wide range of scientific disciplines.

Support of operational services—Defiit support was extended to some of the more significant information services. These included abstracting and indexing services which provide access to the current and retrospective scientific literature. The support covered the major disciplines, including biology, chemistry, mathematics, earth sciences, the social sciences, and engineering.

Support for research and studies—This is the area which described the future outlook for the field of science information. The studies focused on the communication behavior of scientists and engineers, on methods for evaluating the performance of information systems, and on theoretical foundations for indexing and organizing information for effective retrieval. This area also included support for mechanical translation, which was further redefined as automatic language processing, and eventually termed computational linguistics. Support for research and studies was designed to secure improved understanding in order to provide the base for future developments.

Support of prototype systems—A small effort was supported that may be described as prototype systems. These consisted of innovative systems that departed from traditional approaches. They served the dual purpose of testing innovations and providing a test bed for experimentation where scientists as subjects became users of nontraditional approaches to information service.

FOUNDATION SUPPORT IN 1969

By 1969, the programs and policies of the Foundation had undergone significant alterations. This, however, did not apply across the board. Some of the support functions continued unchanged because the requirements for such support remained essentially unchanged. Thus, translation of important documents in Russian, Chinese, Japanese, and some other languages required continued support because the lack of familiarity of American scientists with such languages had not changed. The importance of the material in such languages had increased as had the interest of scientists in general for translations secured through both the domestic program and the foreign currency program. Similarly, meritorious publications that were not commercially viable continued to require support. Again support of operations of information services aimed at the major disciplines had to be continued.

The key difference, however, was that support emphasis had shifted to system development. This shift was tied to the fact that the computer and other technologies were no longer a promise but an effective reality. The implications of the new support pattern have been many:

Support for information system development programs has been centered in the professional societies or organizations oriented to the major disciplines in science and engineering.

The network implications of such system development programs have resulted in support to efforts designed to accommodate the various liaison, cooperation, and related activities necessary to achieve interconnections of the developing systems.

The predictable products, particularly machine-readable products, of the emerging information systems imply the need for development and of new capabilities as well as new services in the varied nodes of the emerging information network.

Although research continues to be an indispensible adjunct to the broader developmental effort, its support has been refined.

(*a*) Research that is required as part of a specific effort in a given system development program is supported as part of that program. In these programs it is expected that developmental efforts will reveal research requirements rather than find that research will reveal fruitful developmental avenues.

(*b*) Research that cuts across developmental programs is supported independently and includes support for advanced research of an applied character for future exploitation.

(*c*) Undirected research of a more fundamental kind is also supported. This support takes two forms: (1) the project support form, characterized as research of opportunity involving considerations of the merit of the proposal and the capability of the investigator, and (2) the support of research centers at universities where research is interdisciplinary, and graduate student training functions are stressed. An important feature of these research centers is associated with an operating information system to ensure that the centers' activities are relevant to significant problems. Two such centers, one at the Georgia Institute of Technology, and another at Ohio State University, are currently operational.

The support of costly system development programs has consequences which need to be mentioned. Unlike the typical research project, a development program has built into it considerably more financial exigencies. The typical developmental program comprises activities that yield a system concept, program definition, system design, steps leading to acquisition of the system, capabilities requisite for its operation in terms of human and machine resources, and the system's transition to operational status. This sequence is subject to specific planning and checks on progress. The costs are likewise predictable and have a cyclical character; with relatively modest start-up requirements, progressively mounting as the definition efforts lead first to design and then to acquisition stages, holding level or slightly declining at the point of operational transition, and dropping when steady-state operation is reached. Characteristic of this pattern is the fact that the existing operating system which is to be superseded must be maintained in parallel with the developmental effort through to the transition to the new system. Such programs entail an important commitment on the part of both the organization devoting itself to the developmental effort and the Foundation providing financial assistance. Neither can afford to risk dislocation of the developmental plan by virtue of capricious budgeting; both must accommodate to the realities of the budget process and to the requirements of the developmental process.

PRESENT POLICIES AND GUIDELINES

The changed circumstances of the past five or six years that I have described have been influenced, and in turn have influenced the policies and guidelines which govern the administration and program formulation for science information activities in the Foundation. Some of these have been touched upon in passing, but I believe it is useful to describe them as explicitly as possible.

Our fundamental orientation is to the user of scientific and technical information—to the scientists and engineers who produce and use this information in the course of their research and their work. This emphasis was particularly highlighted by and, according to our view, was the single most important contribution of the Weinberg report. The policy that follows from this orientation is one of ensuring that the user determines requirements, assesses system performance, expresses evaluative preferences among alternatives, and generally develops a responsible attitude with respect to scientific and technical information services. The orientation is opposed to seeking these functions among operators of information systems, government officials, contractors with prospective solutions to system problems, entrepreneurs with plans for unburdening the Government, and so forth. All of the latter have their proper role, but the policy is one that seeks to focus responsibility and decisions on the user—the scientist and engineer.

In order to accomplish the goals of this policy, we encouraged the emergence of organizations that reflect the collective requirements and decisions of the user community. The criteria that have been identified include: (1) *representativeness*—the organization must be representative of the scientists and engineers in the discipline for which it proposes to mount an information system program; (2) *responsibility*—the organization must be responsible to the community which it represents, and this responsibility must be demonstrated rather than merely asserted; and (3) *readiness*—the organization must be ready to undertake such a developmental program in the full sense of providing organizational support, management, and technical capabilities.

The same criteria have become operative in our exploratory program to develop university centered systems which will become integral parts of the developing network of information systems. In the case of universities, it is the university administration rather than the library, or department, or computer center that we see as the locus of responsibility and representativeness.

It must be granted that the readiness of different societies to mount information system development programs varies widely. Happily, this third criterion is one about which we can do something. We cannot create representativeness and responsibility—either they are or are not representative and responsible—we have been able, by means of fiscal resources, to repair or enhance or improve the state of readiness. This has been an important aspect of our program in support of system development.

I want to mention that the policy, which seeks to locate responsibility for the development of information systems within the user community was indeed anticipated by the Chairman of this Subcommittee. In the course of the hearings, on April 27, 1964, on a National Research Data Processing and Information Retrieval Center you said:

". . . a national system which will flow through a nerve center, a command post, call it what you like, which would, with the cooperation of all existing facilities, maintain a running inventory on what is being done, where, by whom, and what is already available in the respective disciplines, so that, as I have said many, many times, the *scientific community will be able then to impose its own discipline against waste and duplication.*"

We call attention to your emphasis on the hope you then expressed, and to the policies that we have developed, which indeed lead to a capability on the part of the scientific community to impose its own discipline on the nature and quality of the information services provided to them.

COORDINATION IN 1969

Coordination, cooperation, intercommunication, compatibility, and networking of systems and between systems is still of concern. Our experience is that these collaborative efforts benefit when the performing organizations themselves realize the need and importance of them. As the need becomes manifest, we have provided support. The support is not exclusively financial, but has also consisted of contributions of expertise from among our staff. To a degree we have helped in speeding the recognition of the need. But have been cautious about imposing our views; lest by doing so we dilute the responsibility assumed by the organizations providing leadership and actively pursuing the necessary developmental programs.

In this connection, there is increasing awareness that the information systems operated by agencies of the Federal Government in pursuit of their agency missions have an influence and bearing on the developing discipline-oriented systems. The Government systems also have requirements for the services of discipline-oriented systems. Inter-agency coordination has become the central concern of the Committee on Scientific and Technical Information of the Federal Council for Science and Technology. This Committee is closely linked to the operations of the Office of Science and Technology. The National Science Foundation has agreed with the Office of Science and Technology to focus its coordinative responsibilities toward the information services outside of government. Its participation in the deliberations of the Committee on Scientific and Technical Information provides a necessary, although not exclusive, link between the Government and private sectors. The Foundation's budget has included funds by means of which the planning and coordinating responsibilities that are conceived as a national responsibility of the Office of Science and Technology in the area of scientific and technical information are financed.

The fact that scientific and technical information systems in the United States have developed services which are used internationally, and the fact that these services have become increasingly computer-based, has led the advanced industrial countries to seek similar capabilities. The need for a continuing relationship with U.S. services has stimulated a number of international governmental and nongovernmental organizations to consider suitable mechanisms for the development of international networks for scientific and technical information. The Organization for European Cooperation and Development serves as a forum for the discussion of national policies with respect to scientific information and as a seat of discussions on common problems of planning and economics in the development of large information systems. The United Nations Educational, Scientific, and Cultural Organization has joined forces with the International Council of Scientific Unions in planning the base for an international network of information systems. Discussions between representatives of the American Chemical Society and the National Library of Medicine with representatives from individual countries have been held. These have been concerned with training of foreign nationals in the operations and utilization of the American systems to the end that the country that is party to the agreement would contribute to the total system operations. Similar discussions and developments can be expected in the earth sciences, in the field of nuclear energy, and others. The Office of Science and Technology and the Committee on Scientific and Technical Information also have specific interests in this area. The latter has organized an International Panel with representation from its member agencies, including the National Science Foundation and the Department of State, to ensure coordinated participation in these international developments. It is Foundation policy to encourage the development of these relationships in the interest of international exchange of information from which our scientists cannot help but benefit.

UNRESOLVED POLICY ISSUES

We do not profess to have developed successful policies to meet all contingencies nor to have answers to all questions and problems. The increasing involvement of industry in providing commercial information services will pose policy questions. We will be assisted in dealing with these issues by the Science Information Council, established by Title IX of the National Defense Education Act. This Council has had and continues to have forceful industry representation.

Developing information systems, particularly the discipline-oriented information services, are moving into a pattern that entails computerized services involving distribution of tapes with information and data. These will involve computer searches of varying lengths and complexity, direct and on-line exchanges between inquirer and central or remote stores, and special services of many kinds. The economics of these new patterns have not yet been tested.

Nor is it well understood how one moves from the conventional publishing service which secures economic returns through the simple means of subscription arrangements to computer services of the complexity just enumerated.

The trend among the discipline-oriented information systems and services is to develop what has been termed "wholesaler" capabilities. Their products will have a general utility to a wide audience. The needs of specialized groups of scientists and engineers in subdisciplines, interdisciplinary teams, and so forth may have to be met by "retail" services such as are being organized on university campuses and by industry. Policies and mechanism for support of these services will require continued exploration.

Another area of policy uncertainty derives from the uncertainties of future fiscal resources. In principle, all disciplines that receive research support from the Foundation are eligible candidates for support for information system development, assuming that the conditions with respect to the availability of a representative and responsible organization for the discipline are also met. The fact remains that present and foreseeable fiscal resources are insufficient to meet a situation in which all candidate disciplines proposed such development programs.

FUTURE PROSPECTS

Let me turn to a description of future lines of development, as I visualize them:

Effective information systems for the major disciplines can be expected to be operational within the next decade.

Similarly, information systems in Federal agencies serving broad society-oriented missions, will be further developed and their number can reasonably be expected to increase.

Smaller information systems serving narrower discipline communities as well as subdisciplines or interdisciplinary groups will emerge. One can anticipate a mixed setting for these systems. Some will be society-based; others may be located in universities, in government agencies, and in private nonprofit as well as commercial organizations.

The products and services produced by these systems will combine the traditional published forms with machine-readable products for computer processing and interactive communication with information or data in computer memories.

The computer-processed information services will provide and, indeed, will encourage reprocessing of information for special interest groups, for special purpose applications, and for increasingly individualized services.

If present trends continue, we may find the university-centered information system serving not only the campus community of scientists, engineers, and students, but also the community located in nearby industry. Some university-centered information services may play the role of regional information centers.

The relationship between discipline-, mission-, and special purpose-oriented information systems based in professional societies, government agencies, university campuses, and industry, will provide constant pressures—pressure for compatibility of machine-readable information products; pressure for standardization on behalf of such compatibility; and pressure for progress in economical and effective storage, processing, and dissemination of information, particularly as the data bases and files become larger and the amount of information for processing grows.

THE NATIONAL SYSTEM

The aggregate of the several systems that are presently in the course of development, and that may be expected to emerge as a result of efforts still to be undertaken, constitutes the national information system. The participants in this network will be drawn from all sectors of our society and will all need a voice in its operation and management.

I have tried to outline some of the steps we have already taken to encourage cooperation and coordination among the components of this national system. Of necessity, more efforts along these lines will be needed, and I welcome the contribution of these hearings in focusing attention on the particular issues and problems that will require solution. I hope, however, that my remarks have reflected the belief that it would be neither practical nor desirable to centrally direct or manage our national array of information services. Nor does it appear desirable at present to establish by legislation a formal National System. The constraints imposed by such a formal system might well inhibit rather than assist the productive evolution of these services. I therefore believe that the enactment of the proposed legislation is not advisable at this time.

I have not provided the many illustrative details of our operations, the activities of the organizations who have had our support, the consequences of those activities, the particular problems that were being pursued or the funds devoted to particular programs. These details, Mr. Chairman, have just recently been presented to the Congress in the authorizations hearings of this past March. I ask permission to submit the statement prepared for those hearings by the Foundation concerning our science information activities for addition to my remarks and inclusion in the record of these hearings.

Thank you, Mr. Chairman.

Mr. PUCINSKI. Before I call upon you to read your statement, I would like to ask Mr. Dellenback if he has anything to add.

Mr. DELLENBACK. No, thank you, Mr. Chairman. I welcome the witness here today and look forward to his testimony.

Mr. PUCINSKI. Mr. Adkinson, you may proceed in any manner you wish.

STATEMENT OF DR. BURTON W. ADKINSON, HEAD, OFFICE OF SCIENCE INFORMATION SERVICE, NATIONAL SCIENCE FOUNDATION; ACCOMPANIED BY HENRY J. DUBESTER, DEPUTY HEAD, OFFICE OF SCIENCE INFORMATION SERVICE; AND CHARLES MAECHLING, JR., DEPUTY GENERAL COUNSEL

Dr. ADKINSON. Mr. Chairman, before I proceed I would like to introduce the two gentlemen with me and identify where they are in the National Science Foundation.

On my right is Mr. Charles Maechling, Jr. the Deputy General Counsel of the National Science Foundation; and on my left is Mr. Henry Dubester, who is Deputy Head of the Office of Science Information, the office which I head.

As you said, rather than read the lengthy statement, I would like to summarize it and give the salient details with the full statement going into the record.

In expressing my apreciation for the opportunity to testify before this subcommittee, I am going beyond the traditional courtesies. The focus of attention of these hearings has been and continues to be my active, day-by-day concern. It is the concern of the staff of the Office of Science Information Service in the National Science Foundation.

The responsibility assigned to the Foundation by the National Defense Education Act, was "to provide or arrange for the provision of indexing, abstracting, translating, and other services leading to a more effective dissemination of scientific information" and to undertake programs to develop new or improved methods, including mechanized systems, for making scientific information available.

In addition, I should mention section 3(a)(3) of the National Science Foundation Act of 1950, as amended, to which NDEA title IX gave specific emphasis.

The terms of this statement serve as a continuing reminder that responsibilities for providing fiscal support to secure a variety of information services is only part of our goal, the easier part. The more difficult part is the one securing more effective dissemination of scientific information and to insure improved methods for making scientific information available.

My reason for emphasizing these responsibilities in relation to today's hearings stems from my appreciation that this subcommittee is motivated by the very same concern. It is this appreciation which has guided me in the preparation of my testimony. In the time at my disposal, I will devote myself to an explication of the programs and policies of the National Science Foundation and the Office of Science Information Service in the field of science information, with particular emphasis on developments since 1963, when the Ad Hoc Subcommittee on a National Research Data Processing and Information Retrieval Center held hearings.

Let me review the past 6 years.

Mr. PUCINSKI. If I may just interrupt here. I am very pleased to hear you remind us that in 1963 we were talking about a center. We have learned a great deal since those early hearings, particularly that we are really talking about a system, not a center, because it is inadvisable to think of putting all of this information under one roof.

But I was struck by your recollection for us to the word "center." That is not our thinking today, 6 years later, not at all.

Dr. ADKINSON. Not at all.

It would be a mistake to suggest that everything has changed since 1963. There are many similarities in the conditions that confront us today with those identified as forceful influences 6 years ago. Let me first enumerate some of the similarities:

The field of science information was concerned with the pressure of increasing literature. The expression on everyone's tongue was "the literature explosion." The pressure is equally evident today, although now we have achieved a greater sophistication in understanding its essential character.

Traditional services were too slow, too cumbersome, too narrow, and at the same time too general in 1963. These same complaints and corresponding demands for more diversified services, for more rapid service, for more individualized service, are heard today.

The information industry was entering the age of the computer 6 years ago and managers of information services were under pressure to start utilizing the computer to solve some of these problems. The pressure for exploitation of advanced technological information processing resources is also present today.

The trend toward increasing specialization resulting in the appearance of new subdisciplines and the merging of older ones was characteristic of science in 1963. Interdisciplinary research efforts were increasing. This ferment in scientific disciplines has not changed today.

The pressures of 1963 for improved coordination and increased cooperation among information services are unchanged today, although there is evidence of change in the response to them.

The demand for more speed and faster service has not changed, although the pressure may be more intense today.

Given these similarities, it is important to stress that there are important differences in 1969 as contrasted to the conditions we knew in 1963. In 1963, science information systems were still operating as they always had been—manually. The computer was still a promise, its effective use was still ahead. Today, active efforts to develop large automated information systems dominate the scene. The computer is being exploited in its various modes depending on requirements and calculated benefits. Processing of increasingly large data banks and files takes advantage of the economies of batch processing, tape and disk memories are utilized, output utilizes online printers, and a variety of online terminals.

Today the user, the scientist or engineer, increasingly wants access to information regardless of organizational affiliation. The biologist who requires access to information in the field of chemistry, the chemist who needs physical data, the engineer concerned with behavioral information, cannot be constrained by historical divisions among disciplines. Effort to link systems will be accelerated.

Another important difference of the past 6 years concerns the entry of commercial information processors into the field. In 1963 the field was not one to attract commercial enterprise aside from its traditional function as an outlet for published products. Today this sector recognizes a valid market for information services.

A final difference I will mention relates to the matter of personnel, talent, and capabilities available to the field of science information. For example, programers and system analysts were not a normal complement of the majority of information facilities in 1963. Today the situation is radically different.

The similarities and differences highlighted between the conditions and the situation of 1963 and of 1969 apply to the field of scientific and technical information in general. The major changes paralleled and in some instances were influenced by support policy changes in the National Science Foundation.

I wish now to contrast Foundation support in 1963 with that of today. Foundation support in 1963 may be characterized as follows:

Support for translation—This included translations accomplished by professional societies within the United States on the basis of their judgment of needs. Scientific journals, mainly Russian but some Chinese and Japanese, were translated cover to cover; a few were published with a selection of the more significant articles in a particular field. The professional societies engaged their own translators in a few instances but relied for the most part on commercial translation organizations for the actual translation as well as the printing and binding of the translated journal. A complementary translation activity consisted of contracts for translation services with organizations in a few foreign countries (Poland, Yugoslavia, Israel) in which excess local currencies had accrued to the credit of the United States under the provision of Public Law 480. The Foundation's appropriations permitted acquiring these currencies, and securing contracted translation and related services on behalf of agencies of the Federal Government.

Support for publications—This involved recurrent requirement for financial assistance to scientists and scientific societies for the publication of monographs. These were works of high scientific merit that showed no profit potential to enlist the interest of commercial publishers. The further requirement for support of scientific journals that needed to pull out of a deficit situation or whose inauguration was beyond dispute was also involved. Support for journals played a relatively small role. The major portion of funds supported publication of scientific monographs in a wide range of scientific disciplines:

The third category of support in 1963 was for support of operational services. Deficit support was extended to some of the more significant information services providing abstracting and indexing of the current and retrospective scientific literature. Some of our funds supported experiments in innovative service. Our support was enjoyed by the major disciplines, including biology, chemistry, mathematics, earth sciences, the social sciences, and engineering.

Another category of support in 1963 was for research and studies. This is the area which described the future outlook for the field of science information. Studies in 1963 focused on the communication behavior of scientists and engineers, on methods for evaluating performance of information systems, and on theoretical foundations for indexing and organizing information for effective retrieval. This area also included support for mechanical translation, which was further redefined as automatic language processing, and eventually termed computational linguistics. Support for research and studies was designed to secure improved understanding in order to provide the base for future developments.

And the last support in 1963 was for prototype systems. A small effort was supported that may be described as prototype systems. These consisted of innovative systems that departed from traditional approaches. They served the dual purpose of testing innovations and providing a test bed for experimentation where scientists as subjects became users of nontraditional approaches to information services.

By 1969, programs and policies of the Foundation had undergone significant alterations. This, however, did not apply across the board. Some support functions persisted because the requirements for such support remained essentially unchanged. Translation of important documents in Russian, Chinese, Japanese, and other languages required continued support because the lack of familiarity of American scientists with such languages had not changed. The importance of foreign-language material had increased as had the interest of scientists in general for translations secured through both the domestic program and the foreign currency program. Similarly, meritorious publications that were not commercially viable continued to require support. Support to operations of information services to the major disciplines also had to be continued.

The key difference, however, was that support emphasis had shifted to system development. This shift was tied to the fact that the computer and other technologies were no longer a promise but an effective reality. The implications of the new support pattern have been many:

Support for information system development programs has been centered in the professional societies or organizations oriented to the major disciplines in science and engineering.

The network implications of such system development programs have resulted in support to efforts designed to accommodate liaison, cooperation, and related activities required to achieve interconnections of the developing systems.

The machine-readable products of emerging information systems imply the need for development of new capabilities as well as new services in the varied nodes of the emerging information network.

Although research continues to be an indispensible adjunct to the broader developmental effort, its support has been refined:

Research that is required as part of a specific effort in a given system development program is supported as part of that program. In these programs it is expected that developmental efforts will reveal research requirements rather than that research will reveal fruitful developmental avenues.

Research that cuts across developmental programs is supported independently and includes support for advanced research of an applied character for future exploitation.

Undirected research of a more fundamental kind is also supported. This support takes two forms: (1) the project support form, characterized as research of opportunity involving considerations of the merit of the proposal and the capability of the investigator, and (2) the support of research centers at universities where research is interdisciplinary, and graduate student training is stressed. An important feature of these research centers is association with an operating information system to insure that the centers' activities are relevant to significant problems. Two such centers, one at the Georgia Institute of Technology, and another at Ohio State University, are presently operational.

The need for support of system development programs has consequences which need to be mentioned.

Unlike the typical research project, a developmental program has built into it considerably more financial requirements. The typical developmental program comprises activities that yield a system concept, program definition, system design, steps leading to acquisition of the system, capabilities necessary for its operation in terms of human and machine resources, and operational transition of the system. This sequence is subject to specific planning and checks on progress. The costs are likewise predictable and have a cyclic character; with relatively modest startup requirements, costs mount as the definition efforts lead to design and then to acquisition stages, hold level or slightly decline at the point of operational transition, and then drop when steady State operation is reached.

Characteristic of this pattern is the fact that the existing operating system which is to be superseded must be maintained in parallel with the developmental effort through to the transition to the new system. Such programs entail an important commitment on the par of both the organization devoting itself to the developmental effort and the Foundation providing financial assistance. Neither can afford to risk dislocation of the developmental plan by virtue of capricious budgeting; both must accommodate to the realities of the budget process.

PRESENT POLICIES AND GUIDELINES

The changed circumstances of the past 5 or 6 years that I have described have been influenced, and in turn have influenced the policies and guidelines which govern the administration and program formulation for science information activities in the Foundation. Some of these have been touched upon in passing, but I believe it is useful to describe them as explicitly as possible.

Our fundamental orientation is to the user or scientific and technical information, to the scientists and engineers who produce and use this information in the course of their research and other work. This emphasis was particularly highlighted by and, according to our view, was the single most important contribution of the Weinberg report. The policy that follows from this orientation is one of insuring that the user determines requirements, assesses system performance, expresses evaluative preferences among alternatives, and generally develops a responsible attitude with respect to scientific and technical information services. The orientation is opposed to seeking these functions among operators of information systems, Government officials, contractors with prospective solutions to system problems, entrepreneurs with plans for unburdening the Government and so forth. All of the latter have their proper role, but the policy is one that seeks to focus responsibilities and decisions on the user—the scientist and engineer.

In order to accomplish the goals of this policy, we encouraged the emergence of organizations that reflect the collective requirements and decisions of the user community. The criteria that have been identified include: (1) Representativeness—the organization must be representative of the scientists and engineers in the discipline for which it is proposing to mount an information system program; (2) responsibility—the organization must be responsible to the community which it represents, and this responsibility must be demonstrated rather than merely be asserted; and (3) readiness—the organization must be ready to undertake such a developmental program where readiness refers to organizational support, management, and technical capabilities.

The same criteria have become operative in our exploratory program to develop university-centered systems which may become integral parts of the developing network of information systems. In the case of universities, it is the university administration rather than the library, or department, or computer center, that we see as the locus of responsibility and representativeness.

It must be granted that the state of readiness of societies to mount information system development programs is extremely variable. Happily, this third criterion is one about which we have been able to do something. We cannot create representativeness and responsibility—either they are or are not representative and responsible—we can do something by means of fiscal support to repair or enhance or improve the state of readiness. This has been an important aspect of our program in support of system development.

COORDINATION IN 1969

Coordination, cooperation, intercommunication, compatibility, and networking of systems and between systems is still of concern. Our experience is that these collaborative efforts benefit when the performing organizations themselves realize the need and importance of them. As the need becomes manifest, we have provided support. The support is not exclusively financial, but has also consisted of contributions of expertise from among our staff. To a degree we have helped in speeding the recognition of the need. But we have been cautious about imposing our views; lest by doing so we dilute the responsibility assumed by the organizations providing leadership and actively pursuing the necessary developmental programs.

In this connection, there is an increasing awareness that the information systems operated by the agencies of the Federal Government in behalf of their agency missions have an influence and bearing on the developing discipline-oriented systems. Interagency coordination has become the central concern of the Committee on Scientific and Technical Information of the Federal Council for Science Technology. This Committee is closely linked to the operations of the Office of Science and Technology. The National Science Foundation has agreed with the Office of Science and Technology on focusing its coordinative responsibilities toward the information services outside of government. Its participation in the deliberations of the Committee on Scientific and Technical Information provides a necessary, although not exclusive, link between the Government and the private sectors. I may also mention that the need for a continuing relationship to U.S. services has stimulated a number of international governmental and nongovernmental organizations to consider suitable mechanisms for the development of international networks for scientific and technical information. Among these are the Organization for European Cooperation and Development, and the United Nations Educational, Scientific, and Cultural Organization which has joined forces with the International Council of Scientific Unions in planning the base for an international network of national information systems.

UNRESOLVED POLICY ISSUES

We do not profess to have developed policies to meet all contingencies nor to have answers to all questions and problems. The increasing involvement of industry in providing commercial information services poses policy questions. We will be assisted with these issues by the Science Information Council, established by title IX of the National Defense Education Act. This Council had had and continues to have forceful industry representation.

Developing information systems, particularly the discipline-oriented information services, are moving into a pattern that entails computerized services involving distribution of tapes with information and data. These will involve computer searches of varying lengths and complexity, direct exchanges between inquirer and central or remote information stores and special services of many kinds. The economics of these new service patterns have not yet been tested. Nor is it well understood how one moves from the conventional publishing service which secures economic returns through the simple means of subscription arrangements to computer services of the complexity just enumerated.

The trend among the discipline-oriented information systems and services is to develop what has been termed "wholesaler" capabilities. Their products will have a general utility to a wide audience. The needs of specialized group of scientists and engineers in subdisciplines, interdisciplinary teams, and so forth may have to be met by "retail" services, such as are being organized on university campus and by industry. Policies and mechanisms for support of these services will require continuing exploration.

Another area of policy uncertainty derives from the uncertainties of future fiscal resources. In principle, all disciplines that receive research support from the foundation are eligible candidates for support for information system development. This assumes that the conditions with respect to the availability of a representative and responsible organization for the discipline are also met. The fact remains that present and foreseeable fiscal resources are insufficient to meet a situation in which all candidates disciplines propose such development programs.

FUTURE PROSPECTS

Let me turn to a description of future lines of development, as I visualize them.

Effective information systems for the major disciplines can be expected to be operational within the next 10 years.

Information systems in Federal agencies serving broad society-oriented missions, will be further developed and their number can reasonably be expected to increase.

Smaller information systems serving narrow discipline communities as well as subdisciplines or interdisciplinary groups will emerge. One can anticipate a mixed setting for these systems. Some will be society-based; others may be located in universities, in Government agencies, and in private nonprofit as well as commercial organizations.

The products and services produced by these systems will combine the traditional published forms with machine-readable products for computer processing and interactive communication with information or data in computer memories.

The computer-processed information services will provide and, indeed, will encourage reprocessing of information for special interest groups, for special purpose applications, and for increasingly individualized services.

If present trends continue, we may find the university-centered information system serving not only the campus community of scientists, engineers, and students, but also the community located in nearby industry. Some university-centered information services may play the role of regional information centers.

The relationship between discipline-, mission-, and special purpose-oriented information systems based in professional societies, Government agencies, university campuses, and industry, will provide constant pressure.

Pressure for compatibility of machine-readable information products.

Pressure for standardization on behalf of such compatibility.

Pressure for progress in economical and effective storage, processing, and dissemination of information, particularly as the data bases and files become larger and the amount of information for processing grows.

THE NATIONAL SYSTEM

The aggregate of the several systems that now exist, that are presently in the course of development, and that may be expected to emerge as a result of efforts still to be undertaken constitutes the national information system. Its participants are and will be drawn from all sectors of our society and all will need a voice in its operation and management.

I have tried to outline some of the steps we have already taken to encourage cooperation and coordination among the components of this national system. Of necessity, more efforts along these lines will be needed, and I welcome the contribution of these hearings in focusing attention on the particular issues and problems that will require solution. And, Mr. Chairman, the next few words represent the consensus of the National Science Foundation and the Bureau of the Budget. I hope, however, that my remarks have reflected the belief that it would be neither practical nor desirable to centrally direct or manage our national array of information services. Nor does it appear desirable at present to establish by legislation a formal national system. The constraints imposed by such a formal system might well inhibit rather than assist the productive evolution of these services.

I have not provided the many illustrative details of our operations, the activities of the organizations which we have supported, the consequences of those activities, the particular problems that were being pursued or the funds devoted to particular programs. These details, Mr. Chairman, have just recently been presented to the Congress in the authorization hearings of this past March. I would ask permission to submit the statement prepared for those hearings in the record of these proceedings.

Thank you, sir.

(The statement follows:)

SCIENCE INFORMATION ACTIVITIES

GENERAL

The Foundation's program for Science Information provides for the information requirements of this country's community of scientists and engineers and ensures that their information services keep pace with the changing conditions under which the community pursues its work. The program consists of four key support components:

Information system development

Crucial elements in this type of support are: securing an integration of information functions and services in each of the major scientific disciplines closely matched with the information requirements, characteristic of each discipline; exploiting the actual available and advanced technology in order to ensure increased speed, selectivity, dependability, and efficiency of existing services as well as their expansion in scope of coverage and depth of penetration; and creating communication channels where none had previously existed.

Operational support for services and publications

Temporary assistance is provided at points of greatest need, where it will do the most good for scientists and engineers. The recipients of the Foundation's support are nonprofit information and publication services in actual operation. The results of this support are effective services which would otherwise be marginal or nonexistent.

Research and development

The central concern is with advancing the technology in handling science information. Just as the overall program is service oriented, the research component is dominantly applications oriented. It funds studies of the changing information requirements of scientists and engineers as well as research on problems that emerge in the course of developing systems and services designed to satisfy the changing requirements. Basic research and advanced development are also supported.

International information and translation

The international character of the scientific and technical activity entails communication across the boundaries of geography and language. Support is provided for participation in the increasing international cooperative efforts to improve communication. The dominant activity provides for our scientists and engineers the published results of foreign research through acquisition of publications and through their translation into English when the original is in a language with which American scientists and engineers are not familiar.

WHY FEDERAL SUPPORT IS ESSENTIAL

Organizing, processing, and communicating scientific and technical information involves the following factors:

Rapid rate of increase in the number of scientists and engineers.

Exponential increase in the amount of information, published and unpublished.

Need to apply costly rapidly evolving technology to information processing.

Requirement for rational planning of expensive systems and complex networks.

Need for cooperation, national and international.

Between the years 1954 and 1966 the number of scientists and engineers has increased approximately 5 percent each year; the number grew from 776,600 in 1954 to 1,412,500 in 1966. Scientific and technical journals have witnessed an even greater rate of increase. In 1960, approximately 1,000,000 individual articles were published. Today the number of published articles approaches 2,000,000. The secondary information services that abstract and index this literature have had to show a parallel growth (see Figure I–1 which shows the growth of chemical literature as reflected in chemical abstracts publication records from 1907–1970).

The growth of scientific and technical literature is not confined to the United States. The literature is published in many countries and in languages not familiar to U.S. scientists. Important journals must be translated into English in order to serve our research needs. This literature must be acquired by indexing and abstracting services and by libraries in this country. The volume and cost of this effort requires outside assistance.

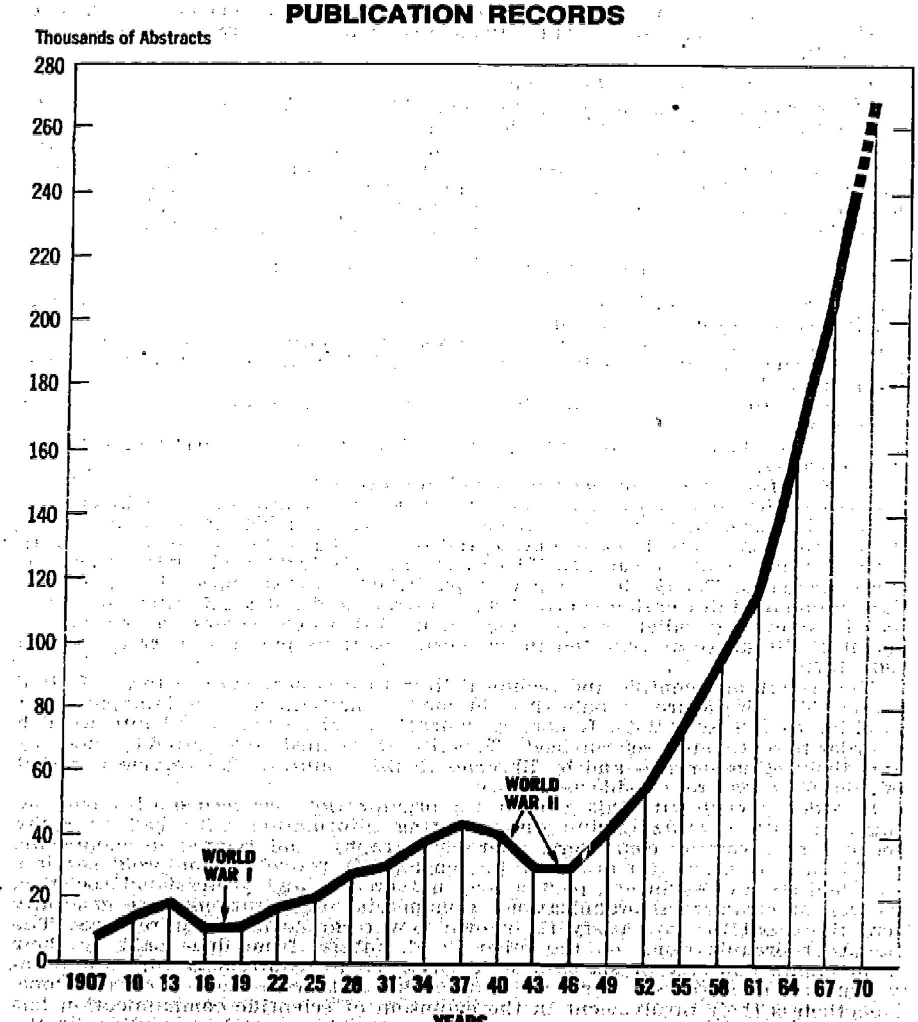
In order to cope with this growth, the organizations concerned with publishing and with organizing and disseminating information have had to apply technology involving computers, microphotography, and related developments.

This has been true for organizations engaged in providing non-profit services to scientists and engineers, particularly universities and professional societies, as well as commercial organizations. Commercial organizations have generally had the capability to satisfy their own new technological requirements. The nonprofit organizations, on the other hand, subsist from dues paid by their membership and sale of specialized services. Their requirement for capital investment for advanced hardware cannot be met from these sources alone. Nonetheless their involvement in the evolution of scientific communication has given the professional societies and universities a special capability in the communication process, which cannot be sacrificed save at the peril of diminishing the overall effectiveness of scientific communication in this country. Federal assistance to these organizations is therefore necessary.

By virtue of the fact that expensive computer and related technology must be called upon to assist in the face of the explosion of the scientific and technical literature, the resulting systems must be designed and operated to effect the maximum efficiency and economy. Growing specialization on the one hand and

Figure I-1

GROWTH OF CHEMICAL LITERATURE AS REFLECTED BY CHEMICAL ABSTRACTS PUBLICATION RECORDS



SOURCE: Adapted from Chemical Abstracts Service.

the increasing interdisciplinary character of research on the other pose two requirements: new and more responsive services for each discipline specialty; and the linking together of the resulting information systems. This linkage involves planning now to ensure the coherence of future developments. Planning, in turn, requires studies and research involving bringing together the managers of government information services with those from the scientific societies, universities, and industry. Since this is an effort not likely to be supported by commercial organizations, Federal support is necessary.

THE FOUNDATION ROLE

The Foundation obligated $14,396,057 for the support of science information activities in FY 1968. Estimated obligations were reduced to $11,000,000 in FY 1969. The $13,000,000 requested for FY 1970 will permit essential support to ongoing system development and improvement efforts on the part of professional societies serving the major scientific and technical disciplines. It will permit a modest start to develop more effective information system planning and development in the university environment. It will permit level support for operational services and publications, for translation of foreign scientific information and for the support of research and studies. Long-range planning, with its valuable feedback to current management and programming will also be continued.

INFORMATION SYSTEM DEVELOPMENT

The single largest investment and the largest amount of progress have been in the development of an information system for chemistry and chemical engineering. Progress has also been marked in other disciplines. Initiative has been taken to explore the development requirements for university-centered information systems. All of this is capped by activities designed to assist in the evolution of the separate system, through effective planning and developmental research into a network of such systems.

Discipline Oriented Systems

Chemistry

The Foundation's support of an information system for chemistry and chemical engineering started in the late 1950's with a series of small grants to the American Chemical Society to initiate research on chemical documentation and to develop computer-produced indexes based on titles of chemical articles. The work was performed by the Chemical Abstracts Services (CAS), one of the operating divisions of the Society. Support also was granted to bring the *Chemical Abstracts* subject and formula indexing up to date. These preliminary efforts helped to focus attention on the need to use mechanized techniques to support publication operations for the chemical literature which was growing at a rate of about 9 percent per year.

Computer technology is particularly applicable in chemistry because of the nature of structural diagrams which are the universal language of chemists. Since most chemical literature is compound related, the unique identification of compounds is the natural indexing link. The promise inherent in this capability was that the literature of chemistry, the properties, and the activities of chemicals could all be related to a central registry of compounds. Ultimately, the entire process of storing, searching and retrieving information in this field could be automated.

By 1965, Chemical Abstracts Service had developed suitable techniques which made possible the development of a large computer registry of chemical structure records derived from the current literature. The initial contract with the American Chemical Society for this purpose was funded jointly by the Foundation, the Department of Defense and the Department of Health, Education, and Welfare. Since 1967, this compound registry system has been maintained with support by the Foundation alone.

As the registry system developed, the concept of a total computer-based information system took form. The American Chemical Society information activities include meetings, and primary journal publication as well as abstracting and indexing services. All of these activities were threatened by rapidly increasing costs. The situation was viewed in the following terms: Presently material must be handled many times by the author, editor, compositor, bibliographer, abstractor, indexer, and repeated reviewers throughout the process. Would it not be possible, by means of the computer which could store the information and which would require attention only to the changes, to effect significant economies through improved processing, reduction of man induced errors, and saving of work that was unchanged from the initial stages to the final ones? This indeed is the present plan of the American Chemical Society's information program, which the Foundation is supporting.

The information program in chemistry has made good progress in adopting the techniques of one-time keyboarding of information and multiple-use of computerized data in the current conversion to a total computer base (see Figure I-2). Major goals are:

Computer-controlled production of abstracts and indexes by 1971.

Completed conversion of American Chemical Society journals to computerized production by 1974.

Operation of a world-wide input/output network for *Chemical Abstracts* by 1974.

The promise of cooperation through the Organization of Economic Cooperation and Development and of bilateral arrangements with chemical societies in the United Kingdom, Germany, and other European countries has provided the first steps towards the development of a worldwide network. National groups will process their own literature for merging with the American system. This will result in improved services and major savings for all participants.

In FY 1968, the Foundation obligated $4,236,143 for the support of development of a chemical information system; and $2,600,000 in FY 1969. The estimated obligation for FY 1970 is $3,000,000. The planning in FY 1967 and FY 1968 anticipated a higher obligation level in the present and the next fiscal year. The lower levels presently estimated have required a lengthening of the developmental process.

Support for the overall program has been shared by the Foundation, the American Chemical Society, and the chemical industry. Experience in chemical information processing at E. I. duPont de Nemours and Co., Inc. has been made available to the Chemical Abstracts Service. Computer manufacturers have cooperated in developing special purpose equipment. The National Library of Medicine and the Food and Drug Administration have worked with Chemical Abstracts Service to develop a mechanized link between the chemical and health oriented systems. Company information groups in the pharmaceutical and polymer industries have cooperated in special projects with CAS to measure how well experimental services meet their specialized information requirements. Feedback from such projects is invaluable in defining immediate goals for the developing system.

The American Chemical Society has begun to reorganize its administrative structure in order to assure its capability to manage a complex and developing system as contrasted to the management of several autonomous services. The Society is also participating in the development of information handling standards in cooperation with organizations similarly concerned with system development in physics, engineering, biology, research libraries, and comparable systems abroad.

Other Discipline Programs

The status of information system development in scientific disciplines other than chemistry is summarized in Figure I-3.

Following the example of the American Chemical Society, several other disciplines are now organizing comprehensive programs of system development. In the fields of physics and astronomy, psychology, and linguistics basic system concepts now have the general acceptance of their communities. In each of these fields, a single organization has been identified as responsible for defining a program that will translate the concept into reality.

The concept of a National Physics Information System (see Figure I-4) is typical. The coverage of this system will embrace all branches of physics and astronomy. Its input will include English-language manuscripts submitted by scientists-authors, scientific publications (as contrasted to manuscripts) in English and other languages, as well as such material as patents and technical reports. The system will also accept bibliographic information (abstracts and index data) in computer-manipulable form from cooperating information systems in other disciplines or specialized services in physics and astronomy.

Figure I-2

INFORMATION SYSTEM DEVELOPMENT AND IMPROVEMENT IN CHEMISTRY

FUNCTION	FY 1969 STATUS	FY 1970 PLANS
ACS Central Processing Development	• Work is underway on subsystems for direct-access for structure handling, unified input system, integrated output system, interface modules, photocomposition, substructure searching system • Work is underway on processing development in computer-supported editing, system engineering, computer-supported documentation	• Continue [illegible] text search subsystem [illegible] • Support application studies [illegible] computer [illegible]
Operational Development of Unified Data Base	• In the computer files: 960,000 chemical structures 1,300,000 references 2,000,000 names	• Continue input from current literature [illegible] files, pilot test [illegible]
Distribution Centers Development	• University based Experimental centers established • Foreign-based OECD cooperative effort to assist centers in 8 countries through training and liaison. • Industrial Technical liaison with industrial centers for experimental use of new data bases • Government agencies: Experimental use of special data bases by Food Drug Administration and National Library of Medicine systems completed.	• Start experimental services at centers • Continued training and liaison • Expand decentralized use activities

SOURCE: National Science Foundation

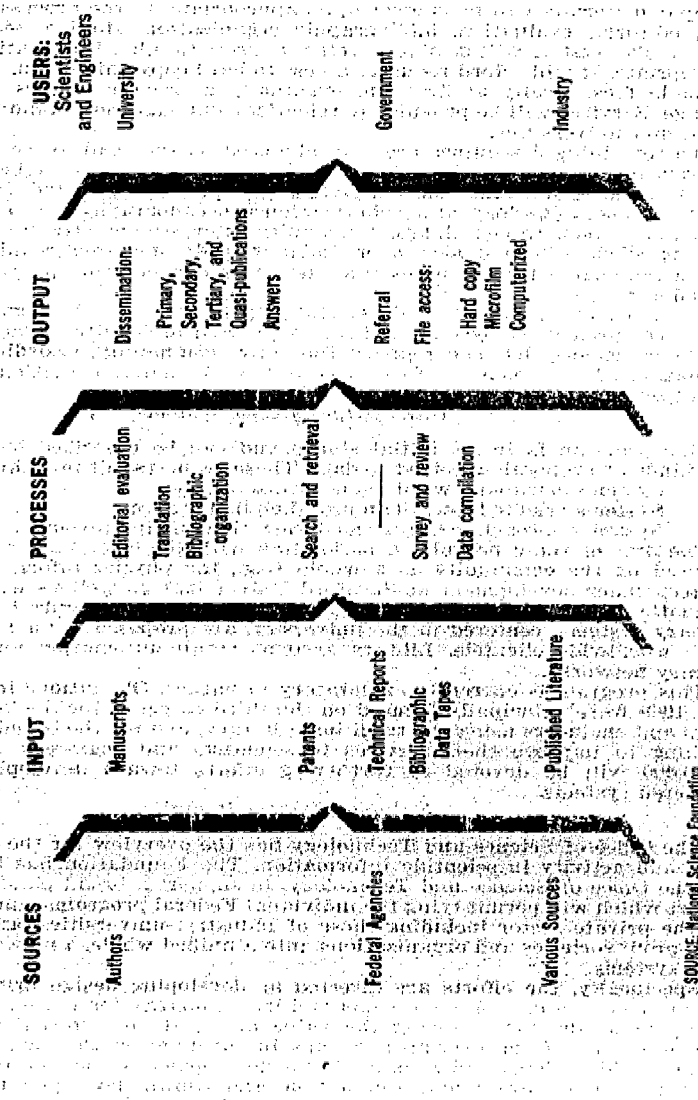
Figure I-3

NSF INFORMATION SYSTEM DEVELOPMENT AND IMPROVEMENT IN SCIENTIFIC DISCIPLINES OTHER THAN CHEMISTRY

DISCIPLINE	FY 1969 STATUS	FY 1970 PLANS
Physics & Astronomy	• Defining comprehensive program of development/acquisition • Developing computerized bibliographic and type-setting capabilities	• Initiate program
Psychology	• Defining comprehensive program of development/acquisition	• Initiate program
Linguistics	• Defining comprehensive program of development/acquisition	
Mathematics	• Preliminary study/liaison • Developing computerized typesetting and editing capabilities	• Initiate program definition
Environmental Sciences	• Preliminary study/liaison	
Engineering Sciences	• Preliminary study/liaison	
Life Sciences	• Developing computerized bibliographic and other capabilities	
Other Social Sciences	• Developing computerized biobibliographic capability in economics	• Preliminary study/liaison

SOURCE: National Science Foundation

Figure I-4
THE NATIONAL PHYSICS INFORMATION SYSTEM



SOURCE: National Science Foundation

Input materials will be subjected, as appropriate, to the processes of translation, editorial evaluation, bibliographic organization, storage, search, and retrieval. The system will be able to refer its users to other information sources as appropriate. It will afford its users access to hard copy, microform, and machine-readable files, locally at first and eventually at remote centers via electronic linkage. Services will be provided to scientists and engineers in industry, Government, and universities.

The remaining disciplines are less advanced on the road to securing effective information system. In the field of mathematics progress in achieving community acceptance of an information system concept has been noted. In the environmental sciences (geology, atmospheric science, oceanography) serious efforts have been undertaken to consolidate community interest. The strategy for the engineering sciences is to support a preliminary study of system requirements upon which the engineering societies can base an implementation program supported by industry.

Development of several independent capabilities (as distinguished from a single comprehensive system) is being supported in the life sciences since there is no one society that can represet the entire community. Coordination or consolidation of independent efforts may follow. A similar condition exists in the social sciences.

University-centered systems

This program is in its initial stages and can be described by summarizing the kinds of proposals received to date. These requests fall into three categories:

Systems oriented toward scientific disciplines
Systems oriented toward an interdiciplinary area
System approach to library modernization and improvement

The first of these provides a major link with the discipline-oriented systems focused on the community as a whole (e.g., the physics information retrieval system under development at Stanford University) as well as with Federal information services and those in adjacent industries (see Figure I–5). Interdisciplinary systems, centered in the university, are proposed for a nationwide and even worldwide clientele. Library systems entail automation and support for library networks.

This program is currently exploratory in nature. Obligations in FY 1968 and FY 1969 were principally focused on the third category for the benefit of scientists and engineers using the traditional library, and for the benefit of librarians seeking to improve their services to scientists and engineers. Approximately $800,000 will be devoted to furthering efforts toward developing university-centered systems.

National System Planning

The Office of Science and Technology has the overview for the entire Federal role and activity in scientific information. The Foundation has been requested by the Office of Science and Technology, to support a broad planning and study effort which will permit tying the individual Federal programs, and the programs in the private sector including those of industry, universities, and professional non-profit societies and organizations, into a unified whole, a network of information systems.

Specifically, the efforts are directed at developing design criteria, technical requirements, and minimum compatability standards for national systems; developing means for assessing the value and costs of alternative information systems; identifying overlap and gaps in coverage on the part of the several systems; identifying and assisting in the development of new means for information storage, retrieval and dissemination; and overall, developing the information base required for policy on national science information systems and networks.

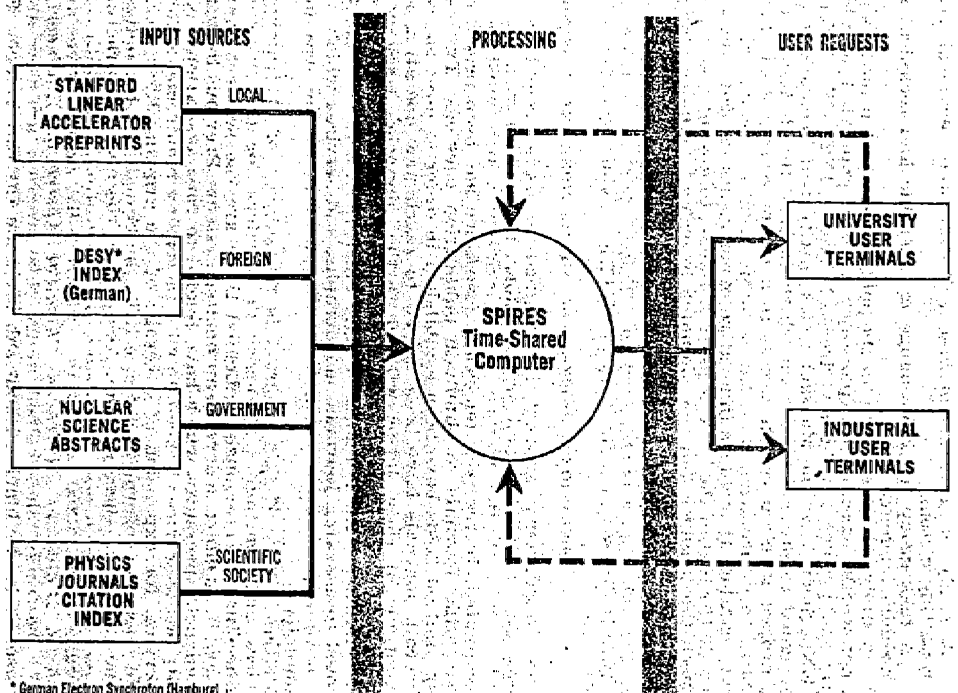
In addition, support is provided for studies and research directed at the solution of long-term science information problems. This effort ranges from fundamental research to sophisticated hardware utilization studies and includes programming, planning, and development of experimental prototype services aimed at advancing the state-of-the-art or exploiting innovative technology. In contrast to basic research, this activity is directed to specific problems in order to develop and evaluate the feasibility of a specific solution.

Examples of the planning and study effort are:

Figure I-5

SPIRES

Stanford Physics Information Retrieval System



* German Electron Synchroton (Hamburg)

SOURCE: National Science Foundation

A study of government-wide scientific and technical research project reporting system.

A task group for interchange of scientific and technical information in machine language.

A study of page charges for the publication of scientific papers.

A noteworthy example of exploratory research supported in order to anticipate operational problems of the next decade is Project INTREX (INformation TRansfer EXperiment), at the Massachusetts Institute of Technology (M.I.T.), which is designed to provide results on which to base the design of future libraries. The project involves remote access to a computer-stored catalog that provides much more information than one is accustomed to receive from the traditional library catalog. It includes innovative experiments in providing extremely rapid access to the text of the book or journal article, following a sophisticated dialogue between the inquirer and the computer in order to remove ambiguity from the original question.

In FY 1968, $964,308 was obligated. In the category of National Systems Planning, the following was obligated: in FY 1969, $600,000, and FY 1970, $1,000,000. FY 1970 includes funds for Project INTREX, which was funded for two years in FY 1968.

OPERATIONAL SUPPORT FOR PUBLICATIONS AND SERVICES

The Foundation's support is designed to assist scientists, through their representative societies and organizations, to keep up with the continuous and rapid growth in the volume of information which must be published and disseminated. In the past ten years assistance has been provided to more than 60 scientific journals to eliminate publication backlogs. Twelve new journals in specialized fields have been established in order to meet emergent needs.

Overall, journals have been helped to reach new operating levels and then to continue at those levels without further financial assistance. During this same period, 245 scientific monographs (books) in all scientific disciplines have been published with Foundation help. Since 1958, a total of $5,112,000 has been devoted to assisting journals, monographs, and services which would otherwise not have appeared or would have disappeared, to the loss of the scientific community.

Another aspect of this program is the support of abstracting and indexing services and continuing bibliographic services for the fields of science and engineering. As previously indicated these are the services that are presently engaged in an effort to develop automated systems. Previous to such undertakings, the financial pressures which have tended to raise operational costs limited the ability of the services to keep up with increasing requirements for diversification of service, for expansion of coverage of the growing literature, and for more rapid release of information. Since 1958, the Foundation has obligated $12,522,000 or the support of these services. As a result, the major abstracting and indexing services have been able to expand their operational capabilities and literature coverage by 80 to 200 percent (see Figure 1-6). Such services as *Mathematical Reviews*, *Biological Abstracts*, *Chemical Abstracts*, *Engineering Index*, and *Metal Abstracts*, once helped under this program are now able to maintain themselves in the black without subsidy from the Government. Foundation support is predicated on planning by the particular service to reach a level of economic independence. In FY 1970, the Foundation plans support in the amount of $1,200,000, of which two-thirds would support abstracting and indexing services and one-third would support all other publications and services.

Science Information Exchange

The Science Information Exchange (SIE), in the Smithsonian Institution, requires special mention as one of the information services supported by the Foundation. The SIE is now twenty years old, was initially supported by a number of Federal agencies but has depended solely on the Foundation for the past five years. The change to single-agency funding commenced in FY 1965 upon the recommendation of the Federal Council for Science and Technology.

The primary mission of the SIE is to assist Government agencies in administering research grants and contracts by maintaining an inventory of ongoing research projects. SIE receives notifications of research projects in progress from Federal agencies as well as from foundations, universities, and other non-

Figure I-6

GROWTH OF ABSTRACTING-INDEXING SERVICES, 1957-70

MAJOR SERVICES (by discipline)	Number of Literature Items Abstracted and/or Indexed (in thousands of citations)														
	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968[1]	1969[1]	1970[1]	TOTALS
BIOLOGY															
Biology Abstracts	40.0	43.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	240.0	265.0	1850.0
CHEMISTRY															
Chemical Abstracts (excl. Patents)	84.2	95.7	98.7	[illegible]	118.3	140.2	[illegible]	161.5	165.8	181.7	199.0	216.0	235.0	258.0	2199.6
PHYSICS															
Physics Abstracts	10.0	9.0	14.0	21.4	21.2	24.2	26.0	31.0	34.0	38.0	40.8	43.0	45.0	45.0	402.6
MATHEMATICS															
Mathematical Reviews	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	17.0	17.0	17.0	178.3
Computing Reviews	—	—	—	—	—	—	—	1.6	[illegible]	2.2	[illegible]	[illegible]	3.5	3.5	17.9
EARTH SCIENCES															
Geoscience Abstracts	—	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	—	41.5
Bibliography & Index of Geology, Exclusive of North America	6.8	6.0	6.5	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	30.0	138.4
Meteor. & Geoastro. Abstracts	5.3	4.8	7.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12.0	122.3
SOCIAL SCIENCES															
Psychological Abstracts	9.1	6.1	11.2	8.5	7.4	8.4	8.4	10.5	[illegible]	[illegible]	17.2	[illegible]	21.0	22.5	180.1
Sociological Abstracts	1.0	[illegible]	[illegible]	1.9	[illegible]	3.0	[illegible]	6.1	5.7	5.7	5.7	5.7	5.7	5.7	55.3
ENGINEERING															
Engineering Index[1]	26.3	27.0	30.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	75.0	645.9
Applied Mechanics Reviews	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	106.6
Int'l Aerospace Abstracts	—	—	—	—	[illegible]	[illegible]	16.1	18.6	26.9	33.2	33.1	34.0	35.0	36.0	255.8
Review of Metals Literature	8.2	9.0	10.0	11.0	12.0	[illegible]	[illegible]	[illegible]	[illegible]	20.0	26.8	24.0	24.0	24.0	216.7
TOTALS	201.4	215.1	259.9	279.4	335.2	382.4	396.4	438.0	481.8	564.6	632.4	677.5	743.2	803.7	6411.0

	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969[1]	1970[1]	TOTALS
Amount of NSF Support Provided these Services (in thousands of $)	30.0	47.0	270.0	636.0	492.0	878.0	813.0	765.0	1015.0	959.0	1083.0	897.0	600.0	1000.0	9475.0

[1] Estimates

SOURCE: National Science Foundation

(shaded bar) = period of NSF support

Federal organizations. Each notification consists of a description of the research and indicates the principal investigator, where the work is performed, who supports it, the funding level, and the duration of the project.

This information is processed into a computerized data bank which enables the SIE to provide a number of different services. When requested by a Federal research administrator, the SIE can provide information about research projects in its file pertaining to a particular subject (see Figure I-7), information about research projects in which an individual scientist is engaged and listings of research projects pertaining to a broad subject field, e.g., *Water Resources Research Catalog*. SIE can also provide "Administrative Compilations" which list Federal awards to an individual institution, projects reported by a given agency, research performed on a given subject at a given location, and similar variations. In FY 1969, the support level for SIE was reduced from $2,000,000 to $1,800,000 on the basis of streamlining and automation of operations, and the introduction of service fees to all SIE users. The $1,600,000 requested for SIE support in FY 1970 reflects a continuation of this trend.

RESEARCH AND DEVELOPMENT

This program is oriented toward the support of basic and applied research, and evaluative studies in science information. The aims are:

To define the scope and character of science information problems by investigating the processes of communication in the sciences and the utility to scientists and engineers of existing and proposed information services.

To stimulate and support research essential to the development of better methods of handling large volumes of scientific and technical information.

To investigate the possibility of adapting or devising new ideas, concepts, methods, techniques, equipment and systems to the solution of science information problems.

To encourage utilization of proven techniques and devices of innovative character which contribute to the development of discipline-oriented, multidisciplinary, and university-centered information systems or for use in information systems and services provided by the Federal Government.

The program comprises two categories: individual research or study projects focused generally on a single problem; the support of science information research centers.

Research Projects

Primary emphasis is on the support of individual projects by highly qualified investigators. Typical examples are:

Studies aimed at determining the nature of scientists' and engineers' information needs and the manner in which those needs are currently met as well as the relation between the use of information and ultimate performance in research and development projects.

Experimentation in indexing, involving computer applications, to determine whether the content of indexed material is better represened by individual words or by phrases automatically selected out of context.

Development of measures and measurements criteria for the evaluation of the various functions of document retrieval systems in order to provide an objective method for determining the efficiency and utility of new developments and applications.

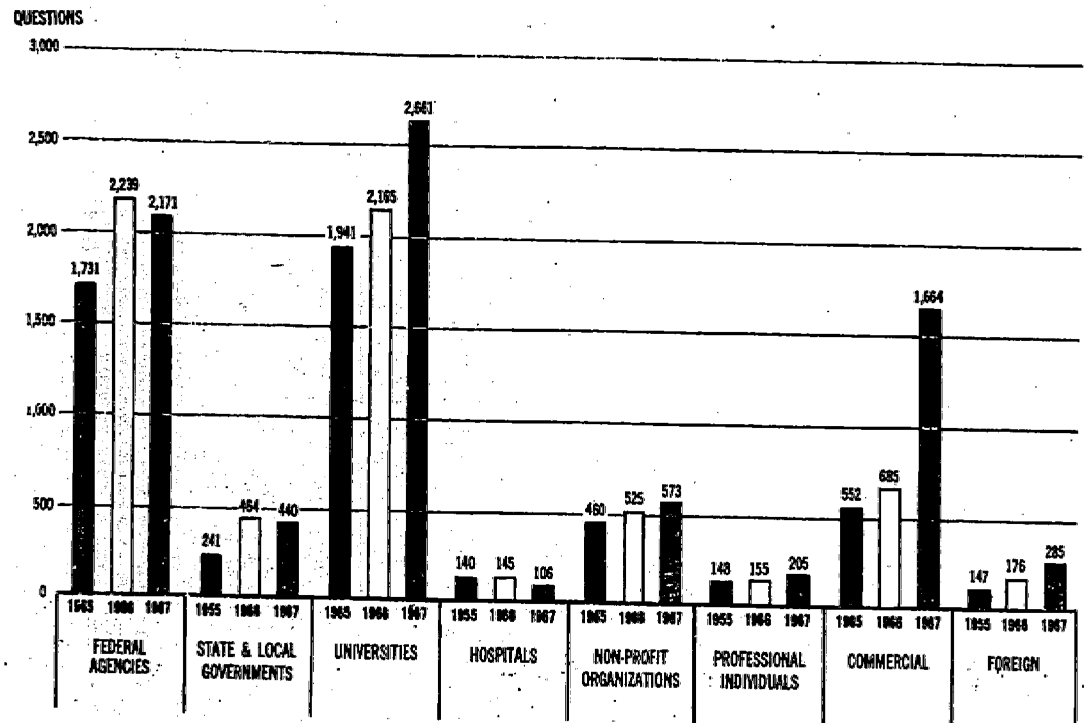
Research Centers

Support of science information research centers began in FY 1965. It is aimed at concentrating both human and financial resources for research in science information within an environment that attracts capable scientists from a number of needed disciplines such as information science, behavioral science, economics, and management. The university provides this environment and fulfills the vital role of training a new generation of information scientists who can apply their research talent to the operational problems present in the university setting (see Figure I-8).

The Foundation now supports two centers, one at Ohio State University and another at the Georgia Institute of Technology. Both institutions possess the key elements of the ideal research center—interdisciplinary research, graduate education in information science, and operational problems. The center at Georgia Institute of Technology has formulated a broad program of theoretical research

Figure I-7

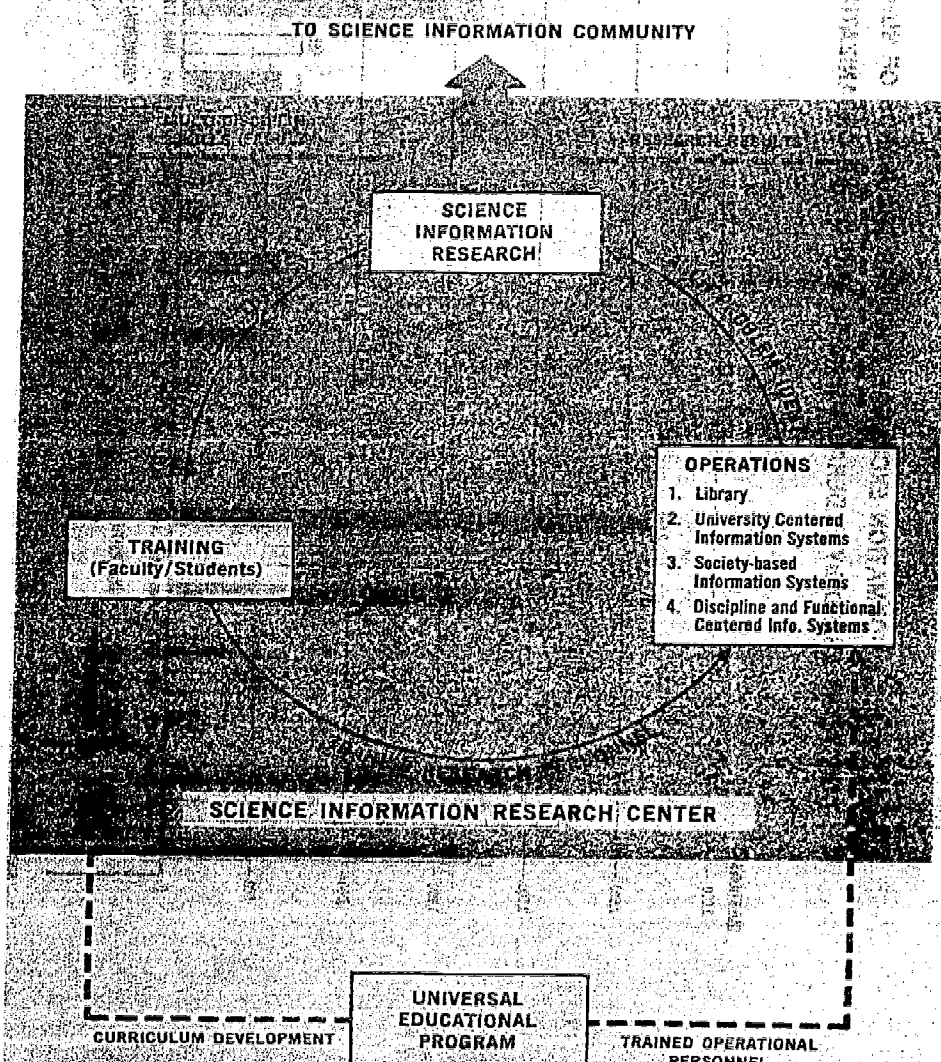
THE SCIENCE INFORMATION EXCHANGE ANSWERS THOUSANDS OF SUBJECT QUESTIONS ASKED BY FEDERAL AGENCIES AND OTHER ORGANIZATIONS



SOURCE: National Science Foundation

Figure I-8

FUNCTIONAL RELATIONSHIPS OF A SCIENCE INFORMATION RESEARCH CENTER



SOURCE: National Science Foundation

closely linked to a graduate degree program in information science. The Institute's library provides a strong role, actively proceeding with automation and mechanization and providing an operational environment for the research program. The center at Ohio State University has an excellent staff and has a close working relationship with the university's computer science center. This program also entails joint research with the Battelle Memorial Institute and with the Chemical Abstracts Service, both neighboring organizations.

Of the $900,000 requested for FY 1970, $300,000 will be used to support individual research projects. The remaining $600,000 is required for continued support of the research centers at Ohio State University and the Georgia Institute of Technology.

INTERNATIONAL INFORMATION AND TRANSLATION

One-half of the world's scientific and technological literature is published in languages unfamiliar to 95 percent of our scientists and engineers (see Figure I-9). The Foundation has developed two complementary translation activities toward making this literature available and usable by Americans:

Domestic translation—accomplished in the United States.

Foreign translation—accomplished in foreign countries through contractors, utilizing foreign currencies.

Domestic Translation

The Foundation supports professional and scientific societies in the United States for the translation and publication of primary foreign scientific literature which contain results of current research. Since the inception of this program in 1952, 66 journals and a number of books have been translated to a total of 670,000 English pages. Thirty-four of these journals are now being published without Foundation support and 14 of the remaining 32 are expected to become self-sufficient. The total cumulative production of these journals is nearly one million pages (see Figure I-10).

Translation projects are proposed to the Foundation by scientific and professional societies on the basis of expressed needs of their membership. The actual translation is accomplished by the societies' professional staffs or by means of a subcontract with a commercial translation firm. The translanted product is sold by subscription at a price considerably higher than for the average scientific journal. Subscriptions are also sold to other countries.

In FY 1970 twenty journals will require continued Foundation support. New journals can be subsidized only as older ones become self-sufficient.

Foreign Translation

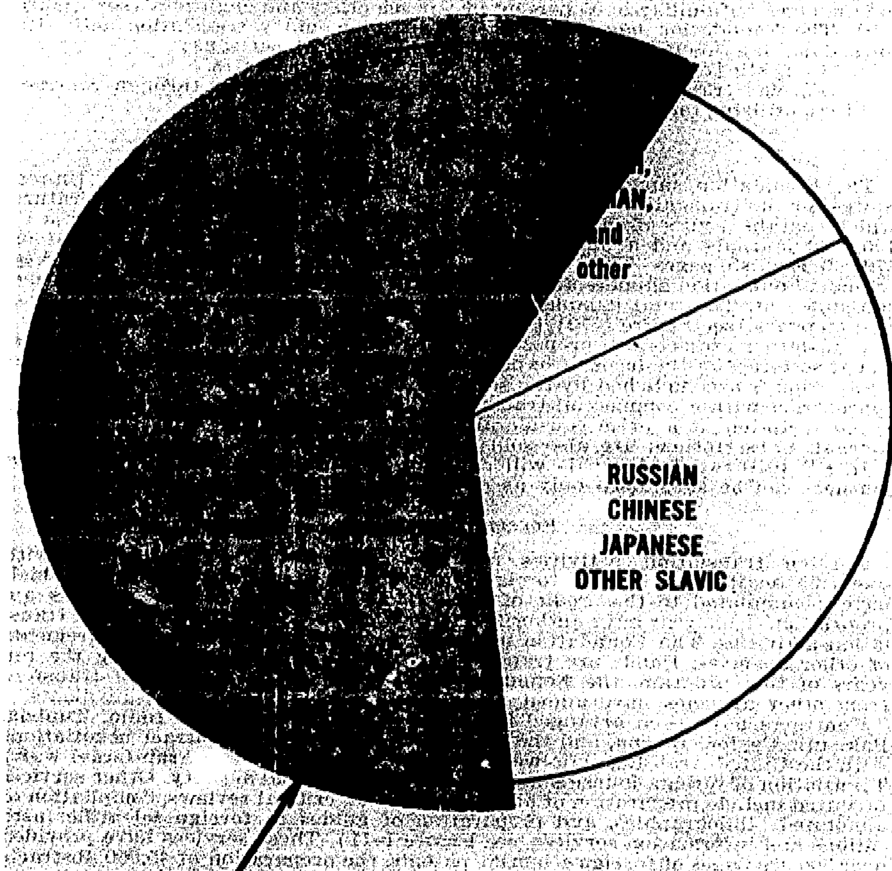
Foreign translation activities are accomplished through contracts with scientific institutions in nine foreign countries utilizing local currencies which have accumulated to the credit of the U.S. Goverment. The Foundation's appropriations each year have authorized the obligation of $1,000,000 for these translation activities. The Foundation manages the foreign translation requirements of other agencies. Funds are transferred from these agencies. During the ten years of this program, the Foundation has allocated $8,763,000 and transfers from other agencies have added $5,886,000 in foreign currency equivalents.

Contracts have been arranged in Israel, Poland, Yugoslovia, India, Tunisia, Pakistan, Ceylon, Burma, and the United Arab Republic. (Contract negotiations with the United Arab Republic were suspended because of the Arab-Israel war.) Translation of foreign journals and books is the principal activity. Other services procured include preparation of abstracts, digests, critical reviews, compilation of annotated bibliographies, and preparation of guides to foreign scientific institutions and information services, see Figure I-11). These services have provided over 500,000 pages of foreign scientific patents, the preparation of 45,000 abstracts and digests, and more than 100 bibliographies (see Figure I-12).

As contrasted to the domestic translation activity, which responds to requirements of our scientific community expressed through scientific and professional societies, the foreign procurement effort responds to requirements of other agencies of the Federal government. In both instances, the value of the programs have elicited numerous testimonials with specific examples of how time, talent, and fiscal resources have been conserved through the availability and utilization of these services. One of the more dramatic examples concerns

Figure I-9

LANGUAGES OF THE WORLD'S SCIENTIFIC LITERATURE



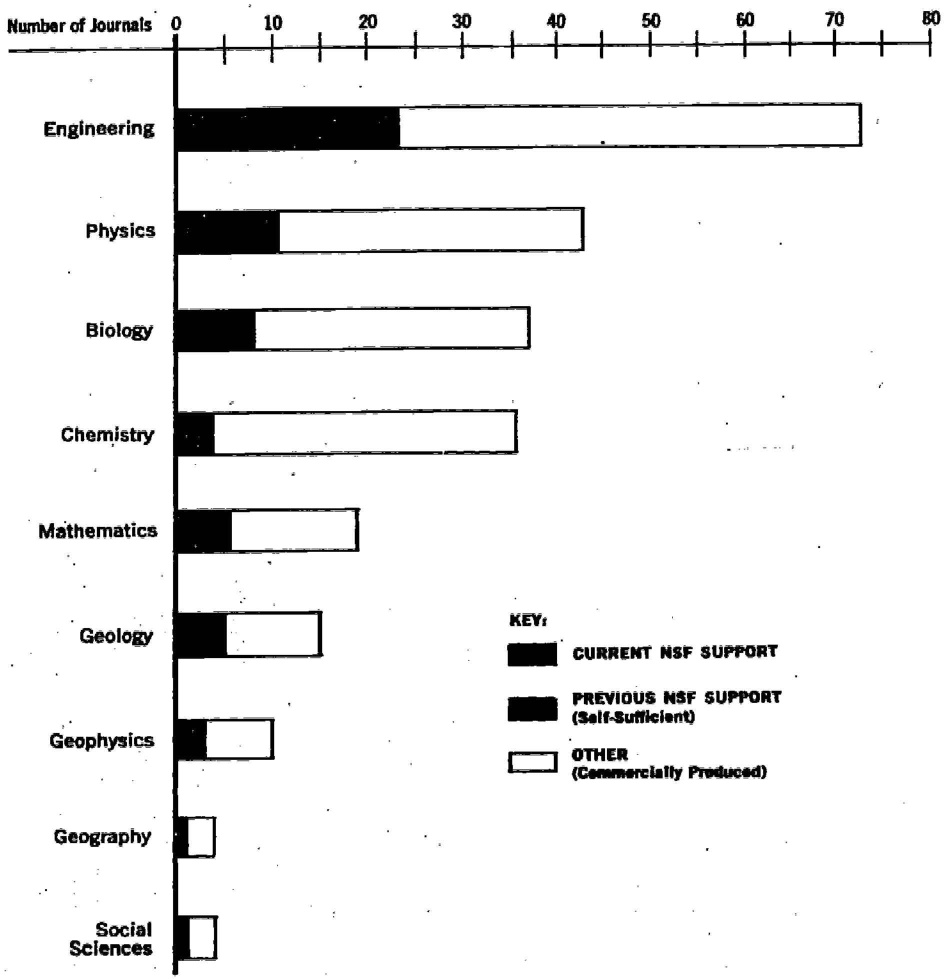
Percentage of comprehension by U.S. scientists.

SOURCE: National Science Foundation.

Figure I-10

TRANSLATION JOURNALS FOR U.S. SCIENCE

TOTAL—241 JOURNALS



SOURCE: National Science Foundation

Figure I-11

SPECIAL FOREIGN CURRENCY SCIENCE INFORMATION PROGRAM
DIVERSITY OF ACTIVITIES

SCIENCE INFORMATION			PARTICIPATING AGENCIES													
[illegible]	[illegible]	FIELD	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Translation & Publication	Books	Various	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Monographs	Various	x	x	x	x	x	x	x	x	x	x		x	x	
	Theses	Various	x			x										
	Articles	Various	x	x	x	x	x	x	x	x		x			x	
	Abstracts (R.Zh.)	Bio-Medical	x	x												
	Journals	Various	x	x	x	x	x	x	x	x		x			x	
Simultaneous Publication	Journals	Various	x	x		x	x	x	x			x		x		
Pub. English Editions only	Journals	Various		x	x											
	Info. brochures	PL-480 Activities				x										
	Books	Various	x	x												
Preparation & Publication	Annotated Bibliographies	Sedimentation				x										
		Shallow subsidence						x								
		Fisheries						x								
		Education			x											
	Digests	Drug		x												
	Abstracts	Biological	x													
		Oral Research		x												
		Drug		x												
		Meteorological					x									
		Fisheries						x								
		Education			x		x									
		Thermochemical					x									
	Indexes	Patent Classif.					x									
		UDC—Geology					x									
	Patents	Various					x									
	Directories	Scientific Research	x	x												
	Guides	Research	x	x												
	Manuals	Sci. Info. Services	x	x												
Acquisition	Journals	Various					x	x								
	Books	Various	x					x								
	Patents	Various					x									
Planned: Preparation	Critical Reviews	Various														
	Abstracts	Various														
Microfilming	Patents	Various														

SOURCE: National Science Foundation

Figure I-12

SPECIAL FOREIGN CURRENCY SCIENCE INFORMATION PROGRAM, 1959-68

In Pages by Categories and Countries

Country	Translations	Abstracts	Patents	Bibliographies		Directories		Total Pages	Percentage
				Pages	Number	Pages	Number		
Israel	274,171	38,031	9,350	2,442	20	1,096	2	325,090	63.0
Poland	98,921	4,585	11,500	1,650	28	916	2	117,572	22.8
Yugoslavia	51,678	3,090	—	1,050	21	600	1	56,418	10.9
India	11,875	—	—	550	8	—	—	12,425	2.4
Tunisia	2,634	—	—	400	8	—	—	3,034	0.6
Burma	—	—	—	300	6	—	—	300	0.1
Ceylon	—	—	—	400	8	—	—	400	0.1
Pakistan	—	—	—	400	8	—	—	400	0.1
Totals	439,278	45,706	20,850	7,192	107	2,612	5	515,639	100.0
Percentage	85.2	8.9	4.0	1.4	—	0.5	—	100	—

SOURCE: National Science Foundation

the translation of a Russian research report on hail suppression in the Caucasus in 1965 (*Findings of the Caucasus Anti-Hail Expedition*, by G. K. Sulakvelidze) which made available a blueprint for a specific test in this field. If the Russians model proves to be valid for hailstorms in the United States, it is anticipated that at least five years of exploratory research and $20,000,000 will have been saved.

The FY 1970 requirement for foreign translation is $1,400,000. Domestic translation will require $500,000 and the foreign activity will require $900,000. Each amount will be used for supporting and procuring high priority translations for the benefit of Amercan scientists and engineers.

Authorization for excess foreign currencies

An authorization of $2,000,000 in excess foreign currencies is requested in order to obtain valuable foreign scientific translations from those countries where the use of excess currencies is authorized.

International Participation

The central and critical role of information to scientific and technical progress is not unique to the United States. Most technically advanced countries have recognized the need to increase their capacities for the organization and improved communication of scientific and technical information. Our own professional societies and Federal agencies have found it necessary to develop a cooperative posture vis-a-vis other countries for the sake of economy and effective development The resulting pattern of cooperation and interaction takes many forms, ranging from bilateral exchanges of information and cooperation to organized programs in international organizations both governmental and non-governmental.

To foster international science information exchange, the Foundation supports the Abstracting Board and the Committee on Data for Science and Technology of the International Council of Scientific Unions, the International Federation of Documentation, the Pacific Science Association, and The International Federation of Documentation. The funds in support of these organizations are less than $100,000 per annum. Valuable assistance is provided by the staff of the Foundation in the work of these organizations either directly or through advice to other American participants. Organizations as the Organization for Economic Cooperation and Development; the U.N. Educational, Scientific and Cultural Organization; the International Organization for Standardization; and the International Council of Scientific Unions, are initiating programs involving international communication networks and standardization of procedures for compatible information processing systems. American leadership is necessary for the success of these efforts and to assure that the systems and services that emerge from these efforts are compatible and of value to our science and technology.

Other International Activities

The Foundation also supports the acquisition of difficult-to-obtain scientific materials and the preparation and publication of guides and directories that provide U.S. scientists and engineers with information on organizations, individuals, policies and information resources in other countries (see Figure I-13). Support is based on demonstrated need that cannot be satisfied through private efforts. Plans for FY 1970 are limited to updating guides and directories of demonstrated utility produced in the past but now no longer current.

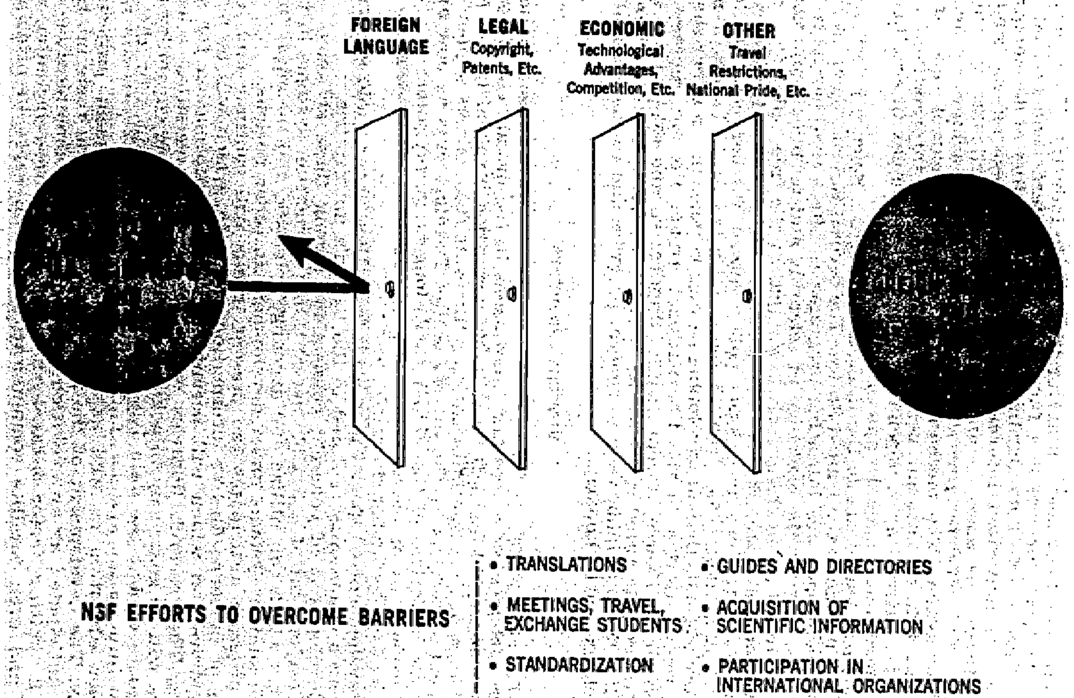
The requirement for FY 1970 of $300,000 for international activities, exclusive of translations, is an increase of $100,000 over the obligations planned in FY 1969. These funds entail no new starts.

FEDERAL-PRIVATE AND INTERNATIONAL RELATIONSHIPS

The interaction between the two sectors is extremely complex. Numerous Government agencies are charged by law to provide information services to the general public in order that the public can benefit from Federal efforts in medical and health research, from technological developments resulting from defense, space, and agricultural research and development, and from work in the fields of air pollution, water resources, etc. The Federal information services cannot be completely independent of the scientific and technical research accomplished in the private sector and disclosed by the information services organized to

Figure I-13

INTERNATIONAL SCIENCE INFORMATION BARRIERS



SOURCE: National Science Foundation

serve scientists and engineers in universities and in industry. The eventual interconnection of these services is a function of this interdependence, but requires enormous efforts to effect standardization and compatibility of developing systems and in new computerized information processing. These efforts must seek a balance between the missions and purposes of the particular system vs. loss of autonomy and self-determination necessary in order to achieve standardization and interconnection. The mechanism for the achievement of this interconnection, looking toward national networks of the major information systems, is still in its formative stages, depending chiefly on a complex interaction between numerous government agencies and committees.

A similar problem exists on the international scene. Science information problems are not unique to the United States. The several international organizations previously mentioned are initiating programs to effect the emergence of international networks for the exchange of scientific and technical information. National self-interest all too frequently is set against the free and open interchange of information. Language differences, accentuated by national pride, complicate this problem. Variations in science policy afford further complications in a rapidly changing field. The problem for the United State is less a matter of expenditure of funds than of developing its own policies in a manner that permits effective representation in the international arena. Present representation is characterized by diverse, uncoordinated, duplicative and exploratory activities. A positive and integrated approach by U.S. representatives on the international scene will contribute immensely to general progress and to the particular benefit of U.S. science and technology.

FUTURE PROSPECTS

The long-range prospects for science information and its dissemination depend on the technological advances and innovations in the broad field of communication. Adaptation of these advances to the activities involved in the processing and exchange of scientific information will result from efforts supported by the Government as well as by the private sector. Developments as now anticipated describe the objectives of the Foundation's long-range program:

Development of effective and efficient information systems to serve all fields of science and engineering.

Development of special purpose information systems and services for the research community centered in the nation's universities.

Development of coherent connections among these systems.

Development of a flexible network of information systems in the United States which can utilize and exchange scientific and technical information with similar systems under development in other nations.

This program anticipates the present trends will continue and lead to the creation of immense files of information and data, which will be manipulated by computers and which will permit retrieval of information for specialized purposes. The research libraries which serve the universities' scientists and students will be geared up to achieve a presently lacking capability to connect with and to exploit the data bases created and maintained by the discipline-oriented information systems, and will increasingly serve adjacent institutions of higher education as well as research and development projects in local industry. The development of the indicated networks and their interconnection can be anticipated as an evolutionary process. The communication technology is not a limiting factor because the present facilities, including microwave relays, and even satellite communication, can all serve in principle. Before these facilities can be effectively utilized a number of technical, managerial, and economic problems must be solved. These include the problem of the best way to organize large computer files so that they can be searched rapidly, reliably, and economically; the programming and economical organization of computerized systems with multiple access on a real time basis; the development of effective standards at all stages of processing information for utilization in these complex systems and in order that data in one file or in one system can be merged with or used by another; and the evolution of a rational plan for assigning financial and functional responsibilities for maintaining and administering the information systems and their data bases in a manner that optimizes the economic requirements and the needs of the scientists and engineers who depend on them for information.

The program we have outlined above cannot depend exclusively upon Federal funding nor, by virtue of its evolutionary character, can it be designed in special detail now. Its value lies in providing goals which are worthwhile and challenging, so that our immediate programs can be shaped in a perspective that will ensure their future usefulness to the nation's community of scientists and engineers.

Mr. PUCINSKI. Thank you very much, Dr. Adkinson.

When was your agency established, Dr. Adkinson?

Dr. ADKINSON. The National Science Foundation itself was established in 1950 and became operational in 1951.

Mr. PUCINSKI. When did you take over as Director?

Dr. ADKINSON. I took over as Director of the Office of Scientific Information in December of 1957. The Office of Science Information Service was not established until a year later.

Mr. PUCINSKI. You became Director in 1958?

Dr. ADKINSON. Yes.

Mr. PUCINSKI. That was 11 years ago?

Dr. ADKINSON. Right.

Mr. PUCINSKI. Do you have the total expenditures for your agency in the 11 years?

Dr. ADKINSON. No, I do not have, but I could furnish it.

Mr. PUCINSKI. What do you think it was? What is your annual budget?

Dr. ADKINSON. Are you speaking now of the Office of Science Information Service or the Foundation in total?

Mr. PUCINSKI. Just the Science Information Service.

Dr. ADKINSON. The total over that period, I would guess, is somewhere between $50 and $100 million.

Mr. BELL. You asked for the budget for the year.

Mr. PUCINSKI. What is the budget for 1 year?

Dr. ADKINSON. My budget for 1 year ranges—for this year it is $11 million.

Mr. PUCINSKI. For Science Information Services?

Dr. ADKINSON. For next year the request is for $13 million.

Mr. PUNCINSKI. So I understand correctly in my own mind, the Office of Science Information Services is an adjunct of the National Science Foundation?

Dr. ADKINSON. Part of it; yes, sir.

Mr. PUCINSKI. You do not operate the National Science Foundation, the National Science Foundation operates you?

Dr. ADKINSON. That is correct. My office funds represent roughly 2 to 3 percent of the Foundation's funds.

Mr. PUCINSKI. And you have in the last 10 years or thereabouts received somewhere in the vicinity of $100 million for your agency?

Dr. ADKINSON. That is right.

Mr. PUCINSKI. Do you have a science information retrieval system or any science information retrieval system now in the Science Information Service?

Dr. ADKINSON. We do not have, sir. Our main purpose has been to fund organizations that do have those systems or want to develop them.

Mr. PUCINSKI. Now the act which established your agency, according to your testimony, was designed to foster the interchange of scientific information among scientists in the United States and foreign countries. Would you give this committee a list of all the contracts that your Science Information Service has entered into with scientists in the United States and in foreign countries in developing an interchange of scientific information?

Dr. ADKINSON. May I ask a question here, so I am perfectly clear what you would like to have?

You used the word "contract." Are you asking for both contracts and grants?

Mr. PUCINSKI. I am asking for contracts and grants.

Mr. ADKINSON. And over what period of time——

Mr. PUCINSKI. In other words, what have you done in the last 6 years to foster the interchange of scientific information among scientists in this country and in foreign countries?

Dr. ADKINSON. There are several, sir. I mentioned one and stressed it in my testimony; namely, translations which has proven to be very, very useful. I could give you several instances of where this has saved the United States money, where it has given us new techniques that we are using in industry as well as in research. We also make available funds for the support of travel for scientists to international meetings.

Mr. PUCINSKI. You have paid for travel of scientists to meetings?

Dr. ADKINSON. The National Science Foundation, roughly, supports over 700 scientists to attend international meetings every year.

Mr. PUCINSKI. Would you give us a list of those?

Dr. ADKINSON. Of the people?

Mr. PUCINSKI. Yes. And where they went and what meetings they attended.

Dr. ADKINSON. We will try to do that, sir. I think we have that record.

(The information follows:)

The listing that follows represents grants made by the National Science Foundation in Fiscal Year 1968 in support of international scientific exchange and travel to meetings. This list has been published in *National Science Foundation Grants and Awards* (Washington, U.S. Government Printing Office, 1968, NSF 69-2, p. 158-171).

It may be noted that the grants and awards include support both to individuals and to organizations. Block grants to organizations support the travel of several American scientists from different institutions in the United States to the meeting specified in the title of the award.

INTERNATIONAL SCIENTIFIC INFORMATION EXCHANGE (TRAVEL)

INDIVIDUAL AWARDS

Forbes, Robert S.; *VIII Conference on Experimental and Technical Mineralogy and Petrography in Novosibirsk, U.S.S.R., June 10–14, 1968* (A004607); 6 months; $1,055

Anderson, Don R.; *NATO Advanced Study Institute on Paleogeophysics, Newcastle-Upon-Tyne, England, April 1–6, 1968* (GZ1007); 6 months; $576

Hanks, Thomas C.; *NATO Advanced Study Institute on Paleogeophysics, Newcastle-Upon-Tyne, England, April 1–6, 1968* (GZ1008); 6 months; $590

AFRICAN STUDIES ASSOCIATION

Irwin, Graham W.; *Travel for Americans To Attend Second International Congress of Africanists, Dakar, Senegal, December 11–20, 1967* (GS1881); 12 months; $2,500

AMERICAN CHEMICAL SOCIETY—CHEMICAL ABSTRACTS SERVICE

Tate, Fred A.; *The Chemical Society (London) Conference on Mechanized Scientific Information Services, Durham, England, September 22–24, 1967* (GN689); 3 months; $464

Stobaugh, Robert E.; *Annual Meeting of the Belgian Chemical Society, Brussels, Belgium, March 21–22 and the Joint Meeting of the Chemical Society, Institute of Chemistry of Ireland and the Royal Institute of Chemistry, Dublin, Ireland, April 1–5, 1968* (GN739); 6 months; $516

Anzelmo, Frank D.; *The OECD Chemical Information Panel Meeting in Paris, France, April 18–19, 1968* (GN755); 6 months; $506

Tate, Fred A.; *The OECD Chemical Information Panel Meeting in Paris, France, April 18–19, 1968* (GN756), 6 months; $506

AMERICAN GEOLOGICAL INSTITUTE

Hoover, Linn; *Twenty-Third International Geological Congress and (Sixth International Mineralogical Association), Prague, Czechoslovakia, August 19–September 3, 1968* (A001565); 12 months; $11,000

AMERICAN GEOPHYSICAL UNION

Smith, Waldo E.; *Fourteenth General Assembly of the International Union of Geodesy and Geophysics, St. Gall, Switzerland, September 25–October 7, 1967* (A0805 008*); $15,000

AMERICAN INSTITUTE OF PHYSICS

Koch, H. William; *Thirty-Fourth International Federation for Documentation (FID) Conference and International Congress on Scientific Information, To Be Held in Moscow, U.S.S.R., September 9–18, 1968* (GN765); 6 months; $750

AMERICAN PSYCHOLOGICAL ASSOCIATION

Griffith, Belver C.; *The Meeting of the International Union of Psychological Science Committee on Publication and Communication and the 8th International Congress of Applied Psychology, Amsterdam, Netherlands, August 18–22, 1968* (GN768); 6 months; $516

BELL TELEPHONE LABORATORIES

Donovan, Paul F.; *International Conference on Nuclear Structure, Tokyo, Japan, September 7–13, 1967* (GP7789); 8 months; $998

BERNICE P. BISHOP MUSEUM

Sinoto, Yoshiko H.; *VIII International Congress of Anthropological and Ethnological Sciences, Tokyo, Japan, September 3–10, 1968* (GS2127); 6 months; $555

BOSTON UNIVERSITY

Zimmerman, George; *The Eleventh International Conference on Low Temperature Physics, St. Andrews, Scotland, August 21–28, 1968* (GP9076); 6 months; $419

Mendillo, Michael J.; *NATO Advanced Study Institute—Satellite Signal Propagation in the Ionosphere, Viareggio, Italy, June 10–22, 1968* (GZ1026); 6 months; $198

BRANDEIS UNIVERSITY

Linschitz, Henry; *Symposium on Basic Mechanisms in Photochemistry and Photobiology, Caracas, Venezuela, December 4–7, 1967* (GB7050); 6 months; $5,000

Matsusaka, Teruhisa; *The International Colloquium on Algebraic Geometry, Bombay, India, January 16–23, 1968* (GP8009); 6 months; $1,119

Seeley, Robert T.; *The First Latin American School of Mathematics, Rio de Janeiro, Brazil, June 15–August 2, 1968* (GP9063); 6 months; $656

BROWN UNIVERSITY

Cardona, Manuel; *Ninth International Semiconductor Physics Conference, Moscow, U.S.S.R., July 23–29, 1968* (GP8863); 6 months; $816

Quinn, John J.; *The Eleventh International Conference on Low Temperature Physics, St. Andrews, Scotland, August 21–28, 1968* (GP9086); 6 months; $485

Schempp, Ellory; *NATO Advanced Study Institute on Nuclear Quadrupole Resonance Spectroscopy, Frascati, Italy, October 11–21, 1967* (GZ750); 12 months; $534

Symonds, Paul S.; *Conference on Engineering Plasticity, Cambridge, England, March 25–29, 1968* (K002491); 6 months; $390

CALIFORNIA INSTITUTE OF TECHNOLOGY

Cameron, Roy E.; *Second SCAR Symposium on Biology, Cambridge, England, July 28–August 6, 1968* (A004306); 6 months; $400

Hanks, Thomas C.; *NATO Advanced Study Institute on Paleogeophysics, New Castle-Upon-Tyne, England, April 1–6, 1968* (GZ-1008); 6 months; $517

Tombach, Ivar H.; *NATO Advanced Study Institute on Transition from Laminar to Turbulent Flow, London, England, June 30–July 6, 1968* (GZ1052); 6 months; $725

Hanson, David M.; *NATO Advanced Study Institute on Properties of Organic Crystals, Enschede, The Netherlands, July 8–12, 1968* (GZ1058); 6 months; $779

Kohler, Bryan E.; *NATO Advanced Study Institute on Molecular Crystals, Enschede, Holland, July 8–12, 1968* (GZ1057); 6 months; $782

Ceasar, Gerald P.; *NATO Advanced Study Institute on Determination of Molecular Geometry, Aarhus, Denmark, July 29–August 10, 1968* (GZ1061); 6 months; $577

Brinkmann, Robert T.; *NATO Advanced Study Institute on Aurora and Airglow, As, Norway, July 29–August 9, 1968* (GZ1071); 6 months; $587

CARNEGIE INSTITUTE OF TECHNOLOGY

Krutar, Rudolph A.; *NATO Advanced Study Institute on New Trends in Programming New Applications and Language Theories, Copenhagen, Denmark, August 12–24, 1968* (GZ1075); 6 months; $568

Pierce, W. H.; *IEEE International Symposium on Information Theory, Athens, Greece, September 11–15, 1967* (K002482); 6 months; $780

CARNEGIE MELLON UNIVERSITY

Baker, Earl W.; *Symposium on Fluoro-Organic Chemistry, Birmingham, England, March 27–29, 1968* (GP8227); 9 months; $446

Castellano, Salvatore M.; *Second International Symposium on Nuclear Magnetic Resonance, Sao Paulo, Brazil, July 8–11, 1968* (GP8806); 6 months; $561

Van Dyke, Charles H.; *Second International Symposium on Organosilicon Chemistry, Bordeaux, France, July 9–12, 1968* (GP8819); 6 months; $556

Rayne, John; *The Eleventh International Conference on Low Temperature Physics, St. Andrews, Scotland, August 21–28, 1968* (GP9083); 6 months; $470

Holstein, Barry R.; *NATO Advanced Study Institute on Invariance Principles and Particle Physics, Erice, Sicily, July 15–28, 1968* (GZ1066); 6 months; $445

Perlis, Alan J.; *II Latin American Congress on Electronic Computation, Lima, Peru, June 9–15, 1968* (J000299); 6 months; $531

CASE WESTERN RESERVE UNIVERSITY

Kuwana, Theodore; *Discussions of Faraday Society, Newcastle-on-the-Tyne, England April 2–4, 1968* (GP8046); 11 months; $298

Reswick, James B.; *Technical and Biological Problems of Control—An IFAC Symposium, Yerevan, U.S.S.R., September 24–28, 1968* (K004443); 6 months; $700

CHAS. F. KETTERING RESEARCH FOUNDATION

Keister, Donald L.; *International Congress of Photosynthesis Research, Freudenstadt, Germany, June 4–8, 1968* (GB7658); 6 months; $320

CITY COLLEGE

Ettenberg, Morris; *XXIV All Union Science Convention, Moscow, U.S.S.R., May 14–16, 1968* (K004208); 6 months; $758

CITY UNIVERSITY OF NEW YORK SYSTEM OFFICE

Heller, Alex; *Conference in Algebraic Topology, Oberwolfach, Germany, August 29–September 10, 1967* (GP7755); 9 months; $360

CLARK UNIVERSITY

Ahmadjian, Vernon; *Second (SCAR) Symposium on Antarctic Biology, Cambridge, England, July 28–August 6, 1968* (A004310); 6 months; $370

COLUMBIA UNIVERSITY

Gregor, Harry P.; *Meeting on 30 Years of Ion Exchangers, Leipzig, Germany, June 4–8, 1968* (GP8226); 12 months; $540

Bass, Hyman; *Meeting on Rings Modules and Homological Methods, Oberwolfach, Germany, March 3–8, 1968* (GP8280); 9 months; $479

Hoobler, Raymond T.; *Meeting on Rings Modules and Homological Methods, Oberwolfach, Germany, March 3–8, 1968* (GP8286); 9 months; $479

Dailey, Benjamin P.; *Second International Symposium on Nuclear Magnetic Resonance, São, Paulo, Brazil, July 8–11, 1968* (GP-8805); 6 months; $522

Fried, Morton H.; *VIII International Congress of Anthropological and Ethnological Sciences, Tokyo, Japan, September 3–10, 1968* (GS2135); 6 months; $865

Cohen, Myron L.; *VIII International Congress of Anthropological and Ethnological Sciences, Tokyo, Japan, September 3–10, 1968* (GS2187); 6 months; $865

Rosenberg, Lloyd; *NATO Advanced Study Institute on Signal Processing With Emphasis on Underwater Acoustics, Enschede, the Netherlands, August 12–23, 1968* (GZ1072); 6 months; $493

Dexter, David D.; *NATO Advanced Study Institute on Determination of Molecular Geometry, Aarhus, Denmark, July 29–August 7, 1968* (GZ1082); 6 months; $564

Kolesar, Peter J.; *NATO Advanced Study Institute on Engineering Applications of Statistical Extremes, Faro, Portugal, September 18–22, 1967* (GZ731); 1 month; $379

Mindlin, R. D.; *Third U.S.S.R. National Congress of Theoretical and Applied Mechanics, Moscow, U.S.S.R., January 25–February 1, 1968* (K002488); 6 months; $548

CORNELL UNIVERSITY

Harwit, Martin O.; *COSPAR Eleventh Plenary Meeting in Tokyo, Japan, May 8–21, 1968* (A001599); 6 months; $970

Bolgiano, Ralph, Jr.; *Meeting of International Association of Meteorology and Atmospheric Physics, Lucerne, Switzerland, September 28–October 1, 1967* (A1219); 12 months; $508

Noble, Robert W.; *Second Lacura Conference on Hemoglobin, Rome, Italy, June 12–25, 1968* (GB7656); 6 months; $650

Gundermann, Ellen J.; *Meeting of Physics of Quasars, Manchester, England, September 5–7, 1967* (GP7753); 9 months; $352

Fisher, Michael E.; *Seminar on Phase Transitions, Budapest, Hungary, October 10–14, 1967* (GP7953); 8 months; $357

Batterman, B. W.; *International Meeting on Accurate Determination of X-ray Intensities and Structure Factors, Cambridge, England, June 24–28, 1968* (GP8208); 15 months; $432

Fuchs, Wolfgang H.; *Conference on the Theory of Functions of a Complex Variable, Oberwolfach, Germany, March 17–23, 1968* (GP8204); 6 months; $387

Rosenberg, Alex.; *Meeting on Rings Modules and Homological Methode, Oberwolfach, Germany, March 3–8, 1968* (GP8283); 9 months; $516

Orear, Jay; *XIV International Conference on High Energy Physics in Vienna, Austria, on August 28–September 5, 1968* (GP8606); 11 months; $558

McDaniel, Boyce D.; *XIV International Conference on High Energy Physics in Vienna, Austria on August 29–September 5, 1968* (GP8842); 6 months; $815

Silverman, Albert; *XIV International Conference on High Energy Physics in Vienna,* *Austria, on August 28–September 5, 1968* (GP8843); 6 months; $615

Hoffmann, Roald; *International Union of Pure and Applied Chemistry Symposium, Karlsruhe, Germany, September 8–11, 1968* (GP8849); 6 months; $562

Reppy, John; *Eleventh International Conference on Low Temperature Physics, St. Andrews, Scotland, August 21–28, 1968* (GP9081); 6 months; $406

DARTMOUTH COLLEGE

Hornig, James F.; *Fourth Molecular Crystal Symposium, Enschede, Netherlands, July 8–12, 1968* (GP8104); 9 months; $592

Cleland, Robert L.; *Study and Lecture at the Universities at Uppsala, Sweden, and Strasbourg, France,* (GP8853); 24 months; $676

DEPARTMENT OF THE INTERIOR

Kenyon, Karl W.; *Second SCAR Symposium on Biology, Cambridge, England, July 28–August 6, 1968* (AO10104); 6 months; $500

DUKE UNIVERSITY

Woods, Frank W.; *Fifteenth Easter School in Agricultural Sciences, Nottingham, England, April 1968* (GB7496); 3 months; $433

EMORY UNIVERSITY

Goldsmith, David J.; *Fifth International Symposium on the Chemistry of Natural Products, London, England, July 8–13, 1968* (GP8814); 6 months; $519

Davenport, Richard K., Jr.; *VIII International Congress of Anthropological and Ethnological Sciences, Tokyo, Japan, September 3–10, 1968* (GS2141); 6 months; $830

ENTOMOLOGICAL SOCIETY OF AMERICA

Nelson, R. H.; *Thirteenth International Congress of Entomology, Moscow, U.S.S.R., August 2–9, 1968* (GB7503); 6 months; $10,000

FLORIDA STATE UNIVERSITY

Gille, John C.; *International Radiation Symposium, Bergen, Norway, August 21–28, 1968* (GA1638); 6 months; $644

FORD SCIENTIFIC LABORATORY

Klamkin, Murray S.; *International Committee for Mathematics Instruction-Colloquium, Utrecht, Netherlands, August 21–25, 1967* (GZ729); 1 month $527

GEOLOGICAL SURVEY

Schmidt, Dwight L.; *First International Symposium on Gondwana Stratigraphy and Paleontology, Mar Del Plata, Argentina, October 1–4, 1967* (A1265); 6 months; $756

GEORGIA INSTITUTE OF TECHNOLOGY

Zalkow, Leon H.; *Fifth International Symposium on the Chemistry of Natural Products, London, England, and To Visit Laboratories in Strasbourg, France, and Zurich, Switzerland, July 8–13, 1968* (GP8106); 6 months; $664

Fink, Richard W.; *International Conference on Electron Capture and Higher Order Processes in Nuclear Decays, Debrecen, Hungary, July 15–10, 1968* (GP8107); 6 months; $300

Young, R. A.; *International Meeting on Accurate Determination of X-ray Intensities and Structure Factors, Cambridge, England, June 24–28,* 1968 (GP8950); 6 months; $541

HARVARD UNIVERSITY

Sagan, Carl; *COSPAR Eleventh Plenary Meeting in Tokyo, Japan, May 8–21, 1968* (A001600); 12 months; $931

Menzel, Donald H.; *The International Symposium on the Total Solar Eclipse of November 12, 1966, in Sao Jose Dos Campos, Brazil, February 5–11, 1968* (A1350); 12 months; $656

Porter, Keith R.; *Australian Conference on Electron Microscopy, Canberra, Australia, February 19–22, 1968* (GB7818); 6 months; $750

Guidotti, Guido; *Second Lacura Conference on Hemoglobin, Rome, Italy, June 12–25, 1968* (GB7653); 6 months; $620

Rochow, Eugene G.; *Second International Symposium on Organosilicon Chemistry, Bordeaux, France, July 9–12, 1968* (GP8822); 6 months; $474

Doering, Von Eggers; *International Union of Pure and Applied Chemistry Symposium, Karlsruhe, Germany, September 8–11, 1968* (GP8852); 6 months; $470

Ramsey, Normal F.; *International Symposium on Physics of One- and Two-Electron Atoms, Munich, Germany, September 9–13, 1968* (GP9067); 6 months; $520

Lipset, Seymour M.; *Third International Conference of the Research Committee on Political Sociology, Berlin, Germany, January 16–20, 1968* (GS1885); 6 months; $495

Apfel, Robert E.; *NATO Advanced Study Institute on Stochastic Problems in Underwater Sound Propagation, La Spezia, Italy, September 18–23, 1967* (GZ737); 12 months; $402

ILLINOIS STATE GEOLOGICAL SURVEY

Simon, Jack A.; *International Committee for Coal Petrology, Sheffield, England, September 4–8, 1967* (A1223); 1 month; $498

ILLINOIS INSTITUTE OF TECHNOLOGY

Frocht, Max M.; *JSME 1967 Semi-International Symposium, Tokyo, Japan, September 4–8, 1967* (K002479); 6 months; $985

INDIANA UNIVERSITY

Gajewski, Joseph J.; *International Union of Pure and Applied Chemistry Symposium, Karlsruhe, Germany, September 8–11, 1968;* (GP8848); 6 months; $600

Swihart, James; *Eleventh International Conference on Low Temperature Physics, St. Andrews, Scotland, August 21–28 1968* (GP–9084); 6 months; $499

Masani, Pesi R.; *Conference on Abstract Spaces and Approximation, Oberwolfach, Germany, July 18–27, 1968* (GP9106); 6 months; $627

INSTITUTE FOR ADVANCED STUDY

Mostert, Paul S.; *International Symposium on Semigroup Theory and Applications, Smolenice, U.S.S.R., June 17–21, 1968* (GP8338); 6 months; $632

SOCIETY FOR THE STUDY OF REPRODUCTION

Melampy, R. M. and Dutt, R. H.; *Sixth International Congress on Animal Reproduction and Artificial Insemination, Paris, France, July 21–26, 1968* (GB7644); 12 months; $10,000

IOWA STATE UNIVERSITY

Gilman, Henry; *Second International Organosilicon Symposium, Bordeaux, France, July 9–12, 1968* (GP8132); 6 months; $534

Jacobson, Robert A.; *International Meeting on Accurate Determination of X-ray Intensities and Structure Factors, Cambridge, England, June 24–28, 1968* (GP8953); 6 months; $523

Creel, Roger; *NATO Advanced Study Institute on Nuclear Quadrupole Resonance Spectroscopy, Frascati, Italy, October 11–21, 1967* (GZ751); 21 months; $498

JACKSON LABORATORY

Blake, Robert L.; *NATO Advanced Study Institute on Control Mechanisms of Molecular Biology, Bergen, Norway, May 20–30, 1968* (GZ1042); 6 months; $395

JOHNS HOPKINS UNIVERSITY

Sladen, William J. L.; *Second SCAR Symposium on Biology, Cambridge, England, July 28–August 6, 1968* (A004321); 6 months; $331

Cowan, Dwaine O.; *International Conference on Photochemistry, Munich, Germany, September 6–9, 1967* (GP7758); 9 months; $388

Igusa, Jun-Ichi; *International Colloquium on Algebraic Geometry, Bombay, India, January 16–23, 1968* (GP8010); 6 months; $1,128

Pevsner, Aihud; *XIV International Conference on High Energy Physics in Vienna, Austria, August 28–September 5, 1968* (GP8608); 11 months; $602

Murphy, Peter J.; *NATO Advanced Study Institute on Transition From Laminar to Turbulent Flow, London, England, June 30–July 6, 1968* (GZ1047); 6 months; $441

LOUISIANA STATE UNIVERSITY, New Orleans

Good, Mary L.; *Second International Symposium on Nuclear Magnetic Resonance, Sao Paulo, Brazil, July 8–11, 1968* (GP8800); 6 months; $576

LEHIGH UNIVERSITY

Zettlemoyer, Albert C.; *Fifth International Congress on Surface Activity, Barcelona, Spain, September 9–13, 1968* (GP8810); 6 months; $508

Spriggs, Richard M.; *Fabrication Science Symposium, Leeds, England, September 18–20, 1967* (K002478); 6 months; $450

MACKINAC COLLEGE

Keitt, George W., Jr.; *NATO Advanced Study Institute on Transport of Plant Hormones, Izmir, Turkey, October 16–30, 1967* (GZ752); 3 months; $831

MASSACHUSETTS GENERAL HOSPITAL

Grillo, H. C.; *Seminar on Wound Healing and Tissue Regeneration, Varanasi, India, November 15–18, 1967* (GB7080); 6 months $1,200

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Allen, Thomas J.; *Forty-second Annual Conference, Association of Special Libraries and Information Bureaux, University of Kent, Canterbury, England, September 23–25, 1968* (GN763); 6 months; $399

Weisskopf, Victor F.; *International Symposium Commemorating 100th Anniversary of the Birth of Marie Curie, Warsaw, Poland, October 17, 1967* (GP7756); 29 months; $585

Gatos, Harry C.; *Ninth International Semiconductor Physics Conference, Moscow, U.S.S.R., July 23–29, 1968* (GP8865); 6 months; $500

Shoemaker, David P.; *International Meetings on Accurate Determination of X-ray Intensities and Structure Factors, Cambridge, England, June 24–28, 1968* (GP8952); 6 months; $215

Brown, Sanborn C.; *Third Symposium on Plasma Physics and Controlled Nuclear Fusion Research, Novosibirsk, U.S.S.R., August 1–7, 1968* (GP9072); 6 months; $500

Rose, Robert; *Eleventh International Conference on Low Temperature Physics, St. Andrews, Scotland, August 21–28, 1968* (GP9088); 6 months; $420

Manheimer, Wallace; *NATO Advanced Study Institute on Plasma Waves in Space and in the Laboratory, Roros, Norway, April 17–26, 1968* (GZ1005); 6 months; $360

Bergeron, Robert F.; *NATO Advanced Study Institute on Transition from Laminar to Turbulent Flow, London, England, June 30–July 6, 1968* (GZ1036); 6 months; $432

Smith, Robert A.; *NATO Advanced Study Institute on Processing of Optical Data by Organisms and by Machines, Varenna, Italy, July 15–27, 1968* (GZ1039); 6 months; $589

Albert, Jeffrey H.; *NATO Advanced Study Institute on Pseudo-Differential Operators, Stresa, Italy, August 25–September 3, 1968* (GZ1076); 6 months; $544

Kabat, Jonathan P.; *NATO Advanced Study Institute on Recent Progress in Immunology, Paris, France, September 20–30, 1967* (GZ-736); 12 months; $431

Cornell, C. Allin; *NATO Advanced Institute on Engineering Applications of Statistical Extremes, Faro, Portugal, September 18–27, 1967* (GZ749); 12 months; $463

Vinson, Walter C.; *NATO Advanced Study Institute on Activation of Genes in the Embryonic Development, Palermo, Italy, September 25–October 14, 1967* (GZ754); 3 months; $580

Ogilvie, Robert E.; *Visit Various Universities and Companies Employing High Energy Electron Microscopes, November 6–16, 1967, in Japan* (K002486); 6 months; $561

Uhlmann, Donald R.; *Eighth International Congress on Glass, London, England, July 1–6, 1968* (K004358); 6 months; $435

Robsenow, Warren M.; *Mass and Heat Transfer in Turbulent Boundary Layers, Herceg-Novi, Yugoslavia, September 1–15, 1968* (K004413); 6 months; $410

Young, Laurence Retman; *Technical and Biological Problems of Control—An IFAC Symposium, Yerevan, U.S.S.R., September 24–28, 1968* (K004442); 6 months; $840

MICHIGAN STATE UNIVERSITY

Blatt, Frank; *Eleventh International Conference on Low Temperature Physics, St. Andrews, Scotland, August 21–28, 1968* (GP 9080); 6 months; $350

MISSOURI BOTANICAL GARDEN

Gates, David M.; *Fortieth Congress of the Australian and New Zealand Association for the Advancement of Science, Christchurch, New Zealand, January 24–31, 1968* (GB7168); 6 months; $1,200

NORTH CAROLINA STATE UNIVERSITY, Raleigh

Robison, Odis W.; *NATO Advanced Study Institute—International Summer School on Biomathematics and Data Processing in Animal Experiments, Elsinore, Denmark, June 30–July 13, 1968* (GZ1038); 6 months; $595

Zorowski, Carl F.; *Eighth International Machine Tool Design and Research Confer-*

ence, Manchester, England, September 12–15, 1967 (K002476) ; 6 months ; $360

NEW YORK ZOOLOGICAL SOCIETY

Penney, Richard L.; *Second SCAR Symposium on Biology, Cambridge, England, July 28–August 6, 1968* (A004301) ; 6 months ; $337

NATIONAL ACADEMY OF SCIENCES

Coleman, John S.; *Task Order for Symposium on Micropaleontology of Bottom Sediments* (C031013700) ; 3 months ; $6,253

David, Henry; *Partial Support of U.S. Travel to the Twelfth International Congress of the History of Science and the General Assembly of the Division of History of Science/IUHPS* (C310145*) ; 10 months ; $1,000

———; (C310145*) ; 10 months ; $9,000

———; (C310145*) ; 10 months ; $2,500

Paul, Martin A.; *Partial Support for U.S. Participants to the International Conference on Coordination Chemistry in Israel, September 8–18, 1968* (G310149) ; 6 months ; $7,500

NATIONAL ACADEMY OF SCIENCES—NATIONAL RESEARCH COUNCIL

Cohen, Leon W.; *Partial Support of Travel to the International Federation for Information Processing, Edinburgh, Scotland, August 5–10, 1968* (C310141) ; 14 months ; $12,000

Bailey, Walter H.; *Partial Support of U.S. Travel to the International Geographical Congress and General Assembly of the International Geographical Union, New Delhi, India, December 1–8, 1968* (C310147) ; 12 months ; $11,600

Kelly, William C.; *Meeting of International Commission on Physics Education, Amsterdam, Netherlands, January 9–10, 1968* (GZ921) ; 6 months ; $478

NEW MEXICO STATE UNIVERSITY

Weeks, Owen B.; *Fifth International Symposium on the Chemistry of Natural Products, London, England, July 8–July 13, 1968* (GB 7651) ; 6 months ; $520

NEW YORK UNIVERSITY

Isaacson, Eugene; *Meeting of Basic Problems of Numerical Analysis, Prague, Czechoslovakia, September 11–16, 1967* (GP7822) ; 9 months ; $395

Goldstein, Ronald A.; *NATO Advanced Study Institute on Pseudo-Different Operators, Stressa, Italy, August 25–September 2, 1968* (GZ1081) ; 6 months ; $554

NORTHEASTERN UNIVERSITY

Weinstein, Roy; *XIV International Conference on High Energy Physics, Vienna, Austria, August 28–September 5, 1968* (GP 8607) ; 11 months ; $560

NORTHWESTERN UNIVERSITY

Zelinsky, Daniel; *Meeting on Rings Modules and Homological Methods, Oberwolfach, Germany, March 3–8, 1968* (GP8231) ; 9 months ; $506

Bordwell, Frederick G.; *Third Symposium on the Chemistry of Organic Sulphur Compounds, Caen, France, May 21–25, 1968* (GP 8796) ; 6 months ; $495

Marcus, Jules; *Eleventh International Conference on Low Temperature Physics, St. Andrews, Scotland, August 21–28, 1968* (GP 9077) ; 6 months ; $442

Hsu, Francis L. K.; *VIII International Congress of Anthropological and Ethnological Sciences, Tokyo, Japan, September 3–10, 1968* (GS2133) ; 6 months ; $785

Cember, Herman; *NATO Advanced Study Institute on Dosimetry of Radiation Based on Solid State Phenomena, Brussels, Belgium, September 4–16, 1967* (GZ732) ; 1 month ; $428

OAK RIDGE NATIONAL LABORATORY

McGrory, Joseph B.; *NATO Advanced Study Institute on Nuclear Physics, Les Houches, France, July 14–September 8, 1968* (GZ1009) ; 6 months ; $658

OHIO STATE UNIVERSITY

Rudolph, Emanuel D.; *Second SCAR Symposium on Biology, Cambridge, England, July 28–August 8, 1968* (A004309) ; 6 months ; $365

Fraenkel, Gideon; *Second International Symposium on Nuclear Magnetic Resonance, Sao Paulo, Brazil, July 8–11, 1968* (GP8807) ; 6 months ; $571

Paquette, Leo A.; *International Union of Pure and Applied Chemistry Symposium, Karlsruhe, Germany, September 8–11, 1968* (GP8850) ; 6 months ; $600

Mathis, Robert F.; *NATO Advanced Study Institute on Differential Equations, Edinburgh, Scotland, September 11–23, 1967* (GZ 741) ; 6 months ; $365

Ghosh, Sanjib K.; *Eleventh International Congress of Photogrammetry, Lausanne, Switzerland, July 8–20, 1968* (K004294) ; 6 months ; $615

OHIO WESLEYAN UNIVERSITY

Shirling, Elwood B.; *International Symposium on the Taxonomy of the Actinomycetales, Jena, Germany, September 17–21, 1968* (GB7810) ; 6 months ; $609

OREGON STATE UNIVERSITY

Hedgpeth, Joel W.; *Second SCAR Symposium on Biology, Cambridge, England, July 28–August 6, 1968* (A004312) ; 6 months ; $696

Kice, John L.; *Third Symposium on the Chemistry of Organic Sulphur Compounds, Caen, France, May 21–25, 1968* (GP8795) ; 6 months ; $350

AMERICAN PHYTOPATHOLOGICAL SOCIETY

Young, Roy A.; *First International Congress of Plant Pathology, London, England, July 14–29, 1968* (GB7441) ; 12 months ; $20,000

PENNSYLVANIA STATE UNIVERSITY

Spackman, William; *Sixth International Congress of Carboniferous Stratigraphy and Geology, Sheffield, England, September 3–9, 1967* (A1218) ; 7 months ; $472

Vastola, Francis J.; *International Mass Spectrometry Conference, West Berlin, Germany, September 25–29, 1967* (GP7757) ; 10 months ; $319

Faust, J. W., Jr.; *Second International Conference on Crystal Growth, Birmingham, England, July 15–19, 1968* (GP8809) ; 6 months ; $520

Greenhill, Leslie P.; *International Editorial Board Meeting of Encyclopaedia Cinematographica, Utrecht, Netherlands, June 12–14, 1968* (GZ1037) ; 6 months ; $526

Frymoyer, Edward M.; *NATO Advanced Study Institute on Stochastic Problems in Underwater Sound Propogation, La Spezia, Italy, September 18–23, 1967* (GZ733); 1 month; $637

Haythornthwaite, Robert M.; *Conference on Engineering Plasticity, Cambridge, England, March 25–29, 1968* (K002492); 6 months; $445

Shearer, J. Lowen; *IFAC International Pulse Symposium, Budapest, Hungary, April 8–13, 1968* (K002494); 6 months; $610

Lee, Hai-Sup; *Symposium on Electromagnetic Waves, Stresa, Italy, June 24–29, 1968* (K004221); 6 months; $590

PHOTO TECHNOLOGY RESEARCH, INC.

Denton, Frank; *Science and Humanism Bienal, Sao Paulo, Brazil, November 24–December 6, 1967* (K002485 001); $265

PMC COLLEGES

Ditaranto, Rocco A.; *International Symposium on the Damping of Vibrations of Plates by Means of a Layer, Leuven, Belgium, September 14–15, 1967* (K002471); 6 months; $350

Yiannos, Peter N., *Symposium on "Physico-Chemical" Properties of Fibers, Prague, Czechoslovakia, September 10–14, 1968* (K004551); 6 months; $425

POLYTECHNIC INSTITUTE OF BROOKLYN

Felsen, Leopold B.; *Visit Soviet Academy of Sciences of the U.S.S.R., Moscow, August or September 1967* (GP7752); 9 months; $730

Guggenheimer, Heinrich W.; *International Conference on Differential Geometry, Bologna, Italy, September 27–October 1, 1967* (GP7770); 9 months; $523

Schwartz, Mischa; *IEEE International Symposium on Information Theory, Athens, Greece, September 11–15, 1967* (K002480); 6 months; $735

———; *XXIVth All Union Science Convention, Moscow, U.S.S.R., May 14–16, 1968* (K004209); 6 months; $870

Deutsch, Sid; *Technical and Biological Problems of Control—An IFAC Symposium, Yerevan, U.S.S.R., September 24–28, 1968* (K004440); 6 months; $810

Drenick, Rudolf F.; *Second IFAC/ETAN Symposium on System Sensitivity and Adaptivity, Dubrovnik, Yugoslavia, August 26–30, 1968* (K004469); 6 months; $570

POLYTECHNIC INSTITUTE OF BROOKLYN—GRADUATE CENTER

Hessel, Alexander; *Symposium on Electromagnetic Waves, Stresa, Italy, June 3–8, 1968* (K004222); 6 months; $590

Gould, Gordon; *International Conference on Laser Measurements, Warsaw, Poland, September 24–26, 1968* (K004438); 6 months; $450

PRINCETON UNIVERSITY

Shimura, Goro; *Conference on Automorphic Functions on Arithmetically Defined Groups, Oberwolfach, Germany, July 28–August 3, 1968* (GP8815); 6 months; $564

Fefferman, Charles; *NATO Advanced Study Institute on Pseudo-Differential Operators, Stresa, Italy, August 26–September 3, 1968* (GZ1060); 6 months; $587

Chen, Herbert H.; *NATO Advanced Study Institute on Invariance Principles and Particle Physics, Erice, Sicily, July 15–28, 1968* (GZ1069); 6 months; $629

Lesk, Arthur M.; *NATO Advanced Study Institute on Automatic Interpretation and Classification of Images, Pisa, Italy, August 26–September 7, 1968* (GZ1083); 6 months; $587

Fenn, John B.; *Third Lunar International Laboratory Symposium, Belgrade, Yugoslavia, September 24–30, 1967* (K002473); 6 months; $570

PURDUE UNIVERSITY

Judd, William R.; *International Society for Rock Mechanics, Salzburg, Austria, October 23–28, 1967* (A1278); 7 months; $135

Truce, William E., *Third Symposium on the Chemistry of Organic Sulphur Compounds, Caen, France, May 21–25, 1968* (GP8793); 6 months; $540

Benkeser, Robert A.; *Second International Symposium on Organosilicon Chemistry, Bordeaux, France, July 9–12, 1968* (GP8820); 6 months; $630

Fan, H. Y.; *Ninth International Semiconductor Physics Conference, Moscow, U.S.S.R., July 23–29, 1968* (GP8860); 6 months; $200

Treves, Jean F.; *First Latin American School of Mathematics, Rio de Janeiro, Brazil, July 15–August 2, 1968* (GP9062); 6 months; $430

Garwood, Vernon A.; *NATO Advanced Study Institute on Biomathematics and Data Processing in Animal Experiments, Elsinore, Denmark, June 30–July 13, 1968* (GZ1040); 6 months; $626

King, Jonathan; *NATO Advanced Study Institute on New Methods in Low-Angle X-ray Diffraction and Electron Microscopy for Biological Structure Determination, Cambridge, England, September 16–28, 1968* (GZ1073); 6 months; $396

Lykoudis, Paul S.; *Lecture Tour Under Auspices of the Soviet Academy of Sciences, U.S.S.R., April 22–May 5, 1968* (K004192); 6 months; $655

RENSSELAER POLYTECHNIC INSTITUTE

Corelli, John C.; *Ninth International Semiconductor Physics Conference, Moscow, U.S.S.R., July 23–29, 1968* (GP8861); 6 months; $840

Katz, J. Lawrence; *International Meeting on Accurate Determination of X-ray Intensities and Structure Factors, Cambridge, England, June 24–28, 1968* (GP8949); 6 months; $466

Chang, David D.; *NATO Advanced Study Institute on Molecular Beams and Reaction Kinetics, Varenna, Italy, July 29–August 10, 1968* (GZ1068); 6 months; $459

Cook, John P.; *CIB Symposium on Weathertight Joints in Walls, Oslo, Norway, September 23–27, 1967* (K002474); 6 months; $550

RICE UNIVERSITY

Gordon, W. E.; *URSI Coordinating Committee Meeting, Brussels, Belgium, March 26–27, 1968* (A001468); 6 months; $575

Eather, Robert H.; *Birkeland Symposium on Aurora and Magnetic Storms, Sandefjord, Norway, September 18–22, 1967* (A1179); 6 months; $360

———; (A1179 001); $119

Resnikoff, Howard L.; *Conference on Jordan Algebras and Nonassociative Algebras, Oberwolfach, Germany, August 17–26, 1967* (GP 7748); 9 months; $308

Rorschach, Harold E.; *Eleventh International Conference on Low Temperature Physics, St. Andrews, Scotland, August 21–28, 1968* (GP9078); 6 months; $459

Norbeck, Edward; *VIII International Congress of Anthropological and Ethnological Sciences, Tokyo, Japan, September 3–10, 1968* (GS2142); 6 months; $795

Chappell, Charles R.; *NATO Advanced Study Institute on Aurora and Airglow, As, Norway, July 29–August 9, 1968* (GZ1050); 6 months; $538

O'Neil, Richard; *"Abstract Spaces and Approximation" at the Mathematisches Ferschungsinstitut, Oberwolfach, Germany, July 18–27, 1968* (J000294); 6 months; $398

ROCKEFELLER UNIVERSITY

Struhsaker, Thomas T.; *VIII International Congress of Anthropological and Ethnological Sciences, Tokyo, Japan, September 3–10, 1968* (GS2134); 6 months; $865

Shapley, Robert; *NATO Advanced Study Institute on Optical Data Processing, Varenna, Italy, July 15–27, 1968* (GZ1056); 6 months; $305

RURAL SOCIOLOGICAL SOCIETY

Sauer, Howard M., *Second World Congress of Rural Sociology, Driencrlo, Holland, August 5–10, 1968;* (GS1891) 12 months; $3,000

RUTGERS, THE STATE UNIVERSITY

Leader, Solomon; *International Special Symposium on Extension Theory of Topological Structures, East Berlin, Germany, August 14–19, 1967* (GP7749); 3 months; $82

Osofsky, Barbara L.; *Meeting on Rings Modules and Homological Methods, Oberwolfach, Germany, March 3–8, 1968* (GP8234); 9 months; $202

Petryshyn, W. V.; *Summer Course on Numerical Mathematics, Bezdruzice, Czechoslovakia, June 3–12, 1968* (GP8817); 6 months; $569

Plano, Richard J.; *XIV International Conference on High Energy Physics, Vienna, Austria, August 28–September 5, 1968* (GP8844); 6 months; $395

Lindenfeld, Peter; *Eleventh International Conference on Low Temperature Physics, St. Andrews, Scotland, August 21–28, 1968* (GP9079); 6 months; $423

SCIENCE ENGINEERING ASSOCIATES

Wilson, Basil W.; *International Association for Physical Oceanography, Tsunami Symposium, Berne, Switzerland, September 27, 1967* (K002470); 6 months; $775

SOCIETY FOR DEVELOPMENTAL BIOLOGY

Saunders, John W., Jr.; *Sixth International Congress on Embryology, Paris, France, September 1–7, 1968* (GB7649); 12 months; $10,000

SOILS SCIENCE SOCIETY OF AMERICA

Stelly, Matthias; *Ninth International Congress of Soil Science, Adelaide, Australia, August 6–16, 1968* (GB7511*); 12 months; $15,000

SOUTHERN ILLINOIS UNIVERSITY

Kuipers, Lawrence; *Conference on Analytic Number Theory, Oberwolfach, Germany, March 25–30, 1968* (GP8435); 6 months; $450

SOUTHWEST CENTER FOR ADVANCED STUDIES

Johnson, Francis S.; *The COSPAR Eleventh Plenary Meeting, Tokyo, Japan, May 8–21, 1968* (A001598); 6 months $778

Landisman, Mark; *Fourth UMC Symposium on Geophysical Theory and Computers, Trieste, Italy, September 18–22, 1967* (A1183); 10 months; $702

Hales, Anton L.; *Visit the International Seismological Centre, Edinburgh, Scotland, December 1–10, 1967* (A1322); 6 months; $718

SOUTHWESTERN MEDICAL SCHOOL

Maulsby, Robert; *NATO Advanced Study Institute on Human Electroencephalography, Marseille, France, September 1–13, 1968* (GZ 1080); 6 months; $712

STANFORD RESEARCH INSTITUTE

Smith, Felix T.; *International Symposium on Physics of One- and Two-Electron Atoms, Munich, Germany, September 9–13, 1968* (GP9066); 6 months; $813

STANFORD UNIVERSITY

Chodorow, Marvin; *URSI Coordinating Committee Meeting, Brussels, Belgium, March 26–27, 1968* (A001469); 6 months; $725

Hamilton, Carole L.; *Second Lacura Conference on Hemoglobin, Rome, Italy, June 12–25, 1968* (GB7654); 6 months; $870

Chung, Kai Lai; *Conference on Markov Chains, Oberwolfach, Germany, June 9–15, 1968* (GP8339); 6 months; $806

Spicer, William E.; *Ninth International Semiconductor Physics Conference, Moscow, U.S.S.R., July 23–29, 1968* (GP8862); 6 months; $1,062

Bergman, Stefan; *To Give a Series of Lectures in Paris, France, and Rome, Italy, April through September 1968* (GP9112); 6 months; $520

Stone, Keppler; *NATO Advanced Study Institute on Plasma Waves in Space and in the Laboratory, Roros, Norway, April 17–26, 1968* (GZ1010); 6 months; $524

Crandall, Michael; *NATO Advanced Study Institute on Theory and Applications of Monotone Operators, Venice, Italy, June 17–30, 1968* (GZ1054); 6 months; $853

Primack, Joel R.; *NATO Advanced Study Institute on Invariance Principles and Particle Physics, Erice, Italy, July 13–28, 1968* (GZ 1068); 6 months; $914

Vesecky, John F.; *NATO Advanced Study Institute on Earth's Particles and Fields, Stadt Freising, Germany, July 31–August 11, 1967* (GZ724); 1 month; $856

Lee, Robert W.; *NATO Advanced Study Institute on Structure of the Lower Atmosphere and Electromagnetic Wave Propagation, Aberystwyth, Wales, September 2–16, 1967* (GZ739); 12 months; $610

Linvill, John; *Summer School on Circuit Theory 1968, Prague, Czechoslovakia, June 28–July 12, 1968* (K002497); 6 months; $850

Boudart, Michel; *Fourth International Congress on Catalysis, Moscow, U.S.S.R., June 23–29, 1968* (K004149); 6 months; $1,065

Heffner, Hubert; *XXIVth All Union Science Convention, May 14–16, 1968* (K004178); 6 months; $1,115

Kailath, Thomas; *Popov Society Meeting, Moscow, U.S.S.R., May 14–16, 1968* (K004179); 6 months; $1,079

Lee, Erastus H.; *IUTAM Symposium on Thermoanelasticity, East Kilbride, Scotland, June 27–29, 1968* (K004245); 6 months; $740

Mitchner, Morton; *Fourth International Symposium on Magnetohydrodynamic Electrical Power Generation, Warsaw, Poland, July 24–30, 1968* (K004296); 6 months; $900

STATE UNIVERSITY, Buffalo

Schuster, Todd M.; *Second Lacura Conference on Hemoglobin, Rome, Italy, June 12–25, 1968* (GB7657); 6 months; $580

Findler, Nicholas V.; *Institute on Current Problems in Perception, Thessaloniki, Greece, July 22–26 1968,* (J000268); 6 months; $821

STATE UNIVERSITY, Stony Brook

Le Noble, William J.; *Second International High Pressure Conference, Schloss Elmau, Germany, May 13–17, 1968* (GP8103); 6 months; $530

Ramirez, Fausto; *Fifth International Symposium on the Chemistry of Natural Products, London, England, July 8–13, 1968* (GP8105); 9 months; $484

Lauterbur, Paul C.; *Second Intern[illegible] Symposium on Nuclear Magnetic R[illegible] Sao Paulo, Brazil, July 8–11, 1968* ([illegible] 6 months; $522

Fossan, David B.; *International Symp[illegible] on Nuclear Structures in Dubna, U.S.S.R., July 4–11, 1968* (GP8946); 6 months; $775

Okaya, Yoshi; *International Meeting on Accurate Determination of X-ray Intensities and Structure Factors, Cambridge, England, June 24–28, 1968* (GP8951); 6 months; $442

Zemanian, Armen; *Summer School on Circuit Theory 1968, Prague, Czechoslovakia, June 28–July 12, 1968* (K002496); 6 months; $410

STEVENS INSTITUTE OF TECHNOLOGY

Morgen, Ralph A.; *Third Pan American Congress on Engineering Education, Panama City, Panama, August 11–17, 1968* (GZ1031); 6 months; $316

Michalec, George W.; *JSME 1967 Semi-International Symposium, Tokyo, Japan, September 2–8, 1967* (K002466); 6 months; $650

Kobylarz, Thaddeus J.; *IEEE International Symposium on Information Theory, Athens, Greece, September 11–15, 1967* (K002483); 6 months; $490

SYRACUSE UNIVERSITY

Honig, Arnold; *Ninth International Semiconductor Physics Conference, Moscow, U.S.S.R., July 23–29* (GP8864); 6 months; $831

TEXAS TECHNOLOGICAL COLLEGE

Shine, Henry J.; *Third Symposium on the Chemistry of Organic Sulphur Compounds, Caen, France, May 21–25, 1968* (GP8794); 6 months; $495

INDIVIDUAL AWARDS

Howard, Robert F.; *COSPAR Eleventh Plenary Meeting, Tokyo, Japan, May 8–21, 1968* (A001580); 12 months; $684

Waite, Amory H. Jr.; *International Meeting of Radio Echo Sounding of Ice and Glaciers, Strasbourg, France, September 23–26, 1967* (A1196); 6 months; $392

Schneider, William Joseph; *Seminar on Hydrology of the Lower Mekong Basin, Vientiane, Laos-Bangkok, Thailand, November 19–26, 1967* (A1314); 6 months; $1,279

TUFTS UNIVERSITY

Mumford, George S., III; *Variable Star Conference, Budapest, Hungary, September 5–9, 1968, Colloquim on Mass Loss from Stars, Trieste, Italy, September 12–17, 1968* (GP-9092); 6 months; $600

New, Peter Kong-Ming; *International Conference on Social Science and Medicine, Aberdeen, Scotland, September 4–6, 1968* (GZ 1064); 6 months; $300

ECOLOGICAL SOCIETY OF AMERICA

Gunning, Gerald E. and Lauff, George H.; *Seventeenth International Congress of Limnology, Jerusalem, Israel, August 12–19, 1968* (GB7589); 12 months; $10,000

TULANE UNIVERSITY

Hofmann, Karl H.; *International Special Symposium on Extension Theory of Topological Structures, East Berlin, Germany, August 14–19, 1967* (GP7750); 9 months; $544

[illegible]ITY OF ALASKA

[illegible], Laurance; *Second SCAR Symposium* [illegible]*y, Cambridge, England, July 28–Au*[illegible]*, 1968* (A004308); 6 months; $778

Belon, Albert E.; *The International Union on Geodesy and Geophysics, XIVth General Assembly, Sandefjord, Norway, September 18–22, 1967* (A1168); 6 months; $693

UNIVERSITY OF ARIZONA

Bartlett, Neil R.; *Donders' Centenary—A Symposium on Reaction Time, Eindhoven, the Netherlands, July 28–August 2, 1968* (GB-7650); 6 months; $530

Barfield, Michael; *Second International Symposium on Nuclear Magnetic Resonance, São Paulo, Brazil, July 8–11, 1968* (GP8804); 6 months; $797

Fitch, Walter Stewart; *Variable Star Conference, Budapest, Hungary, September 5–9, 1968* (GP9091); 6 months; $860

Cohn, Harvey; *Conference on Automorphic Functions With Arithmetically Defined Groups, Oberwolfach, Germany, July 28–August 3, 1968* (GP9110); 6 months; $815

Adam, David Peter; *NATO Advanced Study Institute—Palaeogeophysics, Newcastle-Upon-Tyne, England, April 1–6, 1968* (GZ992); 6 months; $650

UNIVERSITY OF ARKANSAS

Amis, Edward S.; *Second International Symposium on Nuclear Magnetic Resonance, São Paulo, Brazil, July 8–11, 1968* (GP8798); 6 months; $437

UNIVERSITY OF CALIFORNIA, Berkeley

Gray, Alfred; *Conference on Jordan Algebras and Nonassociative Algebras, Oberwohlfach, Germany, August 17–26, 1967* (GP 7726); 9 months; $806

Dauben, William G.; *Fifth International Symposium on the Chemistry of Natural Products, London, England, July 8–13, 1968* (GP 8846); 6 months; $485

Phillips, John G.; *International Conference on Laboratory Astrophysics, Lunteren, Netherlands, September 2–5, 1968* (GP9071); 6 months $768

Barankin, Edward W.; *To Lecture at the Bolyai Mathematical Society, Budapest, Hungary, July 1968* (GP9105); 6 months; $290

De Vos, George A.; *VIII International Congress of Anthropological and Ethnological Sciences, Tokyo, Japan, September 3–10, 1968* (GS2136); 6 months; $575

Coroniti, Ferdinand V.; *NATO Advanced Study Institute on Plasma Waves in Space and in the Laboratory, Roros, Norway, April 17–26, 1968* (GZ1006); 6 months; $750

Struble, Gordon L.; *NATO Advanced Study Institute on Nuclear Physics, Les Houches, France, July 14–September 8, 1968* (GZ1027); 6 months; $853

Budnitz, Robert J.; *NATO Advanced Study Institute on Invariance Principles and Particle Physics, Erice, Italy, July 13–28, 1968* (GZ 1065); 6 months; $637

Silverman, Leonard M.; *NATO Advanced Study Institute on Controllability and Observability, Bologna, Italy, July 1–9, 1968* (GZ1067); 6 months; $841

Goudreau, Gerald Lee; *NATO Advanced Study Institute on Engineering Analyses of Viscoelastic Media, Stresa, Italy, August 21–September 1, 1967* (GZ738); 12 months; $830

Mei, Kenneth K.; *Symposium on Electromagnetic Waves, Stresa, Italy, June 24–29, 1968* (K004220); 6 months; $575

Kuh, Ernest S.; *International Symposium on Network Theory, Belgrade, Yugoslavia, September 4–7, 1968* (K004437); 6 months; $610

UNIVERSITY OF CALIFORNIA, Los Angeles

Yeh, Cavour; *Symposium on Electromagnetic Waves, Stresa, Italy, June 24–29, 1968* (A004224); 6 months; $875

Coates, Donald A.; *International Symposium on Gondwana Stratigraphy and Paleontology, Buenos Aires, Argentina, September 26–October 15, 1967* (A1199); 6 months; $783

Smith, Emil L.; *Twelfth General Assembly, International Council of Scientific Unions, Paris, France, June 22–27, 1968* (GF301); 1 month; $1,060

Motzkin, Theodore S.; *Conference on Computational Problems in Abstract Algebra, Oxford, England, August 29–September 2, 1967* (GP7768); 9 months; $726

Anet, Frank A. L.; *International Union of Pure and Applied Chemistry Symposium, Karlsruhe, Germany, September 8–11, 1968* (GP7768); 9 months; $585

Baker, David W.; *NATO Advanced Study Institute on Paleongeophysics, Newcastle-Upon-Tyne, England, April 1–6, 1968* (GZ1011); 6 months; $688

Capell, Alan J.; *NATO Advanced Study Institute on Far Infrared Properties of Solids, Delft, The Netherlands, August 5–23, 1968* (GZ1074); 6 months; $552

Walter, Donald O.; *Technical and Biological Problems of Control—An IFAC Symposium, Yerevan, U.S.S.R., September 24–28, 1968* (K004439); 6 months; $1,040

UNIVERSITY OF CALIFORNIA, San Diego

Elsner, Robert; *Second SCAR Symposium on Biology, Cambridge, England, July 28–August 8, 1968* (A004315); 6 months; $500

Goodkind, John M.; *Eleventh International Conference on Low Temperature Physics, St. Andrews, Scotland, August 21–28, 1968* (GP9085); 6 months; $707

Johnson, Leonard E.; *NATO Advanced Study Institute on Palaeogeophysics, Newcastle-Upon-Tyne, England, April 1–6, 1968* (GZ1000); 6 months; $590

UNIVERSITY OF CALIFORNIA, Santa Cruz

Herbig, George H.; *Variable Star Conference, Budapest, Hungary, September 5–9, 1968* (GP9090); 6 months; $430

Walker, Merle F.; *Variable Star Conference, Budapest, Hungary, September 5–9, 1968, Fourth Symposium on Photoelectronic Image Devices, London, England, September 16–20, 1968* (GP9102); 6 months; $894

UNIVERSITY OF CALIFORNIA, Davis

Goldman, Charles R.; *Second SCAR Symposium on Biology, Cambridge, England, July 28–August 6, 1968* (A004314); 6 months; $768

Devries, Arthur Leland; *Second SCAR Symposium on Biology, Cambridge, England, July 28–August 6, 1968* (A004319); 6 months; $690

Tamura, Takayuki; *Conference on Computational Problems in Abstract Algebra, Oxford, England, August 29–September 2, 1967* (GP7787); 9 months; $450

Smith, Joe Mauk; *Fourth International Congress on Catalysis and Novosibirsk Symposium, Moscow and Novosibirsk, U.S.S.R., June 23–29, 1968* (K004148); 6 months; $650

UNIVERSITY OF CALIFORNIA, Irvine

Shaw, Gordon L.; *XIV International Conference on High Energy Physics in Vienna, Austria on August 28–September 5, 1968* (GP 9017); 6 months; $237

Maradudin, Alexei A.; *Visit Various Institutes and Universities in the Soviet Union During July–December, 1968* (GP9075); 10 months; $1,500

UNIVERSITY OF CHICAGO

Parker, Eugene N.; *The COSPAR Eleventh Plenary Meeting, Tokyo, Japan, May 8–21, 1968* (A001579); 6 months; $854

Roizman Bernard; *International Congress for Virology, Helsinki, Finland, July 14–20, 1968* (GB7660); 6 months; $740

Browder, Felix E.; *Conference on Functional Analysis, Rome, Italy, March 11–15, 1968* (GP8207); 9 months; $619

Baily, Walter L., Jr.; *Conference on Automorphic Functions on Arithmetically Defined Groups Oberwolfach, Germany, July 28–August 3, 1968* (GP8816); 6 months; $689

Hildebrand, Roger H.; *XIV International Conference on High Energy Physics in Vienna, Austria, August 28–September 5, 1968* (GP 8845); 6 months; $644

Telegdi, Valentine L.; *XIV International Conference on High Energy Physics, Vienna, Austria, August 28–September 5, 1968* (GP 8847); 6 months; $601

Douglas, David H., Jr.; *Eleventh International Conference on Low Temperature Physics,* *St. Andrews, Scotland, August 21–28, 1968* (GP9087); 6 months; $500

Dahlberg, Albert A.; *VIII International Congress of Anthropological and Ethnological Sciences, Tokyo, Japan, September 3–10, 1968* (GS2137); 6 months; $785

Schneider, David M.; *VIII International Congress of Anthropological and Ethnological Sciences, Tokyo, Japan, September 3–10, 1968* (GS2179); 6 months; $785

Postmus, Clarence; *NATO Advanced Study Institute on Far Infrared Properties of Solids, Delft, the Netherlands, August 5–23, 1968* (GZ1079); 6 months; $413

Bengtson, Vern; *NATO Advanced Study Institute on Decision-Making and Age, Thessalonika, Greece, August 14–19, 1967* (GZ 735); 1 month; $1,069

UNIVERSITY OF COLORADO

London, Julius; *International Radiation Symposium, Bergen, Norway, August 21–28, 1968* (A001629); 6 months; $365

Garstang, Roy Henry; *Meeting on Forbidden Radiations in Astronomical Bodies, Liege, Belgium, June 24–26, 1968* (GP8438); 6 months; $674

UNIVERSITY OF CONNECTICUT

Bobbitt, James M.; *Fifth International Symposium on the Chemistry of Natural Products, London, England, July 8–13, 1968* (GP 8812); 6 months; $429

Schwarting, Arthur E.; *Fifth International Symposium on the Chemistry of Natural Products, London, England, July 8–13, 1968* (GP 8813); 6 months; $432

UNIVERSITY OF FLORIDA

Adams, Dwight; *Eleventh International Conference on Low Temperature Physics, St. Andrews, Scotland, August 21–28, 1968* (GP 9082); 6 months; $442

UNIVERSITY OF GEORGIA

Pelletier, S. William; *Fifth International Symposium on the Chemistry of Natural Products, London, England, July 8–13, 1968* (GP 8811); 6 months; $541

UNIVERSITY OF HAWAII

Kuo, F. F.; *International Symposium on Network Theory, Belgrade, Yugoslavia, September 4–7, 1968* (K004436); 6 months; $500

UNIVERSITY OF HOUSTON

Willcott, Mark Robert; *International Union of Pure and Applied Chemistry Symposium, Karlsruhe, Germany, September 8–11, 1968* (GP8851); 6 months; $553

UNIVERSITY OF ILLINOIS

Sybesma, Christiaan; *International Congress of Photosynthesis Research, Freudenstadt, Germany, June 4–8, 1968* (GB7659); 6 months; $620

Gottlieb, David; *International Symposium on the Taxonomy of the Actinomycetales, Jena, Germany, September 17–21, 1968* (GB7809); 6 months; $646

Yankwich, Peter E.; *Fifth Symposium on Stable Isotopes, Leipzig, Germany, October 22–29, 1967* (GP7790); 11 months; $614

Holonynk, Nick, Jr.; *To Visit Science Centers in Moscow, Leningrad, and Kiev, U.S.S.R.* (GP7821); 9 months; $872

Axel, Peter; *International Symposium on Nuclear Structure in Dubna, U.S.S.R., July 4–11, 1968* (GP9113); 6 months; $840

Bruner, Edward M.; *VIII International Congress of Anthropological and Ethnological Sciences, Tokyo, Japan, September 3–10, 1968* (GS2144); 6 months; $815

Dale, M. Simonich; *NATO Advanced Study Institute on Satellite Signal Propagation in the Ionosphere, Viareggio, Italy, June 10–22, 1968* (GZ1049); 6 months; $301

Bohan, Thomas L.; *NATO Advanced Study Institute on Paramagnetic Defects in Crystals, Ghent, Belgium, August 28–September 8, 1967* (GZ730); 1 month; $582

Schwebel, John C.; *NATO Advanced Study Institute on Computer Programming, Lyngby, Denmark, August 7–25, 1967* (GZ734); 1 month; $620

Taylor, Charles E.; *JSME 1967 Semi-International Symposium, Tokyo, Japan, September 4–8, 1967* (K002468); 6 months; $750

Ang, Alfredo H. S.; *CEB Symposium and Committee Meeting on Structural Safety, Lausanne, Switzerland, April 19–27, 1968* (K002493); 6 months; $580

Karara, H. M.; *Eleventh International Congress of Photogrammetry, Lausanne, Switzerland, July 8–20, 1968* (K004295); 6 months; $465

UNIVERSITY OF ILLINOIS, Chicago Circle Campus

Milgram, Richard J.; *Conference in Algebraic Topology, Oberwolfach, Germany, August 29–September 10, 1967* (GP7763); 9 months; $553

Hartnett, James P.; *JSME 1967 Semi-International Symposium, Tokyo, Japan, September 4–8, 1967* (K002469); 6 months; $930

UNIVERSITY OF IOWA

Lonngren, Karl E.; *Symposium on Electromagnetic Waves, Stresa, Italy, June 24–29, 1968* (A004225); 6 months; $490

Oliven, Melvin N.; *NATO Advanced Study Institute on Aurora and Airglow, As, Norway, July 29–August 9, 1968* (GZ1041); 6 months; $484

UNIVERSITY OF KANSAS

Teichert, Curt; *First International Symposium on Gondwana Stratigraphy and Paleontology, Mar Del Plata, Argentina, September 26–October 4, 1967* (A1182); 11 months; $698

UNIVERSITY OF LOUISVILLE

Gonkin, James E.; *Sixth International Congress of Carboniferous Stratigraphy and Geology, Sheffield, England, September 11–23, 1967* (A1180); 12 months; $285

UNIVERSITY OF MARYLAND

Lippincott, Ellis R.; *First International Codata Conference, Arnoldshain, Germany, June 30–July 5, 1968* (GP8823); 6 months; $325

UNIVERSITY OF MASSACHUSETTS

Karasz, Frank E.; *Fifth Symposium on Stable Isotopes, Leipzig, Germany, October 22–29, 1967* (GP7791); 12 months; $501

UNIVERSITY OF MIAMI

Fisher, David E.; *Symposium on Meteorite Research, Vienna, Austria, August 7–13, 1968* (A004357); 6 months; $773

UNIVERSITY OF MICHIGAN

Benninghoff, William S.; *Second SCAR Symposium on Biology, Cambridge, England, July 28–August 6, 1968* (A004307); 6 months; $353

Piranian, George; *Conference on the Theory of Functions of a Complex Variable, Oberwolfach, Germany, March 17–23, 1968* (GP 8206); 9 months; $522

Duren, Peter L.; *Conference on Complex Function Theory, Oberwolfach, Germany, March 17–24, 1968* (GP8263); 6 months; $250

Gehring, Frederick W.; *Conference on Complex Function Theory, Oberwolfach, Germany, March 17–24, 1968* (GP8264); 6 months; $272

Lewis, Donald J.; *Conference on Analytic Number Theory, Oberwolfach, Germany, March 25–30, 1968* (GP8434); 6 months; $322

Chagnon, Napoleon A.; *XII International Congress of Genetics, August 19–28, 1968, Kyoto, Japan, and VIII International Congress of Anthropological and Ethnological Sciences, September 3–10, 1968, Tokyo, Japan* (GS2130); 6 months; $815

Gogol, Eugene M.; *NATO Advanced Study Institute on Control Mechanisms in Molecular Biology, Bergen, Norway, May 20–30, 1968* (GZ1023); 6 months; $413

Clark, John A.; *JSME 1967 Semi-International Symposium, Tokyo, Japan, September 4–8, 1967* (K002467); 6 months; $770

Stroke, George W.; *Science and Humanism Bienal, Sao Paulo, Brazil, October 15–November 15, 1967* (K002484); 6 months; $1,075

Denton, Frank; *Science and Humanism Bienal, Sao Paulo, Brazil, October 9–November 24, 1967* (K002485); 6 months; $2,230

Parravano, G.; *Fourth International Congress on Catalysis, Moscow, U.S.S.R., June 23–July 3, 1968* (K004147); 6 months; $900

Carpenter, John M.; *Symposium on Neutron Inelastic Scattering, Copenhagen, Denmark, May 20–29, 1968* (K004170); 6 months; $413

UNIVERSITY OF MINNESOTA

Siniff, Donald B.; *Second SCAR Symposium on Biology, Cambridge, England, July 28–August 6, 1968* (A004297); 6 months; $375

Erickson, Albert W.; *Second SCAR Symposium on Biology, Cambridge, England, July 25–August 8, 1968* (A004299); 6 months; $275

Lumry, Rufus; *Second Lacuro Conference on Hemoglobin, Rome, Italy, June 12–25, 1968* (GB7655); 6 months; $750

Sobel, Milton; *Colloquium on Information Theory, Debrecen, Hungary, September 19–24, 1967* (GP7772); 9 months; $204

Reich, Edgar; *Conduct Research at the University of Zurich, Switzerland* (GP8818); 3 months; $686

Chacon, Van Severen; *Symposium on Ergodic Theory, Oberwolfach, Germany, August 4–10, 1968* (GP9108); 6 months; $686

Yellott, John I., Jr., *NATO Advanced Study Institute on Technique and Results in the Assessment of Short-Term Memory, Cambridge, England, July 30–August 12, 1967* (GZ725); 1 month; $586

Gollwitzer, Herman Ernest; *NATO Advanced Study Institute on Differential Equations, Edinburgh, Scotland, September 11–23, 1967* (GZ742); 6 months; $346

Lawver, J. E.; *Eighth International Mineral Processing Congress, Leningrad, U.S.S.R., June 10–15, 1968* (K002489); 6 months; $840

Dahler, John S.; *Conference of the Fachausschuss Fur Thermodynamik and Statistische Mechanik, Berlin, West Germany, March 18–23, 1968* (K002490); 6 months; $625

Aris, Rutherford; *Fourth European Symposium on Chemical Reaction Engineering, Brussels, Belgium, September 9–11, 1968* (K010173); 6 months; $570

UNIVERSITY OF MISSOURI, Columbia

Muhlestein, Lewis Def; *Symposium on Neutron Inelastic Scattering, Copenhagen, Denmark, May 20–25, 1968* (GP8441); 9 months; $587

Noteboom, William D.; *NATO Advanced Study Institute on Control Mechanisms in Molecular Biology, Bergen, Norway, May 20–30, 1968* (GZ1020); 6 months; $455

UNIVERSITY OF MISSOURI, Rolla

Rusche, Edmund W. Jr.; *International Symposium on Metastable Phases Properties, Pau, France, July 8–12, 1968* (A001642); 6 months; $631

Kreidl, Norbert; *Symposium on Coloured Glasses, Prague, Czechoslovakia, September 13–15, 1967* (K002477); 6 months; $700

———; *Eighth International Congress on Glass, London, England, July 1–6, 1968* (K004361); 6 months; $550

UNIVERSITY OF NORTH CAROLINA, Chapel Hill

Ripperton, Lyman A.; *International Ozone Commission Symposium, Marseilles, France, September 2–7, 1968* (A001644); 6 months; $546

Rollitzer, William S.; *VIII International Congress of Anthropological and Ethnological Sciences, Tokyo, Japan, September 3–10, 1968* (GS2139); 6 months; $890

UNIVERSITY OF NEBRASKA

Smith, Kenneth; *International Symposium on Physics of One- and Two-Electron Atoms, Munich, Germany, September 9–13, 1968* (GP 9068); 6 months; $603

UNIVERSITY OF NEW HAMPSHIRE

Frost, Albert D.; *International Symposium on the Total Solar Eclipse of November 12, 1966, Sao Jose Dos Campos, Brazil, February 5–11, 1968* (A1351); 12 months; $551

UNIVERSITY OF NEW MEXICO

Breiland, John G.; *International Ozone Commission Symposium, Marseilles, France, September 2–7, 1968* (A001630); 6 months; $[illegible]

Peterson, Alan W.; *International Symposium on the Total Solar Eclipse of November 12, 1966, Sao Jose Dos Campos, Brazil, February 5–11, 1968* (A1349); 12 months; $710

Blum, Julius R.; *Symposium on Ergodic Theory, Oberwolfach, Germany, August 4–10, 1968* (GP9109); 6 months; $782

Spuhler, J. N.; *VIII International Congress of Anthropological and Ethnological Sciences, Tokyo, Japan, September 3–10, 1968* (GS 2129); 6 months; $700

UNIVERSITY OF NOTRE DAME

Kenney, V. Paul; *XIV International Conference on High Energy Physics in Vienna, Austria, on August 28–September 5, 1968* (GP 9074); 6 months; $482

Carberry, J. J.; *Fourth International Congress on Catalysis and Novosibirsk Symposium, Moscow and Novosibirsk, U.S.S.R., June 23–29, 1968* (K002500); 6 months; $980

UNIVERSITY OF OKLAHOMA

Dryhurst, Glenn; *Second Society for Analytical Chemistry Conference, Nottingham, England, July 15–19, 1968* (GP9008); 6 months; $644

UNIVERSITY OF OREGON

Morris, Robert W.; *Second SOAR Symposium on Biology, Cambridge, England, July 28–August 6, 1968* (A004313); 6 months; $550

Harrison, David K.; *Meeting on Rings Modules and Homological Methods, Oberwolfach, Germany, March 3–8, 1968* (GP 8232); 9 months; $581

Starr, Patricia R.; *NATO Advanced Study Institute on Control Mechanisms in Molecular Biology, Bergen, Norway, May 20–30, 1968* (GZ1021); 6 months; $690

UNIVERSITY OF PENNSYLVANIA

Rim, Dock S.; *Meeting on Rings Modules and Homological Methods, Oberwolfach, Germany, March 3–8, 1968* (GP8235); 9 months; $262

Middleton, Roy; *International Symposium on Nuclear Structures in Dubna, U.S.S.R., July 4–11, 1968* (GP8945); 6 months; $793

Wood, Frank Bradshaw; *Variable Star Conference, Budapest, Hungary, September 5–9, 1968; Colloquium on Mass Loss From Stars, Trieste, Italy, September 12–17, 1968* (GP 9089); 6 months; $600

Gorn, Saul; *International Federation for Information Processing, Sardinia, Italy, September 6–8, 1967* (J000001); 7 months; $357

———; *Second Meeting of International Committee for the Study of Programming Languages, Copenhagen, Denmark, July 22–26, 1968* (J000324); 6 months; $585

Krodel, Ezra S.; *Technical and Biological Problems of Control—An IFAC Symposium, Yerevan, U.S.S.R., September 24–28, 1968* (K004441); 6 months; $825

UNIVERSITY OF PITTSBURGH

Coetzee, J. F.; *Study at the Max Planck Institute for Physical Chemistry, Gottingen, Germany, May 1, 1968–January 1, 1969* (GP 8091); 18 months; $545

Fite, Wade L.; *International Symposium on Physics of One- and Two-Electron Atoms, Munich, Germany, September 9–13, 1968* (GP–9069); 6 months; $576

UNIVERSITY OF RHODE ISLAND

Vetelino, John F.; *NATO Advanced Study Institute on Far Infrared Properties of Solids, Delft, The Netherlands, August 5–23, 1968* (GZ1077); 6 months; $330

UNIVERSITY OF ROCHESTER

Saunders, William H. Jr.; *Fifth Symposium on Stable Isotopes, Leipzig, East Germany, October 22–29, 1967* (GP7792); 11 months; $544

Montroll, E. W.; *International Symposium on Contemporary Physics, Trieste, Italy, June 1968* (GP8437); 12 months; $25,000

Feldman, Isaac; *Second International Symposium on Nuclear Magnetic Resonnace, Sao Paulo, Brazil, July 8–11, 1968* (GP8801); 6 months; $627

Fulbright, Harry W.; *International Symposium on Nuclear Structures, in Dubna, U.S.S.R., July 4–11, 1968* (GP8947); 6 months; $815

Lubin, Moshe Joel; *Third Symposium on Plasma Physics and Controlled Nuclear Fusion Research, Novosibirsk, U.S.S.R., August 1–7, 1968* (GP9073); 6 months; $755

Armstrong, Michael F.; *NATO Advanced Study Institute on New Trends in Programming, New Applications and Language Theories, Copenhagen, Denmark, August 12–24, 1968* (GZ1078); 6 months; $306

Su, Gouq-Jen; *Eighth International Congress on Glass, London, England, July 1–6, 1968* (K004359); 6 months; $485

UNIVERSITY OF SOUTH CAROLINA

Durig, James R.; *Ninth European Congress on Molecular Spectroscopy, Madrid, Spain, September 10–15, 1967* (GP7732); 10 months; $566

Bragin, Joseph; *NATO Adanced Study Institute on Far Infrared Properties of Solids, Delft, Netherland, August 5–23, 1968* (GZ1070); 6 months; $388

UNIVERSITY OF SOUTH FLORIDA

Dewitt, Hugh H.; *Second SOAR Symposium on Biology, Cambridge, England, July 28–August 6, 1968* (A004362); 6 months; $396

Eichhorn-Von Wurmb, H. K.; *Meeting on Satellite Photographic Plate Reduction, Prague, Czechoslovakia, April 22–27, 1968* (GP8489); 9 months $554

Brooker, H. Ralph; *NATO Advanced Study Institute on Nuclear Quadruple Resonance Spectroscopy* (GZ758); 1 month; $672

UNIVERSITY OF SOUTHERN CALIFORNIA

Ingle, James C., Jr., *International Conference on Planktonic Microfossils, Geneva, Switzerland, September 27–October 3, 1967* (A1253); 6 months; $480

Servis, Kenneth L.; *Second International Symposium on Nuclear Magnetic Resonance, Sao Paulo, Brazil, July 8–11, 1968* (GP8709); 6 months; $628

Dows, David A.; *Fourth Molecular Crystal Symposium, Enschede, Netherlands, July 8–12, 1968* (GP8854); 6 months; $768

Ingersoll, Alfred C.; *The III Pan American Congress on Engineering Education, Panama City, Panama, August 11–17, 1968* (GZ1029); 6 months; $824

Carlson, Robert W.; *NATO Advanced Study Institute on Aurora and Airglow, As, Norway, July 29–August 9, 1968* (GZ1051); 6 months; $621

UNIVERSITY OF TEXAS, AUSTIN

Mackin, J. Hoover; *Congress, International Association Hydrogeologists, Istanbul, Turkey, September 10–23, 1967* (A1185); 13 months; $700

Wagner, Robert P.; *Symposium on Nuclear Physiology and Differentiation, Belo Horizonte, Brazil, December 1–6, 1968* (GB7823); 12 months; $4,800

Bailey, Philip S.; *International Symposium on the Chemie Der Organischen Peroxide, East Berlin, Germany, September 13–15, 1967* (GP7769); 10 months; $728

Cornell, John B.; *VIII International Congress of Anthropological and Ethnological Sciences, Tokyo, Japan, September 3–10, 1968* (GS2131); 6 months; $785

UNIVERSITY OF UTAH

Grant, David M.; *Second International Symposium on Nuclear Magnetic Resonance, Sao Paulo, Brazil, July 8–11, 1968* (GP8808); 6 months; $499

UNIVERSITY OF VIRGINIA

Fredrick, Laurence W.; *International Conference on Laboratory Astrophysics, September 2–6, 1968, Luteren, Netherlands; Meeting on Photoelectric Image Devices, London, England, September 16–20, 1968* (GP9070); 6 months; $550

UNIVERSITY OF WASHINGTON

Hobbs, Peter V.; *International Symposium on Physics of Ice, Munich, Germany, September 9–14, 1968* (A001627); 12 months; $365

Ugolini, Fiorenzo C.; *Second SCAR Symposium on Biology, Cambridge, England, July 28–August 6, 1968* (A004303); 6 months; $696

Lenfant, Claude; *Second SCAR Symposium on Biology, Cambridge, England, July 28–August 6, 1968* (A004304); 6 months; $696

Dayton, Paul K.; *Second SCAR Symposium on Biology, Cambridge, England, July 28–August 6, 1968* (A004311); 6 months; $521

GENETICS SOCIETY OF AMERICA

Stadler, David R.; *Twelfth International Congress of Genetics, Tokyo, Japan, August 19–28, 1968* (GB7816); 12 months; $20,000

UNIVERSITY OF WASHINGTON

Arsove, Maynard G.; *Conference on the Theory of Functions of a Complex Variable, Oberwolfach, Germany, March 17–23, 1968* (GP8205); 9 months; $690

Kunstadter, Peter; *VIII International Congress of Anthropological and Ethnological Sciences, Tokyo, Japan, September 3–10, 1968* (GS2138); 6 months; $490

Swindler, Daris R.; *VIII International Congress of Anthropological and Ethnological Sciences, Tokyo, Japan, September 3–10, 1968* (GS2143); 6 months; $660

Wulbert, Daniel E.; *NATO Advanced Study Institute on Theory and Application of Monotone Operators, Venice, Italy, June 17–30, 1968* (GZ1058); 6 months; $780

Wolak, Jan; *Eighth International Machine Tool Design and Research Conference, Manchester, England, September 12–15, 1967* (K002475); 6 months; $594

UNIVERSITY OF WISCONSIN, Madison

Black, Robert F.; *IGU Commission on the Evolution of Slopes and on Periglacial Geomorphology, Wroclaw, Lodz, Krakow, Poland, September 20–30, 1967* (A1184); 12 months; $706

Dott, Robert H.; *International Symposium on Continental Drift and the South Atlantic Ocean, Montevideo, Uruguay, October 16–19, 1967* (A1262); 6 months; $643

West, Robert C., Jr.; *Second International Organosilicon Symposium, Bordeaux, France, July 9–12, 1968* (GP8131); 6 months; $581

Osterbrock, Donald E.; *Meeting "Forbidden Radiations in Astronomical Bodies," June 24–26, 1968, Liege, Belgium* (GP8440); 6 months; $582

Robinson, John T.; *VIII International Congress of Anthropological and Ethnological Sciences, Tokyo, Japan, September 3–10, 1968* (GS2140); 6 months; $675

Uhr, Leonard; *International Pattern Recognition Meeting, Delft, the Netherlands, August 12–15, 1968* (J000323); 6 months; $423

VASSAR COLLEGE

Clark, Patricia A.; *NATO Advanced Study Institute on Quantum Theory of Reactivity of Organic Molecules, Menton, France, July 4–19, 1968* (GZ1025); 6 months; $592

VIRGINIA POLYTECHNIC INSTITUTE

Benoit, Robert E.; *Second SCAR Symposium on Biology, Cambridge, England, July 28–August 6, 1968* (A004318); 6 months; $371

WASHINGTON STATE UNIVERSITY

Duvall, George E.; *International Union of Theoretical and Applied Mechanics Symposium, Paris, France, September 11–15, 1967* (K002472); 3 months; $650

———; (K002472 001); $45

WASHINGTON UNIVERSITY

Bennett, John W.; *VIII International Congress of Anthropological and Ethnological Sciences, Tokyo, Japan, September 3–10, 1968* (GS2126); 6 months; $525

WATER POLLUTION CONTROL FEDERATION

Fuhrman, R. E.; *International Conference of the Institute of Water Pollution Control, East London, South Africa, May 13–27, 1968* (K002499); 6 months; $980

WAYNE STATE UNIVERSITY

Der Hovanesian, Joseph; *Symposium on the Engineering Uses of Holography, Glasgow, Scotland, September 17–20, 1968* (K004414); 6 months; $460

WEST VIRGINIA UNIVERSITY

Slack, John M.; *International Symposium on the Taxonomy of the Actinomycetales, Jena, Germany, September 17–21, 1968* (GB 7811); 6 months; $600

WESTERN RESERVE UNIVERSITY

Douglas, Robert G.; *International Conference on Planktonic Microfossils, Geneva, Switzerland, September 27–October 4, 1967* (A1128); 8 months; $530

Rustad, Ronald C.; *NATO Advanced Study Institute on Microbeam and Partial Cell Irradiation With Ancillary Techniques, Cannes, France, September 20–28, 1967* (GZ757); 12 months; $551

WOFFORD COLLEGE

Stephens, B. G.; *Second Society for Analytical Chemistry Conference, Nottingham, England, July 15–19, 1968* (GP9010); 6 months; $590

YALE UNIVERSITY

Crompton, A. W.; *Partial Support of Travel To Attend First International Symposium on Gondwana Stratigraphy and Paleontology, Mar Del Plata, Argentina, September 27–October 4, 1967* (GB6955); 3 months; $370

Hsiang, Wu-Chung; *Conference in Algebraic Topology, Oberwolfach, Germany, August 29–September 10, 1967* (GP7762); 9 months; $826

Fuoss, Raymond M.; *Second Australian Conference on Electrochemistry, Melbourne, Australia* (GP7954); 11 months; $670

Smith, Allan L.; *International Conference on Optical Pumping and Atomic Line Shape, Warsaw, Poland, June 25–28, 1968* (GP9047); 6 months; $335

Conklin, Harold C.; *Eighth International Congress of Anthropological and Ethnological Sciences, Tokyo, Japan, September 3–10, 1968* (GS2128); 6 months; $865

Alper, Joseph S.; *NATO Advanced Study Institute on Molecular Beams and Reaction Kinetics, Varenna, Italy, July 29–August 10, 1968* (GZ1062); 6 months; $364

YESHIVA UNIVERSITY

Lipsicas, Max; *Second International Symposium on Nuclear Magnetic Resonance, Sao Paulo, Brazil, July 8–11, 1968* (GP8802); 6 months; $522

French, Joseph H.; *NATO Advanced Study Institute on Pathological Neurochemistry, Coimbra, Portugal, July 8–15, 1967* (GZ722); 1 month; $456

Goldstein, Martin; *Eighth International Congress on Glass, London, England, July 1–6, 1968* (K004360); 6 months; $445

INDIVIDUAL AWARD

McLeod, John H.; *Seventh International Conference on Medical and Biological Engineering, Stockholm, Sweden, August 14–19, 1967; Fifth Congress of the International Association of Analog Computers, Lausanne, Switzerland, August 28–September 2, 1967* (K002465); 6 months; $865

List of Grants and Contracts Awarded for Science Information Activities, Fiscal Year 1963 Through Fiscal Year 1968

With reference to the following lists, attention is called to the fact that the program activity areas, under which grants and contracts are grouped vary from year to year to reflect the changing categories as presented in the Foundation's annual budget requests.

Each award listing provides information regarding the amount awarded, the grantee organization, the title of the project, the award number, followed by the award date and the project's duration. A distinction as to the award mechanism used can easily be made; e.g., each award number is preceded by "G" for grant, "C" for contract, and an occasional "P.O." for purchase order.

PROGRAM/ACTIVITY SUMMARY
SCIENCE INFORMATION ACTIVITIES
FISCAL YEAR 1963

DOCUMENTATION RESEARCH

Information Needs of Scientists

$ 94,185	AMERICAN INSTITUTE OF PHYSICS, "Documentation Research Project," GN-120, 5/21/63, 1 yr.
69,900	AMERICAN PSYCHOLOGICAL ASSOCIATION, "Coordinated Study of Information Exchange in Psychology," G-18494.1, 9/25/62, 2 mos. ext.
48,600	DREXEL INSTITUTE OF TECHNOLOGY, "Research on Engineers' Use of Information Sources," GN-170, 6/24/63, 1 yr.
34,100	LEHIGH UNIVERSITY, "Studies in the Methodology of Measuring Information Requirements and Use Patterns," GN-22, 9/11/62, 2 yrs.

Information Organization and Searching

$ 20,500	CAMBRIDGE LANGUAGE RESEARCH UNIT, "New Techniques for Classification: The Theory of Clumps," GN-112, 3/29/63, 1 yr.
75,000	COMMERCE DEPT./National Bureau of Standards, "Research on Picture and Language Processing," GN-107, 3/26/63, 1 yr.
4,148	ENGINEERS JOINT COUNCIL, "Study of Engineering Terminology and Relationships Among Engineering Terms," G-24836.1, 3/12/63
36,149	HARVARD UNIVERSITY, "Research on and Evaluation of Some Models for Automatic Document Retrieval Systems," GN-82, 12/28/62, 1 yr.
64,920	INFORONICS INC., "Machine Recording of Textual Information During the Publication of Scientific Journals," C-315, 1/26/63, 1 yr.
16,200	LEHIGH UNIVERSITY, "Mathematical Theories of Relevance with Respect to the Problems of Indexing," GN-177, 6/29/63, 2 yrs.
475	NATIONAL BIOMEDICAL RESEARCH FOUNDATION, "for the purchase of 500 copies of <u>Selected Bibliography of the International Geophysical Year: An Example of Thesaurus Formats</u>." P.O. 63-741, 2/26/63
24,048	SYSTEM DEVELOPMENT CORPORATION, "Steps Toward the Establishment of Computer-Derived Classification System for Scientific Documentation," GN-73, 11/30/62, 1 yr.
59,900	WESTERN RESERVE UNIVERSITY, "Automatic Processing of Metallurgical Abstracts for the Purpose of Information Retrieval," GN-156, 6/15/63, 1 yr.

Mechanical Translation

$249,000	THE UNIVERSITY OF CALIFORNIA/Berkeley, "Research on Machine Translation and Related Information Systems," GN-92, 2/1/63, 18 mos.
235,450	HARVARD UNIVERSITY, "Automatic Translation and Mathematical Linguistics," GN-162, 6/29/63, 16 mos.
$100,000	THE OHIO STATE UNIVERSITY RESEARCH FOUNDATION, "Research on Syntactic Analysis," GN-174, 6/24/63, 30 mos.
152,084	RAMO-WOOLDRIDGE, A Division of Thompson Ramo-Wooldridge, Inc., "Computer-Aided Research in Machine Translation," C-233.2, 3/1/63, 1 yr.
200,000	THE UNIVERSITY OF TEXAS, "Development of a Linguistic Computer System," GN-54, 9/27/62, 1 yr.

Tests and Evaluation of New Techniques

$ 19,416	HERNER AND CO., "A Study of the Character and Degree of Use of the AIChE <u>Chemical Engineering Thesaurus</u> and the Index Data Provided for Articles in <u>Chemical Engineering Progress</u>," C-296, 10/30/62, 9 mos.
74,746	MASSACHUSETTS INSTITUTE OF TECHNOLOGY, "Technical Information System: Phase Two," GN-121, 5/21/63, 1 yr.
141,800	UNIVERSITY OF PENNSYLVANIA, "Analysis of Chemical Notations," GN-161, 6/15/63, 2 yrs.

State-of-the-Art Surveys and Research Information Centers

$ 17,250	AMERICAN METEOROLOGICAL SOCIETY, "Pilot Project to Further Explore Possibilities for Mechanization of Universal Decimal Classification (UDC) Schedules," GN-131, 6/3/63, 5 mos.
95,000	COMMERCE DEPT./National Bureau of Standards, "Research Information Center and Advisory Service on Information Processing," GN-119, 5/25/63, 1 yr.
11,000	COMMERCE DEPT./Office of Technical Services, "Service to Assure Availability of Publications Listed in Current Research and Development in Scientific Documentation," GN-43, 10/1/62, 1 yr.
53,250	COMMERCE DEPT./Patent Office, "Foreign Research Associates Program," GN-4, 8/10/62, 1 yr.
2,000	DOCUMENTATION INC., "for the purchase of 500 additional copies of The State of the Art of Coordinate Indexing," P.O. 63-252, 9/14/62
10,000	HERNER AND CO., "for services to be performed in Assisting in the Preparation of an Indexed Bibliography of Reference to all Reports and Publications Cited in the NSF/OSIS Publication, Current Research and Development in Scientific Documentation, Issues No. 1 thru 11," P.O. 63-805, 3/15/63
50,223	RAMO-WOOLDRIDGE, A Division of Thompson Ramo-Wooldridge, Inc., "Study Concerning the Establishment of a Center to Collect and Provide Text in Machine-Usable Form," C-320, 8/20/63, 4 mos.
23,550	RUTGERS, THE STATE UNIVERSITY, "Seminars on Systems for the Organization of Information," GN-99, 2/20/63, 1 yr.
200,000	WAYNE STATE UNIVERSITY, "Comprehensive Electronic Data Processing of Two Russian Lexicons," GN-159, 6/15/63, 2 yrs.

FOREIGN SCIENCE INFORMATION

Translations

	Domestic/Slavic:
$ 49,071	ACTA METALLURGICA, "Translation and Publication of the 1962 Issues of Four Russian Journals: Metallurg; MITON; Ogneupory; and Physics of Metals and Metallography," G-25109, 7/23/62, 1 yr.
23,980	AMERICAN GEOGRAPHICAL SOCIETY, "Translation and Publication of Soviet Geography: Review and Translation for Calendar Year 1963," GN-72, 11/15/62, 1 yr.
115,685	AMERICAN GEOLOGICAL INSTITUTE, "Publication of (A) Vol. V, 1963, International Geology Review; (B) Translation of 3 Russian Journals, Izvestiya-Geology Series, Soviet Geology, and Paleontological Journal, for Publication of Selected Articles in IGR, including Selective Translations and Abstracts from Geological Materials of Other Foreign Languages; and (C) Translations Screening and Information Services," GN-164, 6/24/63, 1 yr.
32,000	AMERICAN GEOPHYSICAL UNION, "Translation and Publication of Russian Works in Oceanography: The Oceanology Sections of Doklady and the Trudy of the Marine Hydrophysical Institute," GN-84, 1/9/63, 2 yrs.
49,000	AMERICAN GEOPHYSICAL UNION, "Translation and Publication of the 1963 Issues of Izvestiya, Geophysics Series," GN-87, 1/22/63, 1 yr.
34,830	AMERICAN GEOPHYSICAL UNION, "Translation and Publication of Vol. 2, Nos. 4-6, 1962, and Vol. 3, Nos. 1-6, 1963, of the Journal, Geomagnetism and Aeronomy, USSR," GN-108, 4/4/63, 18 mos.
19,235	AMERICAN GEOPHYSICAL UNION, "Translation and Publication of Soviet Hydrology: Selected Papers, Russian Literature for 1963," GN-126, 5/6/63, 15 mos.
23,870	AMERICAN GEOPHYSICAL UNION, "Translation and Publication of the 1963 Issues of the Russian Journal, Geodesy and Aerophotography," GN-130, 6/12/63
41,620	AMERICAN INSTITUTE OF CHEMICAL ENGINEERS, "Translation and Publication of the International Chemical Engineering Journal," GN-122, 5/8/63, 8 mos.
128,577	AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS, "Translation and Publication of the 1962 Issues of Three Russian Journals: Radio Engineering; Radio Engineering and Electronic Physics; and Telecommunications," GN-24, 10/23/62, 1 yr.
139,200	AMERICAN INSTITUTE OF PHYSICS, "Translation and Publication of the 1962 Issues of Eight Russian Journals: Acoustics; Astronomy; Technical Physics; Solid State Physics; JETP; Uspekhi; Crystallography; and Doklady, Physics Section," G-25107, 7/31/62
129,500	AMERICAN INSTITUTE OF PHYSICS, "Translation and Publication of the 1963 Issues of Eight Russian Journals: Acoustics; Astronomy; Technical Physics; Solid State Physics; JETP; Uspekhi; Crystallography; and Doklady, Physics Section," GN-143, 6/10/63, 1 yr.
$ 47,651	AMERICAN MATHEMATICAL SOCIETY, "Translation and Publication of Volume III, 1962 Issues, of the Russian Journal, Soviet Mathematics--Doklady," G-20083.1, 9/13/62, 18 mos.
68,724	AMERICAN MATHEMATICAL SOCIETY, "Program for Selected Translations of Mathematical Research Articles from the Russian and Other Languages," G-20115.1, 9/13/62, 1 yr.
34,067	AMERICAN MATHEMATICAL SOCIETY, "Translation of Six Russian Mathematical Books," GN-57, 10/11/62, 1 yr.
12,213	AMERICAN METEOROLOGICAL SOCIETY, "Translation and Publication of the Russian Book, Investigation of Clouds, Precipitation and Thunderstorm Electricity," GN-100, 2/13/63, 6 mos.
75,090	AMERICAN ROCKET SOCIETY, INC., "Selected Translations of Russian Material in the Field of Astronautics," GN-19, 9/13/62, 1 yr.
12,554	AMERICAN SOCIETY OF MECHANICAL ENGINEERS, "Publication in English of Vols. 15 and 16, Russian Serial, Friction and Wear in Machinery," GN-136, 6/12/63
10,200	ANNUAL REVIEWS, INC., "Preparation and Publication of Selected Reviews of Russian Science," C-120.2, 11/9/62, 1 yr.
2,415	COLUMBIA UNIVERSITY, "Review and Translation of Articles Published in

	Russian, Geology of Ore Deposits," GN-12, 8/4/62, 3 yrs.
6,100	COMMERCE DEPT./Weather Bureau, "Editorial and Abstracting Services for AGU's Project of Translating Soviet Hydrology Literature for 1963," GN-115, 4/12/63, 15 mos.
82,396	CONSULTANTS BUREAU ENTERPRISES, "Translation, Editing, Composition, and Printing of the Calendar Year 1962 Issues of the Russian Scientific Journals: Doklady (Biological Sciences Section, Biochemistry Section, and Botanical Sciences Sections); Microbiology; and Soviet Plant Physiology," C-315, 4/30/63, 10 mos.
13,000	CONSULTANTS BUREAU ENTERPRISES, "Circulation of the Calendar Year 1962 Issues of the Russian Scientific Journals: Doklady (Biological Sciences Sections, Biochemistry Section, and Botanical Sciences Section); Microbiology; and Soviet Plant Physiology," C-316, 4/30/63, 34 mos.
88,000	CONSULTANTS BUREAU ENTERPRISES, "Translation, Editing, Composition, Printing, and Circulation of the Calendar Year 1963 Issues of the Russian Scientific Journals: Doklady (Biological Sciences Section, Biochemistry Section, and Botanical Sciences Section); Microbiology; and Soviet Plant Physiology," C-327, 6/30/63, 30 mos.
27,078	THE GEOCHEMICAL SOCIETY, "Transltion and Publication of the 1962 Issues of the Russian Journal, Geokhimiya," GN-34, 9/25/62, 1 yr.
56,701	INSTRUMENT SOCIETY OF AMERICA, "Translation and Publication of the 1963 Issues of Four Russian Journals: Automation and Remote Control; Industrial Laboratory; Instruments and Experimental Techniques; and Measurement Techniques," GN-123, 6/15/63, 1 yr.
4,000	OPTICAL SOCIETY OF AMERICA, "Translation and Publication of the Cumulative Index Volumes I-X (1956-61) for the Russian Journal, Optika I Spektroskopiya," GN-11, 8/4/62, 1 yr.
62,816	SCRIPTA TECHNICA, INC., Translation, Editing, Composition and Printing of the Calendar Year 1962 Issues of the Russian Scientific Journals: Soviet Soil Science and Entomological Review," C-312, 4/25/63, 10 mos.
$ 10,200	SCRIPTA TECHNICA, INC., "Circulation of the Calendar Year 1962 Issues of the Russian Scientific Journals: Soviet Soil Science and Entomological Review," C-313, 4/25/63, 34 mos.
70,560	SCRIPTA TECHNICA, INC., "Translating, Editing, Composing, Printing, and Circulation of the Calendar Year 1963 Issues of the Russian Scientific Journals: Soviet Soil Science and Entomological Review," C-326, 6/30/63, 30 mos.
	Domestic/Oriental:
23,267	AMERICAN MATHEMATICAL SOCIETY, "Translation and Publication of the 1962 Issues of the Journal Chinese Mathematics - Acta," GN-58, 11/2/62, 1 yr.
94,435	INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC., "Translation and Publication of the 1963 Issues of Two Japanese Journals: Proceedings of Electrical Engineers of Japan and Proceedings of Electrical Communications Engineers of Japan," GN-101, 4/4/63, 1 yr.
6,830	JAPAN SOCIETY FOR THE PROMOTION OF SCIENCE, "Translation and Publication of a Directory of Research Institutions in Japan Natural and Applied Sciences," G-25080, 8/24/62, 1 yr.

Special Foreign Currency Translation Program

$598,925	ISRAEL	C-244.2, 1/21/63
301,075	POLAND	C-250.2, 2/21/63 @ $300,000; and $1,075, G-11147.2, 10/30/62, via State Dept.
100,000	YUGOSLAVIA	C-251.2, 3/1/63

Studies, Analyses and Exchanges

$ 1,661	AMERICAN DOCUMENTATION INSTITUTE, "Page Charges and Reprints of Papers Presented at the 1961 Pacific Science Congress which Appeared in American Documentation, Vol. 13, #3, July 1962," P.O. 63-395, 9/13/62
6,266	AMERICAN INSTITUTE OF BIOLOGICAL SCIENCES, "Dissemination of the English Version of the Japanese Journal of Plant and Cell Physiology in the United States," GN-51, 10/10/62, 1 yr.
35,031	AMERICAN MATHEMATICAL SOCIETY, "Provide Russian and Related Mathematical Literature for Abstracting and Research Libraries," G-18993.1, 8/24/62, 1 yr.

1,300 COMMERCE DEPT./Bureau of the Census, "Preparation and Publication of a Bibliographical Survey on Social Science Literature Published in Communist Bloc and Other Difficult Languages," GN-5.1, 2/8/63, 1 yr.

17,825 INDIANA UNIVERSITY FOUNDATION, "Preparation and Publication of a Volume on Current Trends in Far Eastern Linguistics," GN-132, 5/25/63, 2 yrs.

27,007 INTERNATIONAL UNION OF SCIENTIFIC PSYCHOLOGY, "Preparation and Publication of a Second Edition of the International Directory of Psychologists," GN-37, 9/20/62, 1 yr.

$ 1,005 LIBRARY OF CONGRESS, "Census of World-Wide Scientific Serials," GN-28,1, 2/4/63, 1 yr.

10,000 LIBRARY OF CONGRESS, "Preparation and Publication of a Guide to Library, Information, and Documentation Services of International Organizations in Science, Technology, Agriculture, and Medicine," G-13855.4, 1/9/63, 6 mos.

840 LIBRARY OF CONGRESS, "Preparation and Publication of an Analytical Survey and Bibliography of Directories in the Sciences Throughout the World," G-21917.1, 2/8/63, 1 yr.

30,000 LIBRARY OF CONGRESS, "Publication of the Monthly Index of Russian Accessions," G-24441, 6/29/63, 2 mos.

21,070 MASSACHUSETTS INSTITUTE OF TECHNOLOGY, "Acquisition and Compilation of a Current Union List of Communist Chinese Serials," GN-98, 2/8/63, 1 yr.

23,958 MASSACHUSETTS INSTITUTE OF TECHNOLOGY, "Study into the Dissemination of Scientific and Technical Information in the USSR," GN-124, 5/13/63, 1 yr.

36,540 THE MIDWEST INTER-LIBRARY CENTER, "Partial Support of Operation of the Scientific Journals Center," GN-81, 12/28/62, 1 yr.

12,480 NATIONAL ACADEMY OF SCIENCES/NATIONAL RESEARCH COUNCIL, "Study of Science Research and Information Services in East Africa," GN-91, 3/7/63, 1 yr.

1,223 NATIONAL DIET LIBRARY OF JAPAN, "Publication and Distribution of the Directory of Japanese Learned Periodicals, 1962 - Natural and Medical Sciences," G-25138, 8/24/62, 1 yr.

21,060 NATIONAL DIET LIBRARY OF JAPAN, "Compilation and Printing of the English Version of the Japanese Periodicals Index, Natural Science Section," GN-15, 8/24/62, 1 yr.

65,000 UNIVERSITY OF NOTRE DAME, "Microfilming of Scientific Manuscripts from the Ambrosiana Library in Milan, Italy," GN-83, 1/9/63, 1 yr.

23,403 PRINCETON UNIVERSITY, "Preparation of a Guide to Soviet Sciences," G-17474.1, 4/4/63, 1 yr.

45,678 SPECIAL LIBRARIES ASSOCIATION, "Collateral Support of the Operation of the Translations Center," GN-14, 8/4/62, 1 yr.

16,462 SYRACUSE UNIVERSITY RESEARCH INSTITUTE, "User Study of Translated Soviet Scientific Journals," G-19275.1, 9/14/62, 3 yrs.

Support of International Science Information Activities

$ 29,440 AMERICAN INSTITUTE OF PHYSICS, "Establishment of an Information Center of International Physics Activities," GN-111, 3/29/63, 1 yr.

15,000 BERNICE P. BISHOP MUSEUM, "Partial Support of the Permanent Secretariat of the Pacific Science Association," GN-46, 9/27/62, 5 yrs.

15,738 BERNICE P. BISHOP MUSEUM, "Operation of the Pacific Science Information Center," GN-60, 11/2/62, 1 yr.

6,804 COLUMBIA UNIVERSITY PRESS, "Publication of Two Studies: Science in Czechoslovakia, and Science in East Germany," GN-62, 10/26/62, 1 yr.

31,235 COMMERCE DEPT./Office of Technical Services, "Operational Phase of the PL 480 Translation Program," GN-[illegible], 1 yr.

600 JAPAN DOCUMENTATION SOCIETY, "Re[illegible]ating of the Kerr Report: Science Information Services in Japan," [illegible]8786.2, 9/25/62, 3 mos.

$ 6,997 LIBRARY OF CONGRESS, "Publication of Part of a Monthly World List of Future International Meetings," G-20569.1, 2/26/63, 6 mos.

114,380 NATIONAL ACADEMY OF SCIENCES/NATIONAL RESEARCH COUNCIL, Continued Support of the "Office of Documentation," GN-79, 12/14/62, 1 yr.

2,650 SYRACUSE UNIVERSITY RESEARCH INSTITUTE, "The Third Conference on Translation Editors," GN-61, 10/26/62, 3 mos.

13,225 UNION OF INTERNATIONAL ASSOCIATIONS (Brussels), "Compilation and Publication of (1) A Monthly Current List and (2) An Annual Bibliography of International Conference Proceedings," GN-48, 11/2/62, 1 yr.

RESEARCH DATA AND INFORMATION SERVICES PROGRAM

Research and Development Reporting

$ 13,260	UNIVERSITY OF CALIFORNIA/Berkeley, "Regional Reference Center for Unclassified U. S. Government Scientific and Technical Reports," GN-148, 6/25/63, 1 yr.
18,825	UNIVERSITY OF CALIFORNIA/Berkeley, "Regional Reference Center for Unclassified U. S. Government Scientific and Technical Reports," GN-149, 6/26/63, 1 yr.
100	CARNEGIE LIBRARY OF PITTSBURGH, "Establishment and Operation of a Regional Reference Center for Unclassified U. S. Government Scientific and Technical Reports, C-24320.2, 3/26/63
14,821	CARNEGIE LIBRARY OF PITTSBURGH, "Continued Operation of a Regional Technical Report Center," GN-146, 6/24/63, 1 yr.
13,139	UNIVERSITY OF COLORADO, "Regional Reference Center for Unclassified U. S. Government Scientific and Technical Reports," GN-153, 6/26/63, 1 yr.
17,528	COLUMBIA UNIVERSITY, "Regional Reference Center for Unclassified U. S. Government Scientific and Technical Reports," GN-154, 6/24/63, 1 yr.
10,000	COMMERCE DEPT./Office of Technical Services, "Establishment and Initial Operation of a System of Twelve Regional Reference Centers," G-18094.1, 1/29/63, 1 yr.
43,200	COMMERCE DEPT./Office of Technical Services, "Twelve Regional Reference Centers for Unclassified U. S. Government Scientific and Technical Reports," G-18094.2, 6/29/63, 1 yr.
97,400	COMMERCE DEPT./Office of Technical Services, "Keywords Index to U. S. Government Technical Reports," G-24466.1, 4/4/63
78,077	DATATROL CORPORATION, "Compilation of a Structured Composite Listing of the Indexing Vocabularies Currently Used by the Technical Information Systems of ASTIA, AEC, and NASA," C-295, 11/16/62, 15 mos.
21,494	GEORGIA INSTITUTE OF TECHNOLOGY, "Establishment and Operation of a Regional Reference Center for Unclassified U. S. Government Scientific and Technical Reports," G-25106, 7/23/52, 1 yr.
13,882	GEORGIA INSTITUTE OF TECHNOLOGY, "Regional Reference Center for Unclassified U. S. Government Scientific and Technical Reports," GN-151, 6/26/63, 1 yr.
6,181	HERNER AND COMPANY, "Study of the Identifying Categories and Codes of U. S. Government Research Reports," C-213.2, 8/20/62 and Amd. #3, 2/25/63
175	THE JOHN CRERAR LIBRARY, "Establishment and Operation of a Regional Reference Center for Unclassified U. S. Government Scientific and Technical Reports," G-24497.1, 3/29/63
10,672	THE JOHN CRERAR LIBRARY, "Regional Reference Center for Unclassified U. S. Government Scientific and Technical Reports," GN-147, 6/26/63, 1 yr.
6,150	LINDA HALL LIBRARY, "Regional Reference Center for Unclassified U. S. Government Scientific and Technical Reports," GN-150, 6/24/63, 1 yr.
$ 17,278	MASSACHUSETTS INSTITUTE OF TECHNOLOGY, "Regional Reference Center for Unclassified U. S. Government Scientific and Technical Reports," GN-173, 6/29/63, 1 yr.
440	PRESENTATION ASSOCIATES, for preliminary design drawings for exhibit "A National System for Dissemination of Scientific Information," P.O. 63-1169, 6/21/63
70,000	SCRIPTA TECHNICA, INC., "Preparation of Reports on <u>Scientific Information Activities of Federal Agencies</u>," C-163.2, 8/30/62, 1 yr.
15,123	SOUTHERN METHODIST UNIVERSITY, "Regional Reference Center for Unclassified U. S. Gove[illegible] Scient[illegible] and Technical Reports," GN-152, 6/26/63, 1 y[illegible]
14,803	U[illegible] [illegible]INGTON, "Regional Reference Center for Unclassified [illegible]. S. Government Scientific and Technical Reports," GN-155, 6/26/63, 1 yr.

Data and Reference Services

	Analysis and Coordination of National Information Service [illegible]:
$142,000	AMERICAN SOCIETY FOR METALS, "Cooperative Support of the Information Searching Service of the American Society for Metals," GN-[illegible], 11/9/62, 1 yr.
148,000	ARTHUR D. LITTLE, INC., "Study of the Degree of Centralization of Facilities Desirable for the Storage and Dissemination of Scientific [illegible] Documents," C-262.1, 8/30/62, 10 mos.
55,397	C-E-I-R, INC., "Study of a System to Collect and Exploit Data Describing Scientific Information Sources and Services," C-284, 8/9/62, 6 [illegible]
65,800	COLUMBIA UNIVERSITY, "Survey and Analysis of Specialized Information Sources and Services in the Social Sciences," C-278, 8/16/62, 2 yrs.
261,080	LIBRARY OF CONGRESS, "Establishment of a National Scientific and Technical Referral Center," GN-18, 8/24/62 and Amds. #1, #2, and #3
	Pre-Document or Non-Document Information Exchange Program:
47,300	AMERICAN SCIENCE FILM ASSOCIATION, "Central Office for the American Sciences Film Association," GN-21, 10/4/62, 18 mos.
44,000	COMMERCE DEPT./Office of Technical Services, "An Analysis of the Needs of the Textile Industry for Technical Information," GN-109, 5/[illegible]/63, 6 mos.
25,711	TUFTS UNIVERSITY, "Behavioral Analysis of Technical Writing," G-25112, 7/11/62, 1 yr.
	Library Resources Coordination:
5,000	AMERICAN LIBRARY ASSOCIATION, "Preparation of a Report on the Development of an Operating Program of Library Statistics," GN-145, 6/24/63, 1 yr.
45,033	UNIVERSITY OF ILLINOIS, "Programming, Testing, and Evaluation of a Computerized and Integrated Data Processing System for the University Library Procedures," GN-77, 11/30/62, 1 yr.
15,833	THE JOHNS HOPKINS UNIVERSITY, "An Operations Research and Systems Engineering Study of a University Library," GN-31, 9/20/62, 9 mos.
$ 28,360	LIBRARY OF CONGRESS, "Support of Conference on Library Mechanization," GN-104, 3/7/63, 1 yr.
16,200	MEDICAL LIBRARY ASSOCIATION, INC., "Second International Congress of Medical Librarianship," GN-47, 9/27/62, 11 mos.
30,000	UNIVERSITY OF MONTREAL, "Reconstruction and Improvement of Library and Filing Card System," GN-52, 11/2/62, 2 yrs.
8,470	THE NEW YORK PUBLIC LIBRARY, "Development of U. S. Standards in Library Work and Documentation," GN-78, 12/27/62, 1 yr.
5,290	WEST VIRGINIA UNIVERSITY, "Investigation of the Potential Use of the Resources of a Large Academic Library by the Smaller Academic Libraries and the Libraries of Industrial Organizations Within the District Region," GN-176, 6/29/63, 1 yr.
7,500	YALE UNIVERSITY, "Purchase of a Collection of Scientific Papers - the Harrison Reprint Collection," GN-13, 8/7/62, 1 yr.

Science Information Exchange

$225,000	SMITHSONIAN INSTITUTION, "Partial Support for the Annual Operating Expenses of the Science Information Exchange," GN-86, 1/22/63, 1 yr.

SUPPORT OF SCIENTIFIC PUBLICATIONS

Abstracting and Indexing

A&I:

$ 71,500 AMERICAN GEOLOGICAL INSTITUTE, "Continued Support for the Publication of GeoScience Abstracts," GN-142, 6/15/63, 2 yrs.

36,000 AMERICAN MATHEMATICAL SOCIETY, "Continued Support for the Operation and Expansion of Mathematical Reviews," G-17475.3, 6/15/63, 1 yr.

210,000 BIOLOGICAL ABSTRACTS, INC., "Continued Support of Biological Abstracts," GN-88, 1/29/63, 1 yr.

219,000 CHEMICAL ABSTRACTS SERVICE, "Development and Initiation of a Mechanized File of Chemical Information," G-22928.1, 4/4/63 and G-22928.2, 6/26/63

173,000 ENGINEERING INDEX, INC., "Continued Expansion of Engineering Index," GN-105, 5/13/63, 1 yr.

30,000 SOCIOLOGICAL ABSTRACTS, INC., "Support of Sociological Abstracts," GN-7, 8/7/62, 6 mos.

96,200 SOCIOLOGICAL ABSTRACTS, INC., "Continued Expansion of Sociological Abstracts," GN-141, 6/15/63, 2 yrs.

Bibliographies and Specialized Indexes:

17,500 THE ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA, "Support for Preparation and Publication of an Annotated Bibliography on Quaternary Shorelines," GN-163, 6/24/63, 2 yrs.

37,000 AMERICAN ASTRONOMICAL SOCIETY, "Preparation of the U. S. Portion of the International Astronomical Union Bibliography for 1881-1898," G-5977.1, 7/23/62, 2 yrs.

71,000 AMERICAN METEOROLOGICAL SOCIETY, "Continuation of Compilation and Publication of Bibliography on Weather Modification and Cloud Physics," GN-75, 11/30/62, 3 yrs.

22,500 THE UNIVERSITY OF CALIFORNIA/Berkeley, "Compilation of Volume VII of the World Bibliography of Fossil Vertebrates and Paleolithic Anthropology," G-7615.1, 9/27/62, 23 mos.

8,500 UNIVERSITY OF CALIFORNIA/Berkeley, "Publication of an Index Catalogue of Double Stars," GN-158, 6/15/63, 1 yr.

68,000 CORNELL UNIVERSITY, "Bibliography of Natural Radio Emission from Astronomical Sources," G-22414.2, 4/22/63 and G-22414.3, 6/29/63

20,000 BOYCE THOMPSON INSTITUTE FOR PLANT RESEARCH, INC., "Publication of the Bibliography of Seeds," GN-138, 5/25/63, 18 mos.

1,700 MACALESTER COLLEGE, "Preparation of an Annotated Bibliography on Tree Growth and Climate (1950-1962)," GN-32, 9/18/62, 6 mos.

15,500 NATIONAL FEDERATION OF SCIENCE ABSTRACTING AND INDEXING SERVICES, "Publication of a Bibliography of the World's Significant A&I Services of Scientific Interest," GN-9, 8/4/62, 1 yr.

$ 10,000 OPERATIONS RESEARCH SOCIETY OF AMERICA, "Preparation of an Annotated Bibliography on Operations Research, 1958-1960," G-13849.1, 7/23/62, 1 yr.

19,000 SEISMOLOGICAL SOCIETY OF AMERICA, "Study and Evaluation of Indexing Techniques in the Preparation and Publication of a Fifty-Two Year Cumulative Index to the Bulletin," GN-95, 1/29/63, 1 yr.

13,500 STANFORD UNIVERSITY, "Biennial Review of Anthropology," GN-96, 2/4/63, 5 yrs.

A&I Studies:

146,000 AMERICAN METEOROLOGICAL SOCIETY, "Study of the Universal Decimal Classification System for the Mechanical Indexing, Exchange, Publication or Retrieval of Titles of Scientific Articles," GN-50, 10/5/62, 2 yrs.

35,300 HERNER AND COMPANY, "Study of Modular Abstracts and Index Entries," C-329, 6/28/63, 18 mos.

132,250 INSTITUTE FOR SCIENTIFIC INFORMATION, INC., "Preparation of a General Citation Index and Selection of Genetics Portion," C-201.1, 3/14/63, 6 mos.

120,000 INSTITUTE FOR SCIENTIFIC INFORMATION, INC., "Study of the Article-by-Article Coverage of Selected Abstracting Services," C-332, 6/30/63, 6 mos.

9,000 INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS, "Continued Partial Support of the International Abstracting Board," GN-97, 1/29/63, 1 yr.

18,400 SCIENCE COMMUNICATION, INC., "User Survey of the Genetics Citation Index," C-330, 6/28/63, 1 yr.

Other Publications and Services

Research Journals:

$ 10,8[illegible] AMERICAN GENETIC ASSOCIATION, "Partial Support for the Journal of Heredity," GN-71, 11/30/62, 1 yr.

36,7[illegible] AMERICAN GEOPHYSICAL UNION, "Partial Support of the Establishment of Reviews of Geophysics," GN-65, 11/14/62, 3 yrs.

61,385 AMERICAN INSTITUTE OF PHYSICS, "Applied Physics Letters," G-24272.1, 9/25/62, 2 yrs.

52,000 AMERICAN ROCKET SOCIETY, "Partial Publication Support for the American Rocket Society Journal," G-25047.1, 7/23/62, 18 mos.

8,740 AMERICAN SOCIETY OF LUBRICATION ENGINEERS, "Temporary Support for the Journal, ASLE Transactions," GN-45, 1/22/63, 1 yr.

16,500 ASSOCIATION FOR APPLIED SOLAR ENERGY, "Solar Energy: The Journal of Solar Energy and Engineering," GN-20, 8/24/62, 3 yrs.

5,700 THE GLACIOLOGY SOCIETY, "Partial Support of the Journal of Glaciology," G-21111.1, 3/4/63, 1 yr.

12,100 UNIVERSITY OF LOUISVILLE, "Computers in Behavioral Science," GN-139, 6/15/63, 3 yrs.

Monographs:

$ 12,650 AMERICAN CRYSTALLOGRAPHIC ASSOCIATION, "Publication of the Second Edition of Crystal Data," G-2393.2, 11/15/62, 1 yr.

17,290 AMERICAN GEOGRAPHICAL SOCIETY, "Support for the Publication of A History of Scientific Geographical Exploration of the Pacific Basin," GN-110, 4/4/63, 1 yr.

11,615 AMERICAN GEOPHYSICAL UNION, "Support for Preparation and Publication of a Report on U. S. Geophysics for the 13th General Assembly of the International Union of Geodesy and Geophysics," GN-40, 9/24/62, 1 yr.

57,800 AMERICAN GEOPHYSICAL UNION, "Publication of a Series of Antarctic Monographs," GN-55, 10/10/62, 5 yrs.

2,355 AMERICAN MUSEUM OF NATURAL HISTORY, "The Miocene Faunas from Wounded Knee, South Dakota," GN-68, 11/9/62, 1 yr.

15,000 ANNUAL REVIEWS, INC., "Partial Support for the Annual Review of Phytopathology," G-25017, 7/23/62, 3 yrs.

4,200 ARCTIC INSTITUTE OF NORTH AMERICA, "Support to Publish Four Papers on Biological Investigations in the Keewatin District and the Ungava Peninsula," GN-113, 4/1/63, 1 yr.

11,140 BERNICE P. BISHOP MUSEUM, "Partial Publication Support for Insects of Micronesia Series," GN-160, 6/15/63

4,624 BIOGEOGRAPHICAL SOCIETY OF JAPAN, "Partial Publication Support of Volumes IV (Rajidae) and V (Tabanidae) of Fauna Japonica," GN-49, 11/3/62, 1 yr.

9,100 BROWN UNIVERSITY, "Publication of Egyptian Astronomical Texts: The Ramesside Star Clocks," GN-90, 3/18/63, 1 yr.

22,000 UNIVERSITY OF CALIFORNIA/Berkeley, "Support for Publication of the Scientific Results of the NAGA Expedition to the Gulf of Thailand and South China Sea, 1959-61," GN-38, 9/25/62, 2 yrs.

6,570 CENTRAL INSTITUTE FOR THE DEAF, "Publication of an English Translation of a Russian Monograph, Corti's Organ," GN-178, 6/29/63, 1 yr.

6,000 CHICAGO NATURAL HISTORY MUSEUM, "Illustrations for a Monograph, The Giant Panda," GN-116, 6/25/63, 1 yr.

33,478 UNIVERSITY OF CONNECTICUT, "Completion and Publication of a World Catalogue of the Family Lygaeidae," G-24122, 7/10/62, 15 mos.

9,840 DUQUESNE UNIVERSITY, "Partial Publication Support for the English Translation of The Field of Consciousness by Aron Gurwitsch," GN-168, 6/26/63, 1 yr.

2,911 HARVARD UNIVERSITY, "The Fern Flora of Peru," G-15949.1, 6/29/63, 1 yr.

6,960 UNIVERSITY OF HAWAII, "Publication of an Atlas of Charts for EQUAPAC," GN-171, 6/24/63, 1 yr.

23,875 UNIVERSITY OF HAWAII PRESS, "Publication of Volumes XI and XII of Insects of Hawaii," GN-36, 9/24/62, 2 yrs.

12,500 HUMAN RELATIONS AREA FILES, "Publication of an Outline and Atlas, Ethnic Groups of Mainland Southeast Asia," GN-157, 6/15/63, 4 mos.

1,500 INDIANA UNIVERSITY FOUNDATION, "Partial Support of Publication of

	Peoples of Central Asia," GN-106, 3/7/63, 1 yr.
1,610	INDIANA UNIVERSITY FOUNDATION, "Aspects of Altaic Civilization," GN-118, 5/25/63, 1 yr.
$ 31,600	THE NEW YORK BOTANICAL GARDEN, "Support of Publication of an Atlas of North American Astragalus," GN-166, 6/24/63, 1 yr.
3,700	THE NEW YORK BOTANICAL GARDEN, "Publication of Monographic Studies in Cassia," GN-165, 6/24/63, 1 yr.
49,250	NORTH CAROLINA STATE COLLEGE OF AGRICULTURE AND ENGINEERING OF THE UNIV. OF NO. CAR., Raleigh, "Continuation of the Publication of The Catalogue of the Homoptera Auchenorhyncha of the World," GN-85, 2/4/63, 2 yrs.
4,000	UNIVERSITY OF NOTRE DAME, "Partial Publication Support for a Group of Essays Entitled The Concept of Matter," GN-35, 9/25/62, 1 yr.
775	PALEONTOLOGICAL RESEARCH INSTITUTION, "Partial Support of a Publication Entitled Eocene and Miocene Foraminifera from Two Localities in Duplin County, North Carolina," GN-128, 5/24/63, 1 yr.
30,100	UNIVERSITY OF PENNSYLVANIA, "Support of Publication of A Selected Guide to the Literature on the Flowering Plants of Mexico," GN-[illegible], 9/25/62, 1 yr.
11,025	UNIVERSITY OF PENNSYLVANIA, "Support for the Publication of the Monograph, The Woody Flora of Taiwan," GN-53, 10/5/62, 1 yr.
800	UNIVERSITY OF PENNSYLVANIA, "Support for the Compilation and Publication of a Fourth Edition of A Finding List for Observers of Eclipsing Variables," G-23674.1, 5/6/63, 6 mos.
9,660	THE PENNSYLVANIA STATE UNIVERSITY, "Naturalistic Behavior of Non-Human Primates," GN-135, 5/25/63, 1 yr.
40,200	SMITHSONIAN INSTITUTION, "Support of Publication of an English Translation of Flora of Japan, by Jisaburo Ohwi," GN-70, 12/14/62, 1 yr.
10,350	STANFORD UNIVERSITY, "Partial Support for the Publication of Studies in Mathematical Psychology," GN-94, 1/29/63, 3 yrs.
19,378	STANFORD UNIVERSITY PRESS, "Support of a Publication Entitled Manual of the Vascular Plants of Alaska and Neighboring Territory," GN-127, 5/24/63, 18 mos.
13,225	STANFORD UNIVERSITY PRESS, "A Publication Entitled Vegetation and Flora of the Sonoran Desert," GN-129, 6/15/63, 1 yr.
23,036	THE UNIVERSITY OF TEXAS, "Editorial Preparation for the Publication, The Bird Life of Texas," GN-80, 12/14/62, 2 yrs.
200	WILSON, Dr. F. Douglas (individual), "Publication in the Journal Brittonia, of a Taxonomic Revision of the Genus Sitanion," GN-39, 9/25/62, 6 mos.
7,570	UNIVERSITY OF WISCONSIN, "Support for the Publication of a Bilingual Report of Gravity Standardization Measurements in Central and South America," GN-169, 6/24/63, 1 yr.
575	YAMAGUCHI UNIVERSITY, "Publication Support for the Fifth Volume (Hylesininae) of Scolytidae of the Northern Half of the Far East," GN-76, 12/15/62, 1 yr.
	Conference Proceedings:
16,990	AMERICAN INSTITUTE OF BIOLOGICAL SCIENCES, "Publication of the Proceedings of the Second Conference on Brain and Behavior," GN-8, 8/4/62, 1 yr.
4,600	AMERICAN INSTITUTE OF PHYSICS, "Travel of Foreign Participants to the Gordon Research Conference on Scientific Information Problems in Research," GN-103, 2/28/63, 1 yr.
$ 10,070	FEDERATION OF AMERICAN SOCIETIES FOR EXPERIMENTAL BIOLOGY, "Support for Publication of Abstracts and Proceedings of the International Symposium on Temperature Acclimation," GN-6, 8/4/62, 1 yr.
2,320	FORT BURGWIN RESEARCH CENTER, "Publication of the Proceedings of the Fort Burgwin Conference on Paleoecology," GN-117, 5/24/63, 6 mos.
4,600	HARVARD UNIVERSITY, "Partial Publication Support for the Proceedings of the Conference on Crustacea," GN-144, 6/15/63, 1 yr.
11,000	MINERALOGICAL SOCIETY OF AMERICA, "Publication of the Proceedings of the Third General Meeting of the International Mineralogical Association," G-25108, 7/23/62, 1 yr.
2,000	UNIVERSITY OF PITTSBURGH, "Publication of the Proceedings of the Benedum Symposium on Earth Magnetism," GN-89, 3/18/63, 1 yr.
	Studies, Experiments, and Other Special Projects:
3,700	ACTA METALLURGICA, "Study of the Optimum Method of Publication of the Translations of the Russian Journal of Abstracts-Metallurgy," G-25203, 7/12/62, 3 mos.

5,500 AMERICAN ANTHROPOLOGICAL ASSOCIATION, "A Study of Publishing Needs in the Field of Anthropology," GN-64, 11/2/62, 1 yr.

60,8[illegible] AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, "Partial Support of a Project to Develop the Use of Broadcast Television for Communication Among Scientists and Engineers," GN-25, 9/25/62, 1 yr.

[illegible] AMERICAN CHEMICAL SOCIETY, "Analysis of the Role of the Computer in Scientific Publications," GN-140, 6/15/63, 2 yrs.

7,200 AMERICAN MATHEMATICAL SOCIETY, "Support for a Study of Ways to Develop Additional Means of Support for Mathematical Publications," GN-102, 3/4/63, 18 mos.

45,700 BIOLOGICAL ABSTRACTS, INC., "Experiment in Pre-Packaging of Biological Research Information," GN-175, 6/24/63, [illegible] yrs.

3,900 BUREAU OF SOCIAL SCIENCE RESEARCH, INC., "Survey of Scientific Societies," C-324, 6/30/63, 6 mos.

500 CASE INSTITUTE OF TECHNOLOGY, "Operations Research Study of Publication Costs of Scientific Journals," G-16453.1, 2/28/63, 6 mos.

7,41[illegible] HERNER AND COMPANY, "Inventory of Currently-Published English-Language Scientific Newspapers," C-285, 8/3/62, 1 yr.

9,852 HERNER AND COMPANY, "Survey of Professional Scientific Journals," C-325, 6/28/63, 18 mos.

59,000 INTERNATIONAL JOURNAL OF THE SCIENCE OF METALS, INC., "Translation and Publication of the 1963 Issues of the Journal of Abstracts – Metallurgy, Parts A and B," GN-172, 6/29/63, 1 yr.

200 LIBRARY OF CONGRESS, "25-hr. Bibliographic Search Service for Surveys and Studies Published Since 1950 that Relate to Various Aspects of Publishing Scientific and Technical Journals," P.O. 63-522, 12/3/62

59,000 NATIONAL FEDERATION OF SCIENCE ABSTRACTING AND INDEXING SERVICES, "Partial Support of the Federation Secretariat for Fiscal Year 1963," GN-42, 10/2/62, 1 yr.

PROGRAM/ACTIVITY SUMMARY
SCIENCE INFORMATION ACTIVITIES
FISCAL YEAR 1964

RESEARCH AND STUDIES

Communication Patterns

$ 3,300	AMERICAN PSYCHOLOGICAL ASSOCIATION, "Coordinated Study of Information Exchange in Psychology," G-18494.2, 11/20/63
302,600	AMERICAN PSYCHOLOGICAL ASSOCIATION, "Coordinated Study of Information Exchange in Psychology," GN-281, 2 yrs., 5/12/64
15,100	AMERICAN INSTITUTE OF PHYSICS, "Completion and Evaluation of Citation Index to Russian Journals," GN-221, 9 mos., 12/11/63
198,000	AMERICAN INSTITUTE OF PHYSICS, "Study of Dissemination of Information in Physics," GN-291, 24 mos., 5/26/64
54,000	COLUMBIA UNIVERSITY, "Information Requirements of Scientists," GN-185, 18 mos., 8/23/63
48,700	HARVARD UNIVERSITY, "Studies of the Flow of Technical Information and Its Role in Research and Development Decision-Making," GN-305, 12 mos., 6/8/64
12,100	LIPETZ, Ben-Ami (individual), "Literature Survey for Identification and Organization of Case Studies of Scientific Activity," GN-167, 4 mos., 8/2/63
44,200	MASS. INST. OF TECH., "The Role of Information in Parallel R&D Projects," GN-233, 12 mos., 12/16/63
47,700	UNIV. OF PA., "The Norms of Citation Behavior," GN-294, 18 mos., 5/20/64
46,300	YALE UNIV., "Statistical Studies of Networks of Scientific Papers," GN-299, 24 mos., 6/8/64

Information Sources and Services

$ 48,500	NATIONAL ACADEMY OF SCIENCES/NATIONAL RESEARCH COUNCIL, "A Study of Scientific Publications in the Geological Sciences," C-310/Task 71, 12 mos., 12/28/63
2,46[illegible]	HERNER AND CO., For Statistical and Analytical Services to be Performed in Connection with a Two-Month Survey of the Scientific Review Literature," P.O. 64-510, 12/30/63
5,[illegible]	HERNER AND CO., "For services to be performed in assisting in the preparation of an indexed bibliography of references to all reports and publications cited in *Current Research and Development in Scientific Documentation*, Issues No. 1 thru 11," P.O. 63-8[illegible]1, 6/22/64
1,680	HERNER AND CO., "A Survey of Professional Scientific Journals," C-325.1 dtd [illegible]/9/[illegible] plus Amd. 2 dtd 6/30/64
400	HERNER AND CO., "Revising Data Tables Related to the Above Project," P.O. 64-[illegible], 1/9/64
7,733	HERNER AND CO., "A Study of the Character and Degree of Use of the AIChE *Chemical Engineering Thesaurus* and the Index Data Provided for Articles in *Chemical Engineering Progress*," C-29[illegible].2, 9/11/63

Organization and Searching

$ 19,400	ASSOCIATION OF SPECIAL LIBRARIES AND INFORMATION BUREAUX, "An Investigation Into the Performance Characteristics of Indexing Techniques," G23130.1 for 1 yr., 6/9/64
24,450	THE UNIVERSITY OF CHICAGO, "The Application of Selected Indexing Systems to a Common Sample of Scientific Documents," GN-231, 1 yr., 11/20/63
100,000	COMMERCE DEPT./NATIONAL BUREAU OF STANDARDS, "Research Information Center and Advisory Service on Information Processing," GN-317, 12 mos., 6/29/64
9,100	DANISH CENTER FOR DOCUMENTATION, "International Study Conference on Classification Research 1964," GN-249, 3/24/64, 1 yr.
36,700	HARVARD UNIVERSITY, "Research on and Evaluation of Some Models for Automatic Document Retrieval Systems," GN-245, 1/13/64, 12 mos.
19,500	LEHIGH UNIVERSITY, "Study of Theories and Models of Information Storage and Retrieval," GN-283, 15 mos., 6/8/64
159,000	MASS. INST. OF TECHNOLOGY, "Development of a Test Environment for Information Systems," GN-292, 24 mos., 5/25/64
50,000	PRINCETON UNIV., "Experimentation with a Citation Index for Statistical Methodology," 24 mos., GN-297, 6/8/64
30,500	RUTGERS UNIV., "Seminars on Systems for the Organization of Information," GN-300, 24 mos., 6/4/64
9,000	SCIENCE COMMUNICATION, INC., "User Survey of Genetics Citation Index," C-330.1, 1/6/64
74,000	WESTERN RESERVE UNIV., "Automatic Processing of Metallurgical Abstracts for the Purpose of Information Retrieval," GN-303, 12 mos., 6/8/64

INFORMATION SYSTEMS

Information Retrieval

$ 4,500	ARTHUR D. LITTLE, INC., Support to furnish 500 add'l copies of a report entitled "Centralization and Documentation," Purchase Order 64-748, 4/17/64.
18,000	AUERBACH CORPORATION, "Study of Information Storage and Retrieval Hardware," C335, 4 mos., 6/20/63
7,200	AUERBACH CORPORATION, "Study of Information Storage and Retrieval Hardware," C335.2, 3 add'l mos., 2/22/64
102,000	CHEMICAL ABSTRACTS SERVICE, "Development and Initiation of a Mechanized File of Chemical Information," G22928.3, 3 mos., 3/24/64
288,000	CHEMICAL ABSTRACTS SERVICE, "Development of a Computer-Centered Chemical Information Service," GN-318, 7 mos., 6/30/64
58,200	COMMERCE DEPT./NATIONAL BUREAU OF STANDARDS, "Research on Picture and Language Processing," GN-320, 12 mos., 6/29/64
6,000	INFORMATION DYNAMICS CORPORATION, "Synthesis and Analysis of Scientific Information Service Networks," C263.2, add'l 1½ mos., 12/2/63
114,400	INFORMATION DYNAMICS CORPORATION, "Development and Test of Information System Model," C370, 10 mos., 6/12/64
13,400	NAS/NRC, "Conference on Mechanical Processing of Chemical Information," C-310/Task 77, 6 mos., 2/21/64
414,000	UNIVERSITY OF PENNSYLVANIA, "Research on Linguistic Transformations for Information Retrieval," GN-311, 24 mos., 6/11/64
10,220	HOUSTON RESEARCH INSTITUTE, "A Study of Facsimile Transmission in Technical Information Networks," C356 to Prengle, Dukler & Crump, Inc. (name changed 1/29/65), 6 mos., 6/22/64

Mechanical Translation

$240,000	BUNKER-RAMO CORPORATION, "Computer-Aided Research in Mechanical Translation," C372, 18 mos., 6/30/64
167,300	Univ. OF CALIF., "Research on Machine Translation and Related Mechanolinguistic Systems," GN-306, 12 mos., 6/8/64
240,500	HARVARD UNIV., "Research on Automatic Translation and Mathematical Linguistics," GN-329, 18 mos., 6/25/64
200,000	MASS. INST. OF TECH., "Basic Research on Language Problems in Mechanical Translation," GN-244, 15 mos., 1/22/64
59,000	NAS/NRC, "Advisory Committee on Automatic Language Processing," C-310/Task 80, 12 mos., 4/24/64
150,000	UNIV. OF TEXAS, "Research on Syntactic and Semantic Analysis," GN-208, 1 yr., 10/24/63
168,200	UNIV. OF TEXAS, "Research on Syntactic and Semantic Analysis for Mechanical Translation," GN-308, 12 mos., 6/18/64

Library Systems

$ 48,900	UNIV. OF ILLINOIS, "Programming, Testing, and Evaluation of a Computerized and Integrated Data Processing System for University Library Procedures," GN-302, 12 mos., 6/25/64
62,500	THE JOHNS HOPKINS UNIV., "Continued Support of An Operations Research and Systems Engineering Study of a University Library," GN-219, 1 yr., 10/24/63
61,755	YALE UNIVERSITY, "Studies, Experiments, and Demonstration of the Computerization of Card Catalogues in Medical and Scientific Libraries," GN-179, 2 yrs., 8/2/63

Publication Systems

$ 20,074	INFORONICS, INC., "Machine Recording of Textual Information During the Publication of Scientific Journals," C371, 12 mos., 6/26/64

PUBLICATIONS SUPPORT

Abstracting and Indexing

$225,400	AMERICAN MATHEMATICAL SOC., "Preparation and Publication of Mathematical Reviews," GN-323, 2 yrs., 6/30/64
178,000	AMERICAN METEOROLOGICAL SOC., "Expansion of Meteorological and Geoastrophysical Abstracts," GN-181, 1 yr., 8/2/63
100,000	AMERICAN METEOROLOGICAL SOC., "Emergency Support of Meteorological and Geoastrophysical Abstracts," GN-316, 1 yr., 6/29/64
144,000	AM. SOC. OF MECHANICAL ENGINEERS, "Preparation and Publication of Applied Mechanics Reviews," GN-298, 3 yrs., 6/8/64
134,400	AM. SOC. FOR METALS, "Information Searching Service of the American Society for Metals," GN-263, 1 yr., 4/28/64
33,800	BIOLOGICAL ABSTRACTS, INC., "Development Program Leading to Mechanization of Serial and Abstracter Records," GN-325, 1 yr., 6/29/64
44,000	ENGINEERS JOINT COUNCIL, "Preparation of a Thesaurus of Engineering Terms," GN-234, 9 mos., 12/2/63
16,000	COUNCIL FOR OLD WORLD ARCHAEOLOGY, "Cont'd Partial Support for Preparation and Publication of COWA Surveys and Bibliographies," GN-239, 1 yr., 12/23/63
20,000	SAME GRANTEE, and title as above, GN-239.1 (add'l funds), 6/29/64
41,350	HISTORY OF SCIENCE SOCIETY, INC., "Cumulative Indexes and Preparation of Five Annual Bibliographic Sections of ISIS," GN-272, 5 yrs., 5/1/64
20,500	UNIV. OF KANSAS, "Preparation and Publication of an International Bibliography of Vegetation Maps," GN-186, 5 yrs., 8/14/63
170,500	THE MODERN LANGUAGE ASSOC., "Expansion and Improvement of the Linguistic Bibliography," GN-180, 3 yrs., 8/2/63

Publications (Other Than A&I)

Research Journals:

$38,650	AM. GEOPHYSICAL UNION, "Cont'd support for the IG Bulletin, and Support for Planning the Format of a New Geophysics Journal," GN-191, 1 yr., 9/4/63
2,740	AM. GEOPHYSICAL UNION, "Support of the IG Bulletin," G25052.1, 10/24/63 (add'l funds)
30,000	AM. GEOPHYSICAL UNION, "Preparation and Publication of IG Bulletin," GN-322, 9 mos., 6/26/64
$ 23,652	AM. INSTITUTE OF PHYSICS, "Publication support for Applied Optics," G20086.1 (add'l funds), 6/30/64
52,000	ASSOCIATION FOR SYMBOLIC LOGIC, "Preparation and Processing of Accumulated Review Materials for Publication in Journal of Symbolic Logic," GN-280, 3 yrs., 5/28/64
17,000	UNIV. OC CHICAGO, "Journal of Geology," GN-319, 1 yr., 6/29/64
2,200	THE GLACIOLOGICAL SOCIETY, "Partial Support of the Journal of Glaciology," G21111.2 (add'l funds), 6/25/64
16,790	YALE UNIV., "Partial Publication Support for the American Journal of Science," GN-225, 1 yr., 12/23/63

Monographs:

49,000	AMERICAN GEOGRAPHICAL SOCIETY, "Continued Support and Publication of Serial Atlas of the Marine Environment," GN-296, 6/4/64, 12 mos.
22,200	AMERICAN MUSEUM OF NATURAL HISTORY, "Support of Publication of Modes of Reproduction in Fishes," GN-304, 1 yr., 6/8/64
6,100	UNIVERSITY OF CALIF./Berkeley, "Oceanic Observations of the Pacific," G-15841.1, 3/27/64
6,775	UNIV. OF CALIF. PRESS, "Support for Publication of Cloud Structure and Distributions over the Tropical Pacific Ocean," GN-202, 1 yr., 10/23/63
6,500	CARNEGIE MUSEUM, "Partial Publication Support for Lepidoptera of Liberia," GN-229, 1 yr., 11/12/63
4,900	UNIV. OF CONNECTICUT, "Support for Completion and Publication of a World Catalogue of the Family Lygaeidae," G-24122.1, 12/4/63
4,630	HARVARD UNIVERSITY, "Support for the Publication of Mammal Remains from Archaeological Sites, Part I, Southeastern and Southwestern U.S.," GN-254, 1 yr., 2/27/64

980 INDIANA UNIVERSITY FOUNDATION, "Partial Support of Publication of Constituent Structure: A Study of Contemporary Models of Syntactic Description," GN240, 1/10/64, 1 yr.

12,200 INDIANA UNIVERSITY FOUNDATION, "Preparation and Publication of Volume III of Current Trends in Linguistics, subtitled Theoretical Foundations," GN-313, 2 yrs., 6/18/64

6,400 THE NEW YORK BOTANICAL GARDEN, "Publication of The Hepaticae and Anthocerotae of North America," G-21066.1, 12/16/63

12,700 THE NEW YORK BOTANICAL GARDEN, "Support for Publication of Two Issues of North American Flora," GN-327, 1 yr., 6/25/64

1,150 OHIO STATE UNIVERSITY RESEARCH FOUNDATION, "Partial Support of Publication of Acoustical Characteristics of Selected English Consonants," GN-241, 1 yr., 1/10/64

1,840 UNIVERSITY OF PITTSBURGH, "Partial Publication Support for The Development of Arabic Logic," GN-237, 1 yr., 12/2/63

1,970 UNIVERSITY OF RHODE ISLAND, "Publication of the Monograph, A Manual and Revision of Characeae," G-23136.1, 5/8/64

1,725 UNIVERSITY OF WASHINGTON, "Partial Support of Publication of Migration and the Spread and Growth of Urban Settlement," GN-243, 1 yr., 12/24/63

$ 1,460 YALE UNIVERSITY, "Support of Publication of A Systematic and Ecological Study of Birds of New Guinea," GN-223, 1 yr., 10/23/63

2,620 YALE UNIVERSITY, "Partial Support of Publication of A Systematic Study of the Demospongiae of Port Royal, Jamaica," GN-257, 1 yr., 3/9/64

Conference Proceedings:

14,660 AMERICAN DOCUMENTATION INSTITUTE, "Support of the Preparation and Publication of Papers for the October 1963 ADI Annual Meeting," GN-216, 6 mos., 10/4/63

5,900 UNIV. OF CALIF. PRESS, "Partial Support for the Publication of Ecology of Soil-Borne Plant Pathogens," GN-261, 1 yr., 3/19/64

25,000 THE COMBUSTION INSTITUTE, "Publication of the Tenth Symposium on Combustion," GN-260, 6/3/64

3,000 THE NEW YORK ACADEMY OF SCIENCES, "Support for Publication of Proceedings of First Conference on Learning, Remembering and Forgetting," GN-309, 1 yr., 6/30/64

10,350 RUTGERS, THE STATE UNIVERSITY, "Publication of Proceedings of a Symposium on Bacterial Endotoxins to be held at the Institute of Microbiology, Sept. 4-6, 1963," GN-207, 1 yr., 10/3/63

2,360 TORREY BOTANICAL CLUB, "Support for the Publication of the Symposium, Origin and Evolution of Ferns," GN-259, 1 yr., 3/13/64

7,300 THE WISTAR INSTITUTE, "Support for Publication of Symposium Proceedings, Retention of Functional Differentiation in Cultured Cells," GN-328, 1 yr., 6/29/64

Other Special Projects:

$28,483 COMMERCE DEPT./OTS, "Operational Functions of the PL 480 Translations Program," GN-235, 12 mos., 12/27/63

48,000 COMMERCE DEPT./OTS, "Cont'd Support for the Operational Functions of NSF's Special Foreign Currency Sci. Info. Program, During FY 1965," GN-321, 12 mos., 6/29/64

7,500 COMMERCE DEPT./OTS, "Expenses for Handling Subscriptions of AIBS Journals," Direct Charge, 5/26/64

34,300 INTERNATIONAL COMMITTEE FOR SOCIAL SCIENCES DOCUMENTATION (ICSSD), "Four Surveys of Research on Interdisciplinary Problems Within Social Sciences," GN-295, 36 mos., 6/30/64

1,915 NATIONAL DIET LIBRARY OF JAPAN, "Compilation and Printing of the English Version of the Japanese Periodicals Index, Natural Science Section," GN-15.1, add'l funds, 10/24/63

20,320 Same grantee and project title as above, GN-226, 1 yr., 10/31/63

Translations

Domestic/Slavic:

$ 24,303 AMERICAN GEOGRAPHICAL SOCIETY, "Production of an English Edition of Soviet Geography: Review and Translation, Calendar Year 1964," GN-251, 18 mos., 2/28/64

69,340 AMERICAN GEOLOGICAL INSTITUTE, "Translation, Publication and Distribution of the 1962 and 1963 Issues of the Russian Journal, Doklady—Earth Sciences Sections," GN-190, 2 yrs., 9/9/63

135,094	AMERICAN GEOLOGICAL INSTITUTE, "Production of International Geology Review, Vol. VI, 1964," GN253, 18 mos., 3/19/64
41,600	AMERICAN GEOLOGICAL INSTITUTE, "Production of English Edition, Russian Vols. 154-159 (1964), Doklady--Earth Science Sections," GN-284, 18 mos., 5/8/64
4,400	AMERICAN GEOPHYSICAL UNION, "Translation and Publication of the 1961, and One-Half of the 1962 Issues of the Russian Bimonthly Geomagnetism and Aeronomy," G-24438.1, 10/23/63
44,504	AMERICAN GEOPHYSICAL UNION, "Production of an English Edition of Izvestiya, Academy of Sciences, USSR, Geophysics Series, 1964 Volume," GN-250, 18 mos., 3/9/64
38,500	AMERICAN GEOPHYSICAL UNION, "Production of the English Edition of the Information Bulletin of the Soviet Antarctic Expedition, Nos. 31-52 (1961-1965)," GN-258, 24 mos., 3/19/64
38,750	AMERICAN GEOPHYSICAL UNION, "Production of an English Edition of the Bimonthly Journal of Geomagnetism and Aeronomy, USSR, Vol. 1964," GN-265, 18 mos., 3/24/64
26,775	AMERICAN GEOPHYSICAL UNION, "Production of an English Edition of the 1964 Issues of Russian Journal, Geodesy and Aerophotography," GN-264, 18 mos., 4/2/64
19,476	AMERICAN GEOPHYSICAL UNION, "Production in English, Soviet Oceanography, Including Oceanology Sections of Doklady and Trudy of the Marine Hydrophysical Institute, 1964," GN-266, 18 mos., 4/2/64
21,400	AMERICAN GEOPHYSICAL UNION, "Production in English of Soviet Hydrology: Selected Papers, Russian Literature for 1964," GN-275, 18 mos., 4/28/64
5,100	AMERICAN GEPHYSICAL UNION, "Translation and Publication of Vol. 2, Nos. 4-6, 1962, and Vol. 3, Nos. 1-6, 1963, of the Journal Geomagnetism and Aeronomy, USSR," GN-108.1, 5/25/64
72,238	AMERICAN INSTITUTE OF CHEMICAL ENGINEERS, "Translation, Publication and Distribution of an International Chemical Engineering Journal," GN-227, 1 yr., 1/24/64
64,681	AMERICAN INSTITUTE OF PHYSICS, "Production of English Editions, 1964 Issues, Five Russian Journals: Technical Physics; Solid State Physics; Astronomy; Acoustics; and Crystallography," GN-286, 18 mos., 6/26/64
44,227	AMERICAN MATHEMATICAL SOCIETY, "Translation, Publication and Distribution of Volume IV, 1963 Issues of the Russian Journal, Soviet Mathematics--Doklady," GN-194, 1 yr., 8/27/63
64,057	AMERICAN MATHEMATICAL SOCIETY, "Program for Selected Translations of Mathematical Research Articles from Russian and Other Languages," GN-232, 1 yr., 2/3/64
$ 40,684	AMERICAN MATHEMATICAL SOCIETY, "Production of an English Edition, Vol. V, 1964, Soviet Mathematics - Doklady," GN-269, 18 mos., 4/15/64
22,575	AMERICAN MATHEMATICAL SOCIETY, "Production of English Editions, Vols. XII and XIII (1963), Works of the Moscow Mathematical Society," GN-279, 18 mos., 5/14/64
6,787	AMERICAN MATHEMATICAL SOCIETY, "Program for Selected Translations of Mathematical Research Articles from Russian and Other Languages," GN-232.1, 6/22/64
29,700	AMERICAN SOCIETY OF MECHANICAL ENGINEERS, "Translation and Publication of Vol. 27, 1963 Journal of Applied Mathematics and Mechanics," GN-187, 1 yr., 8/27/63
3,549	AMERICAN SOCIETY OF MECHANICAL ENGINEERS, "Publication of English Edition, Vol. 17, Russian Serial, Friction and Wear in Machinery," GN-287, 14 mos., 5/19/64
32,660	ARCTIC INSTITUTE OF NORTH AMERICA, "Translation and Publication of Anthropology of the North: Translations from Russian Sources, No. 5," GN-212, 1 yr., 10/15/63
6,500	COMMERCE DEPT./Weather Bureau, "Editorial and Abstracting Services, AGU's Project for Production in English, Soviet Hydrology: Selected Papers, Russian Literature for 1964," GN-276, 18 mos., 4/28/64
6,000	CONSULTANTS BUREAU ENTERPRISES, INC.,"Translation, Editing, Composition, Printing, and Circulation of the Calendar Year 1963 Issues of the Russian Scientific Journals: Doklady (Biological Sciences Section, Biochemistry Section, and Botanical Sciences Section); Microbiology; and Soviet Plant Physiology," C-327.1, 6/26/64
26,000	ENTOMOLOGICAL SOCIETY OF AMERICA, "Translation, Publication and Distribution of the 1964 Issues, Russian Journal, Entomological Review," GN-242, 18 mos., 1/22/64
29,445	GEOCHEMICAL SOCIETY, "Translation, Publication and Distribution of the 1963 Issues of the Russian Journal of Geochemistry," GN-188, 1 yr., 8/14/63

42,000 GEOCHEMICAL SOCIETY, "Production of an English Edition (1964) of a Journal: Geochemistry International," GN-295, 12 mos., 6/30/64

117,530 INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC., "Translation, Publication and Distribution of the 1963 Issues of Three Russian Journals: Radio Engineering and Electronic Physics; Radio Engineering; and Telecommunications," GN-203, 1 yr., 9/4/63

25,555 INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC., "Translation, Publication and Distribution of the 1963 Issues of a Russian Journal of Power and Automatic Control," GN-204, 1 yr., 9/6/63

31,218 INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC., "Publication and Distribution of an English Edition, 1964 Issues, Russian Journal: Engineering Cybernetics," GN-289, 14 mos., 5/19/64

101,773 INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC., "Translation and Production (1964 Issues) of Three Russian Journals under Two English Titles: Radio Engineering and Electronic Physics; and Telecommunications and Radio Engineering," GN-290, 12 mos., 6/26/64

$ 97,025 INSTRUMENT SOCIETY OF AMERICA, "Production of English Editions, 1964 Issues, Four Russian Journals: Automation and Remote Control; Measurement Techniques; Instruments and Experimental Techniques; and Industrial Laboratory," GN-288, 18 mos., 5/20/64

13,720 INTERNATIONAL JOURNAL OF THE SCIENCE OF METALS, INC., "Translation, Publication, and Distribution of the 1963 Issues of Four Russian Journals: Physics of Metals and Metallography; Metallurgist; Refractories; and Metal Science and Heat Treatment of Metals," GN-224, 1 yr., 11/20/63

22,000 INTERNATIONAL JOURNAL OF THE SCIENCE OF METALS, INC., "Production of English Editions (1964) of Three Russian Journals: Metallurgist; Metal Science and Heat Treatment of Metals; and Refractories," GN-315, 12 mos., 6/26/64

46,300 OPTICAL SOCIETY OF AMERICA, "Translation, Publication and Distribution of the 1963 Issues, Russian Journal of Optics and Spectroscopy," GN-189, 1 yr., 8/19/63

44,703 OPTICAL SOCIETY OF AMERICA, "Production of the 1964 Issues of Russian Journal of Optics and Spectroscopy," GN-262, 18 mos., 3/19/64

8,776 OPTICAL SOCIETY OF AMERICA, "Translation and Editing of the 1962 Issues of the Russian Journal Optics and Spectroscopy," G-20913.1, 6/30/64

19,965 SOCIETY FOR INDUSTRIAL AND APPLIED MATHEMATICS, "Translation, Publication and Distribution of Volume 8 (1963) of the Russian Journal, Theory of Probability and Its Applications," GN-206, 14 mos., 10/3/63

8,682 SOCIETY FOR INDUSTRIAL AND APPLIED MATHEMATICS, "Translation and Publication of Selected Articles on Control Theory in the Journal of the Society for Industrial and Applied Mathematics, Series A, Control," GN-271, 24 mos., 4/16/64

15,573 SOCIETY FOR INDUSTRIAL AND APPLIED MATHEMATICS, "Production of an English Edition, Vol. 9 (1964) Russian Journal, Theory of Probability and Its Applications," GN-278, 18 mos., 5/1/64

41,925 SOIL SCIENCE SOCIETY OF AMERICA, "Production of an English Edition, 1964 Issues Russian Journal, Soviet Soil Science," GN-270, 15 mos., 4/20/64

Domestic/Oriental:

21,927 AMERICAN MATHEMATICAL SOCIETY, "Translation, Publication and Distribution of the 1963 Issues of the Journal, Chinese Mathematics--Acta," GN-195, 1 yr., 8/27/63

22,701 AMERICAN MATHEMATICAL SOCIETY, "Production of an English Edition, 1964 Issues, Chinese Journal of Mathematics--Acta," GN-273, 18 mos., 4/16/64

100,600 INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC., "Production of English Editions, 1964 Issues, Two Japanese Journals: Electronics and Communications in Japan; and Electrical Engineering in Japan," GN-282, 18 mos., 5/25/64

Special Foreign Currency Translation Program

$ 550,000	ISRAEL	C-244.4, 1/29/64 and C-244.5, 2/17/64 @ $275,000 ea.
325,000	POLAND	C-250.5, 3/2/64
125,000	YUGOSLAVIA	C-251.5, 2/17/64

FEDERAL SCIENCE INFORMATION

Science Information Exchange

$240,000 SMITHSONIAN INSTITUTION, "Partial Support for the Annual Operating Expenses of the Science Information Exchange," 1 yr.; GN-201 with 4 amendments provided the total SIE budget of $1,500,000 which was funded on a multi-agency basis (NSF, $240,000; AEC, $100,000; DOD, $375,000; FAA, $25,000; HEW, $300,000; NASA, $395,000; and VA, $65,000)
$200,000, GN-201, 8/30/63
175,000, GN-201.1, 11/8/63
150,000, GN-201.2, 12/31/63
375,000, GN-201.3, 2/14/64
600,000, GN-201.4, 4/17/64

National Referral Center

$350,000 LIBRARY OF CONGRESS, "Support of the National Referral Center for Science and Technology," GN-218, 1 yr., 10/17/63 (NRC's fiscal year: 10/1/63 - 9/30/64)

397,900 LIBRARY OF CONGRESS, "Support of the National Referral Center for Science and Technology," GN-324, 1 yr. (10/1/64-9/30/65), 6/26/64

National Information Centers

$200,000 COMMERCE DEPT./NATIONAL BUREAU OF STANDARDS, "Partial Support During FY 1964 of a 'National Standard Reference Data System (NSRDS);" GN-217, 1 yr., 10/3/63

30,560 COMMERCE DEPT./OFFICE OF TECHNICAL SERVICES, "Keywords Index to U. S. Government Technical Reports," G24466.2, 3 mos., 11/22/63

258,000 transferred to LIBRARY OF CONGRESS for support of Russian Accessions (MIRA-Monthly Index of Russian Accessions) by NSF/JTWilson ltr. of 2/26/64

105,900 NAS/NRC, "Support of Office of Critical Tables," C310/Task 21, Amd. 2, 1 yr., 6/25/64

DOMESTIC AND FOREIGN SCIENCE INFORMATION

Domestic Science Information

$ 17,000	AMERICAN DOCUMENTATION INSTITUTE, "The Continued Growth and Expansion in Activities of the American Documentation Institute," GN-220, 12 mos., 12/2/63
40,205	AMERICAN LIBRARY ASSOCIATION, "To Support a Project, the AMERICAN REFERENCE CENTER," GN-197, 3 yrs., 8/27/63
6,000	BIOLOGICAL ABSTRACTS, INC., "UNESCO Working Party on Scientific Publications, September 16-21, 1963 and ICSU Abstracting Board, September 23-25, 1963," GN-198, 3 mos., 8/27/63 Partial
15,000	FEDERATION OF AMERICAN SOCIETIES FOR EXPERIMENTAL BIOLOGY, "Continued/ Support by NSF of the Office of Biological Handbooks," GN-255, 3/9/64
37,023	MIDWEST INTER-LIBRARY CENTER, "Continued Partial Support of Operation of the Scientific Journals Center," GN-236, 12 mos., 12/23/63
36,400	NATIONAL FEDERATION OF SCIENCE ABSTRACTING AND INDEXING SERVICES, "Partial Support of the Secretariat of NFSAIS," GN-314, 12 mos., 6/29/64
16,940	NEW YORK PUBLIC LIBRARY, "Support of the American Standards Association, Sectional Committee Z39," GN-228, 1 yr., 11/15/63
13,750	UNIVERSITY OF NOTRE DAME, "Participation of Ten European Biological Editors in the May, 1964, CBE Meeting," GN-184, 1 yr., 8/19/63
1,500	UNIVERSITY OF NOTRE DAME, "Participation of Biological Editors in the May 1964 CBE Meeting," Amd. #1 to GN-184.1, 2/24/64
13,838	SPECIAL LIBRARIES ASSOCIATION, "Support of a project, Special Loan Collection of Classification Schemes and Subject Heading Lists," GN-182, 12 mos., 8/2/63
50,113	SPECIAL LIBRARIES ASSOCIATION, " Continued Collateral Support of the Operation of the Translation Center," GN-213, 1 yr., 10/21/63
500	WITTEBORG AND WILLIAMS, INC., "Design of an Exhibit on Scientific and Technical Resources," P.O. 64-941, (Program Contract), 6/30/64

Foreign Science Information

$ 35,000	AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCES, "Partial Support of a Symposium on Japanese Science, to be held in Cleveland, Ohio, December 26-27, 1963," GN-196, 1 yr., 8/27/63
58,880	AMERICAN INSTITUTE OF PHYSICS, "Operation of the Information Center on International Physics Activities," GN-285, 2 yrs., 5/8/64
37,314	AMERICAN MATHEMATICAL SOCIETY, "To Provide Russian and Related Mathematical Literature for Abstracting and Research Libraries," GN-209, 18 mos., 10/3/63
8,844	ARTIC INSTITUTE OF NORTH AMERICA, "Survey of European Institutions Active in Artic Research," GN-256, 24 mos., 3/9/64
47,000	ARTHUR D. LITTLE, INC., "Preparation of a Directory of Research Institutes of Eastern Europe in the Biological and Physical Sciences," C-343, 1 yr., 11/1/63
15,788	BERNICE P. BISHOP MUSEUM, "Continued Support of the Operation of the Pacific Science Information Center," GN-215, 1 yr., 10/14/63
75,500	U. S. DEPT. OF COMMERCE/U. S. BUREAU OF THE CENSUS, "Preparation and Publication of A Bibliographic Survey of Social Science Literature Published in Communist Bloc and Other Difficult Languages," GN-192, 1 yr., 8/27/63
47,000	U. S. DEPT. OF COMMERCE/U. S. BUREAU OF THE CENSUS, "Preparation and Publication of A Bibliographic Survey on Social Science Literature Published in Communist Bloc and Other Difficult Languages," GN-274, 1 yr., 4/28/64
5,000	U. S. DEPT. OF COMMERCE/PATENT OFFICE, "Foreign Research Associates Program," Amd. #1 to GN-4.1, 2 mos., 10/17/63
11,500	U. S. DEPT. OF COMMERCE/PATENT OFFICE, "Foreign Research Associates Program," Amd. #2 to GN-4.2, 3 mos., 11/6/63
56,655	U. S. DEPT. OF COMMERCE/PATENT OFFICE, "Foreign Research Associates

Program," Amd. #3 to GN-4.3, 9 mos., 2/14/64

16,834 DOCUMENTATION, INC., "Obtaining, Evaluating and Abstracting the Serial Literature of Librarianship, Documentation and Information Technology Published in East European Countries," C-347, 18 mos., 11/5/63

10,350 INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS/ABSTRACTING BOARD, "Continued Partial Support of ICSU Abstracting Board," GN-326, 1 yr., 6/25/64

13,373 LIBRARY OF CONGRESS, "Partial Support for the Publication of Part I, World List of Future International Meetings," GN-205, 1-yr., 9/19/63

9,956 MASSACHUSETTS INSTITUTE OF TECHNOLOGY, "Acquisition and Compilation of A Current Union List of Communist Chinese Serials," Amd. #1 to GN-98.1, 12 mos., 2/27/64

12,242 MASSACHUSETTS INSTITUTE OF TECHNOLOGY, "Acquisition and Compilation of A Current Union List of Communist Chinese Serials," Amd. #2 to GN-98.2, 6 mos., 6/29/64

$4 '2,900 MASSACHUSETTS INSTITUTE OF TECHNOLOGY, "Study into the Dissemination of Scientific and Technical Information in the U.S.S.R.," Amd. #1 to GN-124.1, 6/17/64

85,670 NATIONAL ACADEMY OF SCIENCES/NATIONAL RESEARCH COUNCIL, "Continued Support of the Office of Documentation," C-310, Task Order #41.2, 2/6/64

3,389 NATIONAL FEDEFATION OF SCIENCE ABSTRACTING AND INDEXING SERVICES, "Acquisition of Mainland Chinese Journals," GN-277, 12 mos., 4/24/64

11,362 PRINCETON UNIVERSITY, "Preparation of A Guide to Soviet Sciences," Amd. #2 to G-17474.2, 12 mos., 3/13/64

12,650 UNION OF INTERNATIONAL ASSOCIATIONS, "Compilation and Publication of, 1) A Monthly Current List, and 2) An Annual Bibliography of International Conference Proceedings," GN-246, 12 mos., 2/27/64

DATA COLLECTION AND PUBLICATIONS

$ 120	BUREAU OF SOCIAL SCIENCE RESEARCH, INC., "Contract for Scientific Society Survey," Amd. #1 to C-324.1, 3/16/64
21,350	U. S. DEPT. OF COMMERCE/OFFICE OF TECHNICAL SERVICES, "Documentation Research Reports Center," GN-230, 1-yr., 11/15/63
45,360	DATATROL CORPORATION, "Study of Common Vocabulary Approaches for Government Scientific and Technical Information Systems," C-342, 3 mos., 9/13/63
5,336	DATATROL CORPORATION, "Consultation with COSATI Agencies in Connection with Staff Study of Common Vocabulary Approaches for Government Scientific and Technical Information Systems," C-369, 3 mos., 6/30/64
14,500	DATATROL CORPORATION, "Compilation of a Structured Composite Listing of the Indexing Vocabularies Currently Used by the Technical Information Systems of ASTIA, AEC, and NASA," Amd. #1 to C-295.1, 2 mos., 5/5/64
3,089	HERNER AND COMPANY, "For Services to be Performed in Assisting in the Preparation of Current Research and Development in Scientific Documentation, No. 13" P.O. #64-150, 8/6/63
28,770	HERNER AND COMPANY, "Survey and Study of Nonconventional Technical Information Systems," C-362, 9 mos., 6/17/64
5,350	MAZIA ENGINEERING, "Preparation for Publication of Current Research and Development in Scientific Documentation, No. 13," C-352, 5 mos., 2/27/64
12,881	SCRIPTA TECHNICA, INC., "A Series of Bulletins Describing the Scientific Information Activities of Federal Agencies," Amd. #3 to C-163.3, 6 mos., 8/27/63
9,700	SCRIPTA TECHNICA, INC., "A Series of Bulletins Describing the Scientific Information Activities of Federal Agencies," Amd. #5 to C-163.5, 6 mos., 6/22/64

PROGRAM/ACTIVITY SUMMARY
SCIENCE INFORMATION ACTIVITIES
FISCAL YEAR 1965

RESEARCH AND STUDIES

Communication Patterns

$ 30,600 COLUMBIA UNIVERSITY, "Synthesis of Research on the Flow and Use of Scientific and Technical Information," GN-392, 14 mos., 3/19/65
95,300 MASS. INST. OF TECH., "The Role of Information in Parallel R&D Projects," GN-353, 24 mos., 10/26/64
34,800 UNIV. OF PA., "A Behavioral Theory of Communication," GN-389, 12 mos., 3/9/65
57,100 STANFORD UNIV., "Science Information Exchange Among Communication Researchers," GN-434, 24 mos., 6/7/65

Information Sources and Services

$60,500 AMERICAN DOCUMENTATION INSTITUTE, "Support of An Annual Review of Information Science," GN-352, 24 mos., 2/8/65
9,150 AMERICAN METEOROLOGICAL SOCIETY, "Qualitative-Quantitative Evaluation of Foreign Geophysical Journals by the Citation Frequency Method," GN-390, 6 mos., 3/10/65
62,200 UNIV. OF CALIF. (Los Angeles), "Research on the Measurement of File Operating Effectiveness," GN-422, 24 mos., 6/1/65
66,000 GENERAL ELECTRIC COMPANY, "Design of a Program for Gathering Data on the Utility of Indexes," C-412, 9 mos., 6/14/65
31,880 GENERAL ELECTRIC COMPANY, "An Investigation of Basic Processes Involved in the Manual Indexing of Scientific Documents," C-422, 12 mos., 6/30/65
800 INSTITUTE FOR ADVANCEMENT OF MEDICAL COMMUNICATION, "Keypunching and Verification of Abstracts of 285 Documents," GN-442, 3 mos., 6/28/65
113,050 MASS. INST. OF TECH., "Development of a Test Environment for Information Systems," GN-292.1, 6/4/65
23,600 UNIV. OF ROCHESTER, "An Evaluation of Behavior-Related Studies in the Area of Scientific Information Dissemination," GN-398, 14 mos., 5/3/65
59,323 ROWLAND AND COMPANY, "A Study of the Organization of Technical and Professional Information on Documentation," C-421, 12 mos., 6/30/65
447 SCIENCE COMMUNICATION, INC., "User Survey of Genetics Citation Index," C-330.2, 1/29/65
49,900 SYSTEM DEVELOPMENT CORPORATION, "A Method for Analyzing Document Representation Techniques," GN-408, 12 mos., 5/12/65
137,016 SYSTEM DEVELOPMENT CORPORATION, "A Laboratory Approach to the Corporation Study of Relevance Assessments in Relation to Document Searching," C-424, 18 mos., 6/30/65
94,588 WESTERN RESERVE UNIVERSITY, "A Field Experimental Approach to the Study of Relevance Assessments in Relation to Document Searching," C-423, 2 yrs., 6/29/65

Organization and Searching

$2,013 AMERICAN INSTITUTE OF PHYSICS, "Editing Proceedings of the International Conference on Classification Research," GN-395, 3 mos., 5/5/65
89,700 UNIVERSITY OF CHICAGO, "A Study of Indexing Depth and Retrieval Effectiveness," GN-380, 15 mos., 2/2/65
77,700 HARVARD UNIVERSITY, "Research on and Evaluation of Some Models for Automatic Document Retrieval Systems," GN-360, 12 mos., 12/22/64
30,383 HUMAN SCIENCES RESEARCH, INC., "A Critical Review of the Experimental Design Aspects of Testing and Evaluating Information Retrieval Systems and Techniques," C-418, 6 mos., 6/30/65
87,100 RUTGERS, THE STATE UNIVERSITY, "A Classed Thesaurus as an Aid to Indexing, Classifying, and Searching," GN-445, 2 yrs., 6/30/65
28,000 WESTERN RESERVE UNIVERSITY, "Automatic Processing of Metallurgical Abstracts for the Purpose of Information Retrieval," GN-303.1, 6 mos., 2/15/65

INFORMATION SYSTEMS

Information Retrieval

$ 150,500	AMERICAN CHEMICAL SOCIETY, "Research and Development Leading to a Computer-Based Chemical Information System," GN-382.1, 6/2/65
349,500	AMERICAN CHEMICAL SOCIETY, "Experimental Development of a Mechanized Registry System for Chemical Compounds and for Research and Development in Selected Information Handling Problems," C-414, 2 yrs., 6/2/65
215,000	AMERICAN INSTITUTE OF PHYSICS, "The Universal Decimal Classification as an Indexing Language for a Mechanized Reference Retrieval System," GN-433, 24 mos., 6/23/65
251	INFORMATION DYNAMICS CORPORATION, "The Synthesis and Analysis of Scientific Information Service Networks," C-263.3, 7/29/64
49,200	INFORMATION DYNAMICS CORPORATION, "A Study of the Feasibility of Creating a National Inventory of the World's Scientific and Technical Serial Publications," C-413, 6 mos., 5/26/65
18,000	INFORMATION DYNAMICS CORPORATION, "Development and Test of Information System Model," C-370.1, 3 mos., 5/26/65

Mechanical Translation

$ 294,000	UNIVERSITY OF CHICAGO, "Basic Research on Methods of Translating Languages by Machine," GN-412, 24 mos., 5/22/65
244,000	WAYNE STATE UNIVERSITY, "Research in Automatic Russian-English Scientific and Technical Lexicography," GN-430, 24 mos., 6/11/65

Library Systems

$ 184,850	UNIVERSITY OF CHICAGO, "Requirements Study for Future Catalogs," GN-432, 24 mos., 6/22/65
14,400	UNIVERSITY OF MASSACHUSETTS, "Analysis of Library User Circulation Requirements," GN-435, 1 yr., 6/7/65
5,000	WEST VIRGINIA UNIVERSITY, "Investigation of the Potential Use of the Resources of a Large Academic Library by the Smaller Academic Libraries and the Libraries of Industrial Organizations Within the Distinct Region," GN-176.1, 12 mo., 12/24/64

Publication Systems

$ 225,600	AMERICAN CHEMICAL SOCIETY, "Analysis of the Role of the Computer in Scientific Publication," GN-426, 24 mos., 6/30/65
3,000	INFORONICS, INC., "Machine Recording of Textual Information During the Publication of Scientific Journals," C-305.2, 14 mo., 5/5/65

PUBLICATIONS SUPPORT

Abstracting and Indexing

$ 120,400 AMERICAN GEOLOGICAL INSTITUTE, "Preparation and Publication of "GeoScience Abstracts" During Calendar Years 1965-1966," GN-419, 24 mos., 6/22/65

116,616 AMERICAN METEOROLOGICAL SOCIETY, "Emergency Support for *Meteorological and Geoastrophysical Abstracts*," GN-316.1, 2/19/65

187,500 AMERICAN METEOROLOGICAL SOCIETY, "Preparation, Publication and Distribution of the 1965 Volume of *Meteorological and Geoastrophysical Abstracts* (MGA), and A Cumulative Annual Index Relating Thereto," C-417, 12 mos., 6/9/65

68,500 AMERICAN PSYCHOLOGICAL ASSOCIATION, "Preparation and Publication of *Psychological Abstracts* For Calendar Year 1965," GN-418, 12 mos., 6/4/65

750 AMERICAN SHORE AND BEACH PRESERVATION ASSN., "Preparation and Publication of a 30-Year Cumulative Index to SHORE AND BEACH," GN-394, 12 mos., 4/23/65

155,600 AMERICAN SOCIETY FOR METALS, "Expansion and Upgrading of REVIEW OF METAL LITERATURE (RML)," GN-354, 40 mos., 10/29/64

23,800 ASSOCIATION FOR COMPUTING MACHINERY, "Publication of *Computing Reviews*," GN-440, 12 mos., 6/30/65

10,420 ASSOCIATION FOR SYMBOLIC LOGIC, "Preparation and Publication of the *Journal of Symbolic Logic*," GN-429, 1 yr., 6/30/65

112,800 BIOLOGICAL ABSTRACTS, "Publication of *Biological Titles*," GN-415, 12 mos., 5/22/65

184,000 ENGINEERING INDEX, "Computerized Abstracting and Indexing Pilot Program in Plastics and Electrical and Electronics Engineering," GN-383, 14 mos., 2/12/65

120,000 ENGINEERING INDEX, "Preparation and Publication of *Engineering Index* during Calendar Year 1965," GN-409, 12 mos., 5/19/65

88,200 AMERICAN MUSEUM OF NATURAL HISTORY, "Preparation and Publication of *Catalogue of Smaller Index Foraminifera*," GN-417, 36 mos., 5/22/65

72,600 UNIVERSITY OF CALIFORNIA, "Preparation of Volume VIII, Bibliography of Fossil Vertebrates," GN-405, 60 mos., ~~4/1/65~~ 5/22/65

5,610 YALE UNIVERSITY, "Preparation and Publication of a 6-Year Cumulative Index to *Radiocarbon*," GN-396, 12 mos., 4/28/65

Publications (Other than A&I)

Research Journals:

$ 29,337 INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE), "Publication and Distribution of an English Edition, 1965 Issues, Russian Journal, *Engineering Cybernetics*," GN-371, 18 mos., 12/24/64

Monographs:

1,750 AMERICAN MUSEUM OF NATURAL HISTORY, "Publication of a Monograph, *Deltatheridia, a New Order of Mammals*," GN-423, 12 mos., 5/26/65

1,000 BERNICE P. BISHOP MUSEUM, "Publication of *Bibliographic Introduction to New Guinea Entomology*," GN-344, 12 mos., 10/12/64

8,350 CALIFORNIA INSTITUTE OF TECHNOLOGY, "Preparation of Charts and Plates, *Catalogue of Galaxies and Clusters of Galaxies*, Volumes III and V," GN-436, 24 mos., 6/8/65

19,500 HUMAN RELATIONS AREA FILES, INC., "Publication of *A Cross-Cultural Summary*," GN-416, 6 mos., 6/4/65

1,725 INDIANA UNIVERSITY FOUNDATION, "Preparation and Publication of *Current Trends in Far Eastern Linguistics*," GN-132.1, 3/31/65

9,300 LEHIGH UNIVERSITY, "Appraisal of Contemporary Russian and East European Information in Psychology and Related Areas," GN-351, 12 mos., 10/20/64

25,000 NATIONAL ACADEMY OF SCIENCES/NATIONAL RESEARCH COUNCIL, "Publication of *The Quaternary of the United States*," C-310/Task #93, 1 yr., 3/29/65

13,600 NEW YORK BOTANICAL GARDEN, "Publication of Three Issues of *Memoirs of the New York Botanical Garden*," GN-348, 24 mos., 10/28/64

3,425 NEW YORK BOTANICAL GARDEN, "Publication of Manual of the Leafy Hepaticae of Latin America, Part II," GN-402, 12 mos., 5/3/65

11,200 NEW YORK BOTANICAL GARDEN, "Publication of Two Issues of Memoirs of the New York Botanical Garden," GN-413, 12 mos., 6/9/65

1,725 UNIVERSITY OF PITTSBURGH, "Publication of Al-Kindi, An Annotated Bibliography," GN-359, 12 mos., 12/22/64

8,000 RESEARCH INSTITUTE FOR THE STUDY OF MAN, "A Bibliographic Guide for Social Science Research in the Non-Hispanic Territories of the Caribbean," GN-401, 6 mos., 5/3/65

10,350 THE UNIVERSITY OF TEXAS, "Partial Publication Support of the Book entitled The Baboon as an Experimental Animal," GN-349, 12 mos., 10/28/64

31,000 THE UNIVERSITY OF TEXAS, "Publication of Volumes I and II of The Handbook of Middle American Indians," GN-355, 12 mos., 12/8/64

2,125 YALE UNIVERSITY, "Publication of Fossil Mammalia of the Huerfano Formation, Eocene, of Colorado," GN-356, 12 mos., 12/3/64

Conference Proceedings:

1,350 AMERICAN SOCIETY OF NATURALISTS, "Publication of the Symposium Proceedings, Cytoplasmic Units of Inheritance," GN-437, 6 mos., 6/22/65

Other Special Projects:

50,000 AMERICAN SOCIETY FOR METALS, "Cooperative Support of the Information Searching Service of the ASM," GN-427, 12 mos., 6/23/65

1,500 AMERICAN INSTITUTE OF BIOLOGICAL SCIENCES, "Dissemination of the English Version of the Japanese Journal of Plant and Cell Physiology in the United States," GN-51.1, 12 mos., 6/22/65

Translations

Domestic/Slavic:

$ 23,900 AMERICAN GEOGRAPHICAL SOCIETY, "Production and Distribution of a Selected Translation Journal, Soviet Geography: Review and Translation, Vol. VI (1965)," GN-363, 18 mos., 12/24/64

136,070 AMERICAN GEOLOGICAL INSTITUTE, "Production and Distribution of a Selected Translation Journal: International Geology Review, Vol. VII, 1965," GN-364, 18 mos., 12/24/64

38,915 AMERICAN GEOLOGICAL INSTITUTE, "Production and Distribution of an English Edition of Doklady of the Academy of Sciences USSR, Earth Science Sections, 1965 Issues (Mos. 160-165)," GN-369, 18 mos., 12/24/64

48,300 AMERICAN GEOLOGICAL INSTITUTE, "Production and Distribution of a Selective Translation Journal: Geochemistry International, Vol. II (1965)," GN-406, 12 mos., 5/17/65

18,990 AMERICAN GEOPHYSICAL UNION, "Production and Distribution of Soviet Hydrology: Selected Papers, Vol. 1965," GN-366, 18 mos., 12/24/64

57,020 AMERICAN GEOPHYSICAL UNION, "Production and Distribution of English Editions of the 1965 Issues of Two Russian Journals: Izvestiya of the Academy of Sciences USSR: Atmospheric and Oceanic Physics Series, and Earth Physics Series," GN-373, 18 mos., 2/5/65

17,965 AMERICAN GEOPHYSICAL UNION, "Production and Distribution of a Selected Translation Journal: Soviet Oceanography, 1965," GN-374, 18 mos., 2/2/65

25,000 AMERICAN GEOPHYSICAL UNION, "Production and Distribution of an English Edition of the 1965 Issues of Russian Journal: Geodesy and Aerophotography," GN-375, 18 mos., 2/2/65

36,900 AMERICAN GEOPHYSICAL UNION, "Production and Distribution of an English Edition of the Russian Journal: Geomagnetism and Aeronomy, 1965 Issues," GN-378, 18 mos., 2/2/65

35,360 AMERICAN GEOPHYSICAL UNION, "Production and Distribution of an English Edition of the 1965 Issues of Russian Bimonthly Journal Oceanology," GN-420, 18 mos., 6/8/65

53,245 AMERICAN INSTITUTE OF CHEMICAL ENGINEERS, "Production and Distribution of a Selected Translation Journal: International Chemical Engineering, Vol. V (1965)," GN-372, 18 mos., 12/24/64

1,150 AMERICAN INSTITUTE OF PHYSICS, "Scientific Editing of an English Translation of D. Ya. Martynov's Book A Course in Practical Astrophysics," GN-397, 12 mos., 4/28/65

49,860 AMERICAN MATHEMATICAL SOCIETY, "Production and Distribution of an English Edition of Soviet Mathematics - Doklady, Vol. VI (1965)," GN-387, 18 mos., 3/11/65

19,100 AMERICAN MATHEMATICAL SOCIETY, "Production of an English Edition of Transactions of the Moscow Mathematical Society, Vol. XIV (1965)," GN-407, 18 mos., 5/12/65

79,968	AMERICAN MATHEMATICAL SOCIETY, "Program for Selected Translations of Mathematical Research Articles from Russian and other Foreign Languages (1965)," GN-410, 18 mos., 5/17/65
$ 43,815	ARCTIC INSTITUTE OF NORTH AMERICA, "Production of Anthropology of the North: Translations from Russian Sources, Vols. 6-9," GN-362, 18 mos., 12/24/64
3,448	COMMERCE DEPT./Joint Publications Research Service, "Translation and Publication of the Russian Book: A Course in Practical Astrophysics," P.O. 65-243, 12 mos., 9/17/64
6,500	COMMERCE DEPT./Weather Bureau, "Editorial and Abstracting Services for the American Geophysical Union Project for Production and Distribution of Soviet Hydrology: Selected Papers, Vol. 1965," GN-365, 18 mos., 12/24/64
22,400	ENTOMOLOGICAL SOCIETY OF AMERICA, "Production and Distribution of an English Edition of Entomological Review, 1965 Issues," GN-367, 18 mos., 12/24/64
95,555	INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, "Production and Distribution of English Editions of the 1965 Issues of Three Russian Journals, under Two English Titles: Radio Engineering and Electronic Physics, and Telecommunications," GN-379, 18 mos., 2/2/65
100,460	INSTRUMENT SOCIETY OF AMERICA, "Production and Distribution of English Editions of the 1965 Issues of Four Russian Journals: Automation and Remote Control; Instruments and Experimental Techniques; Measurement Techniques; and Industrial Laboratory," GN-370, 18 mos., 2/11/65
3,840	NATIONAL ACADEMY OF SCIENCES/NATIONAL RESEARCH COUNCIL, "Translation and Publication of Soviet Studies in Tufflavas and Ignimbrites," C-310/Task 101, 12 mos., 6/29/65
46,159	OPTICAL SOCIETY OF AMERICA, "Production of English Editions of Russian Journal, Optics and Spectroscopy, 1965 Issues," GN-361, 18 mos., 12/24/64
18,780	SOCIETY FOR INDUSTRIAL AND APPLIED MATHEMATICS, "Production and Distribution of an English Edition of Russian Journal: Theory of Probability and Its Applications, Vol. 10, 1965," GN-376, 18 mos., 12/24/64
51,980	SOIL SCIENCE SOCIETY OF AMERICA, "Production and Distribution of an English Edition of Soviet Soil Science, 1965 Issues," GN-377, 2/11/65, 18 mos.
6,460	SOIL SCIENCE SOCIETY OF AMERICA, "Production of an English Edition, 1964 Issues of the Russian Journal, Soviet Soil Science," GN-270.1, 6/22/65
	Domestic/Oriental:
36,600	AMERICAN INSTITUTE OF PHYSICS, "Translation of the 1965 Issues of (Chinese) Journal, Acta Physica Sinica," GN-393, 15 mos., 4/6/65
39,668	AMERICAN MATHEMATICAL SOCIETY, "Production and Distribution of an English Edition of Chinese Mathematics - Acta, Two 1964 Issues and Six 1965 Issues," GN-388, 18 mos., 3/11/65
7,040	COMMERCE DEPT./Joint Publications Research Service, "Translation of Acta Geologica Sinica, Vol. 44, Nos. 1-4, 1964," GN-399, 12 mos., 5/6/65
96,950	INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, "Production and Distribution of English Editions of the 1965 Issues of Two Japanese Journals: Electronics and Communications in Japan and Electrical Engineering in Japan," GN-381, 18 mos., 2/2/65

Special Foreign Currency Translation Program

$675,000	ISRAEL	C-244.7, 12/24/64
100,000	POLAND	C-250.8, 10/26/64
225,000	YUGOSLAVIA	C-251.8, 11/4/64

FEDERAL SCIENCE INFORMATION

Science Information Exchange

$2,000,000 SMITHSONIAN INSTITUTION, "Continued Support for Annual Operating Expenses of the Science Information Exchange for FY 1965," GN-336, 1 yr., 9/9/64

1,500,000 SMITHSONIAN INSTITUTION, "Continued Support for Annual Operating Expenses of the Science Information Exchange," GN-336.2, 6/30/65

National Referral Center

$ 477,000 LIBRARY OF CONGRESS, "National Referral Center for Science and Technology," GN-444, 1 yr., 6/30/65

National Information Centers

$ 166,521 Transferred to LIBRARY OF CONGRESS for support of Russian Accessions (MIRA-Monthly Index of Russian Accessions) by NSF

Other Projects

$ 10,000 DEPARTMENT OF DEFENSE, "to aid in procuring studies required by the COSATI Task Group on National Systems," MOR 65-38, 4/9/65.

117,300 BATTELLE MEMORIAL INSTITUTE, "Science Information Exchange Requirements Study," C-431, 7½ mos., 6/14/65

DOMESTIC AND FOREIGN SCIENCE INFORMATION

Domestic Science Information

$ 1,500	AMERICAN GEOLOGICAL INSTITUTE, "Resume of Earth Sciences Publications Activities," GN-425, 6 mos., 5/28/65
69,400	ASSOCIATION OF RESEARCH LIBRARIES, "Terminal partial support of the Secretariat of the Association of Research Libraries," GN-368, 36 mos., 12/24/64
1,840	BIOLOGICAL ABSTRACTS, "Resume of Biological Sciences Publications Activities," GN-428, 6 mos., 5/28/65
19,368	THE CENTER FOR RESEARCH LIBRARIES, "Partial Support of the Operation of the Scientific Journal Center," GN-236.1, 6 mos., 3/1/65
48,930	*SPECIAL LIBRARIES ASSOCIATION, "Partial Support of the Operation of the Translations Center," GN-347, 12 mos., 11/6/64
11,720	SPECIAL LIBRARIES ASSOCIATION, "Improvement of the SLA Special Classifications Center," GN-386, 1 yr., 2/15/65
5,725	SYRACUSE UNIVERSITY, "Symposium on 'The Foundations of Access to Knowledge'," GN-400, 12 mos., 5/3/65

Foreign Science Information

$ 5,334	AMERICAN INSTITUTE OF PHYSICS, "Conference on Physics Abstracting," GN-343, 6 mos., 10/5/64
17,540	BERNICE P. BISHOP MUSEUM, "Continued support of the operation of the Pacific Scientific Information Center," GN-357, 12 mos., 11/27/64
26,830	CALIFORNIA INSTITUTE OF INTERNATIONAL STUDIES, "Preparation of a report on 'Science Information in Middle and South America," GN-438, 18 mos., 6/22/65
1,400	COMMERCE DEPARTMENT/CENSUS BUREAU, "Preparation and Publication of a Bibliographic Survey on the Social Science Literature in Communist Bloc and Other Difficult Languages," GN-274.1, 10/23/64
6,225	COLUMBIA UNIVERSITY PRESS, "Publication of a Directory of Selected Research Institutes of Eastern Europe," GN-414, 12 mos., 6/25/65
35,000	FEDERATION OF AMERICAN SOCIETIES FOR EXPERIMENTAL BIOLOGY, "Thirty-first Meeting and Congress of the International Federation for Documentation, Washington, D.C.," GN-342, 1 yr., 10/28/64
$ 10,000	INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS/ABSTRACTING BOARD, "Continued partial support of the ICSU Abstracting Board," GN-384, 12 mos., 2/16/65
14,400	LIBRARY OF CONGRESS, "Support of the Publication of Part I, World List of Future International Meetings," GN-341, 1 yr., 10/7/64
14,940	LIBRARY OF CONGRESS, "Support of the Publication of Part I, World List of Future International Meetings," GN-424, 12 mos., 6/4/65
550	McGRAW-HILL BOOK COMPANY, "For printing 1,000 copies of the missing 56 dictionary pages (Chinese Directory) to be printed as a 64-page, paper-covered, saddle-stitched booklet," P.O. 65-703, 5/28/65
10,900	MASSACHUSETTS INSTITUTE OF TECHNOLOGY, "Dissemination of Scientific and Technical Information in the U.S.S.R.," GN-124.2, 6 mos., 6/7/65
88,950	NATIONAL ACADEMY OF SCIENCES/NATIONAL RESEARCH COUNCIL, "Office of Documentation," C-310, Task #41.3, 1 yr., 10/5/64
4,744	NATIONAL ACADEMY OF SCIENCES/NATIONAL RESEARCH COUNCIL, "Preparation and Publication of a New Edition of the International Directory of Anthropologists," C-310, Task Order #17.3, 4/23/65
21,955	NATIONAL FEDERATION OF SCIENCE ABSTRACTING AND INDEXING SERVICES, "Distribution of scientific and technical journals from Mainland China (Project I), and Publication of an Announcement Journal (Project II)," GN-338, 24 mos., 9/23/64
64,170	THE PENNSYLVANIA STATE UNIVERSITY, "Support of a Critical Review of Developments in Certain Areas of Biological Sciences in Mainland China," GN-391, 24 mos., 3/31/65
27,100	SPECIAL LIBRARIES ASSOCIATION, "Exchange Visits of American and Russian Scientific and Technical Librarians," GN-337, 12 mos., 8/28/64
135,461	SURVEYS AND RESEARCH CORPORATION, "Preparation of a Directory of Communist Chinese Research Institutes and Key Personnel," C-406, 2 yrs., 6/21/65

DATA COLLECTION AND PUBLICATIONS

$ 28,000 U.S. DEPARTMENT OF COMMERCE/OFFICE OF TECHNICAL SERVICES, "Support of Documentation Research Reports Center," GN-350, 1 yr., 10/22/64

36,870 HERNER AND COMPANY, "Preparation of the Publication, Current Research and Development in Scientific Documentation #14," C-404, 1 yr., 3/15/65

10,000 SCRIPTA TECHNICA, INC., "A Series of Bulletins Describing the Scientific Information Activities of Federal Agencies," C-163.7, 1 yr., 6/29/65

PROGRAM/ACTIVITY SUMMARY
SCIENCE INFORMATION ACTIVITIES
FISCAL YEAR 1966

RESEARCH AND STUDIES

Communication Patterns

$173,600	AMERICAN INSTITUTE OF PHYSICS, "Studies of Elements of a Physics Information System," GN-549, 6/30/66
12,200	AMERICAN MATHEMATICAL SOCIETY, "To Plan a Study of Information Exchange and Publication in Mathematics," GN-463, 11/1/65
141,600	AMERICAN PSYCHOLOGICAL ASSOCIATION, "Project on Scientific Information Exchange in Psychology," GN-547, 6/30/66
27,600	HARVARD UNIVERSITY, "Studies of the Flow of Technical Information," GN-305.1, 8/24/65
367,330	JOHNS HOPKINS UNIVERSITY, "A Behavioral Study of Scientific Communications," GN-514, 2/28/66
17,000	UNIV. OF MISSOURI AT KANSAS CITY, "Second Annual Symposium on Communication Theory and Research," GN-500, 2/7/66
31,700	NEW YORK UNIVERSITY, "Synthesis of Research on the Flow and Use of Scientific and Technical Information," GN-454, 9/28/65
94,300	OHIO STATE UNIVERSITY RESEARCH FOUNDATION, "Relationship of the Productivity of Scientists and Technologists and Their Informational Environments," GN-542, 6/2/66
2,940	SYRACUSE UNIVERSITY, "User Study of Translated Soviet Scientific Journals," GN-501, 1/24/66
58,600	YALE UNIVERSITY, "Statistical Studies of Networks of Scientific Papers," GN-527, 5/12/66

Information Sources and Services

$10,000	AMERICAN INSTITUTES FOR RESEARCH IN THE BEHAVIORAL SCIENCES, "A Feasibility Study of the Factor Analysis of the Content of Physics Journals," GN-496, 12/23/65
228,475	CORNELL UNIVERSITY, "Refinement and Tests of Prototype Methods of Automatic Document Retrieval," GN-495, 12/23/65
2,250	GENERAL ELECTRIC COMPANY, "Investigation of Basic Processes Involved in the Manual Indexing of Scientific Documents," C-422.1, 1/27/66
152	HERNER AND COMPANY, "Survey of Professional Scientific Journals," C-325.3, 12/15/65
60,400	LEHIGH UNIVERSITY, "Document Retrieval Theory, Relevance, and the Methodology of Evaluation," GN-451, 9/29/65

Organization and Searching

$10,634	UNIVERSITY OF MARYLAND, "An International Symposium on Relational Factors in Classification," GN-508, 3/21/66
240	NAS/NRC, Purchase of 100 copies of "Supplementary Report on European Nonconventional Notation Systems, No. 12-78," P.O. 66-434, 1/18/66
141,000	UNIVERSITY OF PENNSYLVANIA, "Analysis of Chemical Notations," GN-520, 4/25/66
63,500	PRINCETON UNIVERSITY, "Research on Automatic and Semi-automatic Indexing and Experimentation with a Citation Index," GN-550, 6/30/66
62,800	SYSTEM DEVELOPMENT CORPORATION, "Analysis of Document Representation Techniques," GN-544, 6/8/66
11,400	WESTERN RESERVE UNIVERSITY, "Automatic Processing of Metallurgical Abstracts for the Purpose of Information Retrieval," GN-303.2, 2/8/66

INFORMATION SYSTEMS

Other Information Retrieval

$66,425	AMERICAN CHEMICAL SOCIETY, "Systems Requirements Analysis for Disseminating Primary Literature," GN-563, 6/30/66
72,500	COLUMBIA UNIVERSITY, "A Program of Collaboration and Research Services Among Social Science Data Archives," GS-1258 /SOC award grant number/, 6/30/66
6,000	INFORMATION DYNAMICS CORPORATION, "Study of the Feasibility of Creating a National Inventory of the World's Sci. and Tech. Serial Publications," C-413.1, 12/6/65
978	INFORMATION DYNAMICS CORPORATION, Reprinting 200 copies of the Final Report from C-413, entitled: "A Serial Data Program for Science and Technology," P.O. 66-544, 3/17/66
103,546	NEW YORK UNIVERSITY, "Applications of the String Program to Scientific Texts," GN-559, 6/27/66
136,578	UNIV. OF PENNSYLVANIA, "Research on Linguistic Transformations for Information Retrieval," GN-557, 6/30/66

Machine-Aided Translation

$68,931	BUNKER-RAMO CORPORATION, "Computer-Aided Research in Machine Translation," C-372.1, 6/9/66
197,500	UNIV. OF CALIFORNIA, "Research on Machine Translation and Related Mechanolinguistic Systems," GN-306.1, 1/18/66
75,000	HARVARD UNIVERSITY, "Research on Computational Linguistics," GN-554, 6/24/66
115,420	UNIVERSITY OF TEXAS, "Research on Syntactic and Semantic Analysis for Mechanical Translation," GN-558, 6/27/66
7,000	WAYNE STATE UNIVERSITY, "Conference on Computer-Related Semantic Analysis," GN-465, 11/8/65
(5,000)	AForce transfer for above project
(1,000)	intelligence agency transfer for above project
116,500	WAYNE STATE UNIVERSITY, "Comprehensive Electronic Data Processing of Two Russian Lexicons," GN-555, 6/24/66

Library Systems

$67,500	CENTER FOR RESEARCH LIBRARIES, "A Study of Costs and Service Characteristics of Alternative Methods for Making Serial Publications Available to Users," GN-532, 6/8/66
118,000	UNIVERSITY OF CHICAGO, "Development of an Integrated Computer-Based Bibliographical Data System for a Large University Library," GN-556, 6/29/66
43,250	HERNER AND COMPANY, "A Design Study of the U.S. Medical Library System," C-442, 8/31/65
(43,250)	HEW transfer for the above OST project)
22,790	JOHNS HOPKINS UNIVERSITY, "An Operations Research and Systems Engineering Study of a University Library," GN-538, 6/21/66
527,641	MASSACHUSETTS INSTITUTE OF TECHNOLOGY, "Design, Development and Evaluation of an Unconventional Library Catalog," C-472, 6/30/66
82,338	PURDUE RESEARCH FOUNDATION, "Basic Problems in the Design and Operation of University Libraries," GN-519, 4/26/66

Publication Systems

$140,302	AMERICAN MATHEMATICAL SOCIETY, "Development of Computer Aids for Tape-Control of Photocomposing Machines," GN-533, 6/30/66

INFORMATION SERVICES

Abstracting and Indexing

$748,000	AMERICAN GEOLOGICAL INSTITUTE, "Establishment of a Cooperative Computer-Based Information Service in the Solid Earth Sciences," GN-515, 4/6/66
99,000	AMERICAN GEOLOGICAL INSTITUTE, "Prep. and Pub. of the Glossary of Geology and Related Sciences," GN-531, 5/17/66
11,400	AMERICAN GEOLOGICAL INSTITUTE, "Prep. of Geophysical Patent Abstracts," GN-540, 6/8/66
15,900	AMERICAN MATHEMATICAL SOCIETY, "Prep. and Pub. of Survey Reviews in Mathematics," GN-530, 5/17/66
222,222	AMERICAN METEOROLOGICAL SOCIETY, "Prep., Pub. and Dist. of the 1966 Volume of Meteorological and GeoAstrophysical Abstracts (MGA), and a Cumulative Index Relating Thereto," C-470, 6/20/66
92,600	AMERICAN PSYCHOLOGICAL ASSOCIATION, "Prep. and Pub. of Psychological Abstracts for Calendar Year 1966," GN-512, 3/31/66
38,200	AMERICAN SOCIETY FOR TESTING AND MATERIALS, "Prep. of a CODEN of Periodical Titles," GN-552, 6/28/66
49,600	ASSOCIATION FOR SYMBOLIC LOGIC, "Prep. and Pub. of the Journal of Symbolic Logic," GN-472, 12/23/65
38,200	BOSTON UNIVERSITY, "Prep. and Pub. of COWA Surveys and Bibliographies," GN-545, 6/6/66
26,000	ENGINEERING INDEX, INC., "Computerized Abstracting and Indexing Pilot Program in Plastics and Electrical and Electronics Engineering," GN-383.1, 11/23/65
200,000	ENGINEERING INDEX, INC., "Prep. and Pub. of Engineering Index, Calendar Years 1966-1967," GN-493, 12/23/65
379,400	ENGINEERING INDEX, INC., "Computerized Abstracting and Indexing Program in Plastics and Electrical-Electronics Engineering," GN-518, 4/12/66
18,300	UNIVERSITY OF ILLINOIS, "Prep. and Pub. of Research Digest," GN-480, 12/18/65
	Bibliographies and Specialized Indexes:
$35,725	ENGINEERS JOINT COUNCIL, "Improvement and Extension of Source Indexing Practices of Selected Engineering Journals," GN-477, 12/9/65
79,000	HUMAN RELATIONS AREA FILES, "Prep. and Pub. of a Korean Social Science Bibliography," GN-492, 12/23/65
152,000	INTERNATIONAL ASSOCIATION FOR PLANT TAXONOMY, "Prep. and Pub. of Index Nominum Genericorum," GN-453, 10/5/65
7,730	UNIVERSITY OF MINNESOTA, "Prep. of Annual Reviews and Current Bibliographies on Heat Transfer Research," GN-456, 10/11/65
5,070	SMITHSONIAN INSTITUTION, "Pub. of Second Supplement to Annotated, Subject-Heading Bibliography of Termites, 1961-1965," GN-522, 5/4/66
77,200	SOCIAL SCIENCE RESEARCH COUNCIL, "Prep. and Pub. of a Bibliography on Modern Chinese Society, GN-513, 4/12/66

Other Publications and Services

	Research Journals:
$2,500	AMERICAN FOLKLORE SOCIETY, INC., "Pub. of a Special Issue of the Journal of American Folklore," GN-446, 8/4/65
21,000	AMERICAN GEOPHYSICAL UNION, "Prep. and Pub. of AGU Transactions, 1967," GN-565, 6/30/66
5,320	AMERICAN SOCIETY OF NATURALISTS, "Pub. of Backlog in the American Naturalist," GN-447, 8/5/65
20,000	CANADIAN MATHEMATICAL CONGRESS, "Pub. of the Backlog of Canadian Journal of Mathematics," GN-452, 9/20/65
7,765	UNIVERSITY OF MICHIGAN, "Pub. of the Bulletin of Thermodynamics and Thermochemistry," GN-521, 4/27/66

8,450	OHIO ACADEMY OF SCIENCE, "Pub. of Backlog in The Ohio Journal of Science," GN-481, 12/14/65
30,000	POPULATION ASSOCIATION OF AMERICA, "Prep. and Pub. of the Journal, Demography," GN-535, 5/18/66
12,320	SOLAR ENERGY SOCIETY, "Elimination of the Pub. Backlog for the Journal, Solar Energy," GN-453, 10/11/65
	Monographs:
$7,700	AMERICAN GEOGRAPHICAL SOCIETY, "Pub. of A History of Sci. Geographical Exploration of the Pacific Basin," GN-110.1, 2/16/66
44,500	AMERICAN GEOGRAPHICAL SOCIETY, "Prep. and Pub. of Eight Folios of the Serial Atlas of the Marine Environment," GN-560, 6/29/66
76,200	AMERICAN GEOPHYSICAL UNION, "Pub. of a Series of Antarctic Monographs," GN-55.2, 6/30/66
9,000	BERNICE P. BISHOP MUSEUM, "Partial Pub. Support for Insects of Micronesia Series," GN-160.1, 6/30/66
5,240	CARNEGIE INSTITUTE, "Pub. of a Monograph of the Ithomiidae, Part III, the Tribe Mechanitini," GN-546, 6/24/66
2,000	COMMERCE DEPT./ENVIRONMENTAL SCIENCE SERVICES ADMIN., "Prep. and Pub. of Atmospheric Sciences Vocabulary," AG-9, 12/13/65
6,020	FARMINGTON STATE COLLEGE, "Pub. of a Monograph, Ichneumoninae of Africa South of the Sahara," GN-561, 6/29/66
2,430	GEORGETOWN UNIVERSITY, "Pub. of Nomographic Charts for the Solution of Kepler's Equation in Celestial Mechanics," GN-450, 8/25/65
24,000	HARVARD UNIVERSITY, "Pub. of a Monograph, Tarquinia, Villanovans and Early Etruscans," GN-510, 3/22/66
40,000	NATIONAL BIOMEDICAL RESEARCH FOUNDATION, "Prep. and Pub. of Atlas of Protein Sequence and Structure," GN-564, 6/30/66
4,260	NEW YORK BOTANICAL GARDEN, "Pub. of One Issue of Memoirs of the New York Botanical Garden," GN-526, 5/6/66
2,300	UNIVERSITY OF PITTSBURGH, "Pub. of Galen and the Syllogism," GN-449, 8/12/65
2,840	UNIVERSITY OF PUERTO RICO, "Pub. of Scarabaeinae of the Antilles," GN-548, 6/13/66
12,700	UNIVERSITY OF TEXAS, "Editorial Prep. for the Pub. The Bird Life of Texas," GN-80.1, 3/28/66
79,500	UNIVERSITY OF TEXAS, "Pub. of The Handbook of Middle American Indians," GN-355.1, 4/12/66
58,900	UNIVERSITY OF TEXAS, "The Prehistory of the Tehuacan Valley," GN-509, 4/27/66
5,450	UNIVERSITY OF WASHINGTON, "Pub. of a Monograph, Development and Systematics of Some Pacific Marine Symbiotic Copepods," GN-517, 4/7/66
3,100	YALE UNIVERSITY, "Pub. of Systematic Studies of Marine Sponges," GN-475, 12/9/65
77,200	YALE UNIVERSITY, "Pub. of Peabody Museum of Natural History Bulletin," GN-528, 5/13/66
	Conference Proceedings:
$10,340	AMERICAN PSYCHOLOGICAL ASSOCIATION, "Pub. of Proceedings of the 1966 APA Annual Convention," GN-505, 2/21/66
	Other Services:
2,000	AMERICAN INSTITUTE OF PHYSICS, "A Comparative Study of the Physics Section of Nuclear Science Abstracts With Physical Abstracts," P.O. 66-369, 12/6/65
19,000	ENGINEERING SOCIETIES LIBRARY, "Automation of Serials Control in the Engineering Societies Library," GN-551, 6/16/66
19,000	ENGINEERS JOINT COUNCIL, "EJC Engineering Information Services Program," GN-553, 6/28/66
1,500	NAS/NRC, "Prep. of a List of U.S. Mathematicians for Inclusion in the Revised World Directory of Mathematicians," C-310/Task Order #103, 7/26/65
3,500	WESTERN RESERVE UNIVERSITY, "Special Classification Center," GN-471, 11/22/65

SPECIAL PROJECTS

$129,600	AMERICAN LIBRARY ASSOCIATION, "A Study of the Acquisition of Science Materials for College and University Libraries," GN-541, 6/30/66
177,600	UNIVERSITY OF CALIFORNIA, "The Research Program of the Institute of Library Research of the Univ. of Calif., Phase I: Planning," GN-503, 2/11/66
415,700	OHIO STATE UNIVERSITY RESEARCH FOUNDATION, "To Establish a Program of Information Science," GN-534, 5/18/66

CHEMICAL INFORMATION

$187,908	AMERICAN CHEMICAL SOCIETY, "Exp. Dev. of a Mechanized Registry System for Chemical Compounds and for Res. and Dev. in Selected Information Handling Problems," C-414.1, 6/27/66
28,700	AMERICAN CHEMICAL SOCIETY, same as above, C-414.2, 6/27/66
110,000	COMMERCE DEPT./NATIONAL BUREAU OF STANDARDS, "Res. and Dev. by the NBS in the Chem. Info. Program," GN-455, 10/1/65
(52,050)	NIH transfer for above project
(5,900)	DOD transfer for above project
37,922	GOODYEAR AEROSPACE CORPORATION, "Application of Associative Memory to Chemical Information Storage and Retrieval," C-456, 3/28/66
82,018	INFORMATION MANAGEMENT, INC., "A General System Design and Development Plan for a National Chemical Information System, and Technical Project Management Assistance for the Development of the System," C-463, 4/25/66
15,000	JOHN I. THOMPSON & COMPANY, "Planning Support and Services for the Chemical Information Program," C-447, 9/27/65
(7,500)	NIH transfer for above project
6,163	JOHN I. THOMPSON & COMPANY, same as above, C-447.1, 6/27/66
28,339	UNIVERSITY OF MICHIGAN, "Graph Matrices, Chemical Nomenclature, and Human Group-Structure," GN-566, 6/30/66
39,676	UNIVERSITY OF PENNSYLVANIA, "Analysis and Programming for Interfacing Electronic Structural Input/Output Devices to an Automated Structural Search Program," C-467, 6/30/66

DOMESTIC SCIENCE INFORMATION

Science Information Exchange

$364,130	SMITHSONIAN INSTITUTION, "Operation of the Science Information Exchange," C-437, 2/25/66
38,226	same as above, C-437.1, 4/15/66
1,500,000	same as above, C-437.2, 6/20/66

National Referral Center

$7,913	LIBRARY OF CONGRESS, "National Referral Center for Science and Technology," AG-1.1, 5/4/66

National Information Centers

$174,600	LIBRARY OF CONGRESS -- transfer to L/C for support of Monthly Index of Russian Accessions, 8/3/65

Non-Federal Projects

$26,800	BATTELLE MEMORIAL INSTITUTE, "Science Information Exchange Requirements Study," C-431.1, 2/16/66
8,900	BIOLOGICAL ABSTRACTS, "Conference to Consider a Communications System for Biology," GN-462, 10/20/65
9,500	COUNCIL OF BIOLOGY EDITORS, INC., "Support of a 'Joint Meeting Between Biological and Earth Sciences Editors,'" GN-504, 2/21/66
8,020	GORDON RESEARCH CONFERENCES, INC., "Support of a Conference Entitled 'The Numerical Data of Science and Technology, Its Generation and Critical Evaluation,'" GN-507, 2/25/66
85,000	UNIVERSITY OF MICHIGAN, "Support of an EDUCOM Summer Study Conference to Plan and Design a Pilot University Communications Network," GN-543, 6/13/66
345,000	NAS/NRC, "Support of a Committee on Scientific and Technical Communication," C-310/Task Order #111, 2/25/66
39,900	NAS/NRC, "Support of the Committee on Information in the Behavioral Sciences," C-310/Task Order #116, 4/25/66
185,622	SYSTEM DEVELOPMENT CORPORATION, "A Systems Study of Abstracting and Indexing Services," C-464, 4/25/66

FOREIGN SCIENCE INFORMATION

Translations

	Domestic/Slavic:
$8,000	AMERICAN CRYSTALLOGRAPHIC ASSOCIATION, "Trans. and Pub. of Russian Monograph Symmetry and Structure of Crystals by E. S. Federov," GN-562, 6/30/66
23,900	AMERICAN GEOGRAPHICAL SOCIETY, "Prod. and Dist. of a Selected Translation Journal Soviet Geography: Review and Translation, Vol. VII (1966)," GN-474, 12/9/65
135,000	AMERICAN GEOLOGICAL INSTITUTE, "Prod. and Dist. of a Selective Translation Journal International Geology Review, Vol. VIII (1966), and English Edition of Doklady of the Academy of Sciences, USSR: Earth Science Sections, Nos. 166-171 (1966)," GN-479, 12/18/65
51,675	AMERICAN GEOLOGICAL INSTITUTE, "Trans. for and Pub. of Geochemistry International, Vol. III (1966)," GN-536, 5/18/66
22,550	AMERICAN GEOPHYSICAL UNION, "Prod. and Dist. of an English Edition of Geodesy and Aerophotography (1966)," GN-482, 12/18/65
27,000	AMERICAN GEOPHYSICAL UNION, "Prod. and Dist. of an English Edition of the Russian Journal Geomagnetism and Aeronomy, Vol. VI (1966)," GN-483, 12/21/65
38,000	AMERICAN GEOPHYSICAL UNION, "Prod. and Dist. of English Editions of Two Russian Journals: Isvestiya of the Academy of Sciences USSR: Atmospheric and Oceanic Physics and Physics of the Solid Earth, 1966," GN-484, 12/18/65
29,900	AMERICAN GEOPHYSICAL UNION, "Prod. and Dist. of English Edition of Russian Journal Oceanology (1966)," GN-485, 12/21/65
15,120	AMERICAN GEOPHYSICAL UNION, "Prod. and Dist. of Soviet Hydrology: Selected Papers, Vol. 1966," GN-436, 12/21/65
49,500	AMERICAN INSTITUTE OF CHEMICAL ENGINEERS, "Prod. and Dist. of the Selected Translation Journal International Chemical Engineering, Vol. VI (1966)," GN-478, 12/21/65
19,460	AMERICAN MATHEMATICAL SOCIETY, "Prod. and Dist. of an English Edition of Soviet Mathematics - Doklady, Vol. VII (1966)," GN-457, 10/7/65
18,216	AMERICAN SOCIETY OF MECHANICAL ENGINEERS, "Trans. and Pub. of the Rumanian Monograph Gas Lubrication by V. N. Constantinescu," GN-467, 11/23/65
26,760	ARCTIC INSTITUTE OF NORTH AMERICA, "Trans. and Editing of Anthropology of the North: Translations from Russian Sources, Vols. 10 and 11," GN-537, 5/26/66
7,000	COMMERCE DEPT./ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION, "Editorial and Abstracting Services of Soviet Hydrology: Selected Papers, Vol. 1966," AG-14, 12/23/65
$21,870	ENTOMOLOGICAL SOCIETY OF AMERICA, "Prod. and Dist. of an English Edition of Entomological Review, 1966," GN-488, 12/23/65
33,000	THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC., "Prep., Pub. and Dist. of an English Edition of Russian Journal Engineering Cybernetics, 1966," GN-489, 12/23/65
83,500	THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC., "Prod. and Dist. of Radio Engineering and Electronic Physics and Telecommunications and Radio Engineering, 1966," GN-490, 1/17/66
90,500	INSTRUMENT SOCIETY OF AMERICA, "Prod. and Dist. of English Editions of four Russian Journals: Automation and Remote Control; Instruments and Experimental Techniques; Measurement Techniques; and Industrial Laboratory, 1966," GN-497, 1/17/66
27,000	OPTICAL SOCIETY OF AMERICA, "Prod. and Dist. of an English Edition of Russian Journal Optics and Spectroscopy, Vol. XIX (1966)," GN-459, 10/11/65
20,600	SOCIETY FOR INDUSTRIAL AND APPLIED MATHEMATICS, "Prod. and Dist. of an English Edition of Russian Journal Theory of Probability and Its Applications, Vol. II (1966)," GN-466, 11/15/65
52,000	SOIL SCIENCE SOCIETY OF AMERICA, "Prod. and Dist. of an English Edition of Soviet Soil Science, 1966," GN-487, 12/21/65

	Domestic/Oriental:
8,500	AMERICAN INSTITUTE OF PHYSICS, "Trans. of the 1965 Issues of Chinese Journal Acta Physica Sinica," GN-393.1, 3/31/66
29,700	AMERICAN MATHEMATICAL SOCIETY, "Prod. and Dist. of an English Edition of Chinese Mathematics - Acta, Vol. VII (1966)," GN-460, 10/13/65
98,000	THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC., "Prod. and Dist. of English Editions of Two Japanese Journals: Electronics and Communications in Japan, Vol. 49, (1966), and Electrical Engineering in Japan, Vol. 86, (1966)," GN-491, 12/23/65

Special Foreign Currency Translation Program

$625,000	ISRAEL	C-244.11, 3/31/66
125,000	POLAND	C-250.12,12/10/65
190,000	YUGOSLAVIA	C-251.13, 3/7/66
25,000	INDIA	C-466, 6/30/66

Foreign Science Services and Publications

$5,625	A. D. LITTLE, INC., "Revision of the MS, 'A Directory of East European Research Institutes in the Biological and Physical Sciences,' and the Editing of the Publisher's Proofs," C-438, 8/31/65
4,600	AMERICAN GEOLOGICAL INSTITUTE, "Evaluation of Acta Geologica Sinica, Vol. 44 (1966)," GN-529, 5/16/66
1,755	ARCTIC INSTITUTE OF NORTH AMERICA, "Survey of European Institutes Active in Arctic Research," GN-256.1, 3/28/66
17,950	BERNICE P. BISHOP MUSEUM, "Continued Partial Support of the Pacific Scientific Information Center," GN-511, 3/28/66
14,315	CENTER FOR RESEARCH LIBRARIES, "Operation of the Scientific Journals Center," GN-236.2, 6/24/66
57,292	COMMERCE DEPT./CLEARINGHOUSE, "Operational Functions of NSF's Special Foreign Currency Sci. Info. Program," AG-54, 6/30/66
51,560	GEORGIA INSTITUTE OF TECHNOLOGY, "Scientific and Technical Information Systems and Services in Eastern Europe," GN-539, 6/30/66
10,000	INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS, "Continued Partial Support of the ICSU Abstracting Board," GN-494, 1/17/66
15,680	LIBRARY OF CONGRESS, "Part I, World List of Future International Meetings," AG-43, 5/26/66
1,650	UNIVERSITY OF MASSACHUSETTS, "Pub. of English Translations of Selected East European Papers in Phytonematology," GN-476, 12/9/65
55,800	NAS/NRC, "The Office of Documentation," C-310/Task Order #41.4, 9/28/65
34,150	UNIVERSITY OF NORTH CAROLINA, "The American Standards Association, Sectional Subcommittee Z 39," GN-473, 12/1/65
20,700	UNIVERSITY OF NORTH CAROLINA, same as above, GN-473.1, 6/24/66
10,435	JAPAN DOCUMENTATION SOCIETY, "Prep. and Pub. of a Revision of Science Information in Japan," GN-468, 12/9/65
10,870	NATIONAL FEDERATION OF SCIENCE ABSTRACTING AND INDEXING SERVICES, "Acquisition of Scientific and Technical Journals from Mainland China and Publication of an Announcement Journal," GN-502, 2/8/66
500	SCANDINAVIAN COUNCIL FOR APPLIED RESEARCH, Purchase of 50 copies of "Scandinavian Research Guide, 2nd Edition," P.O. 66-480, 2/10/66
46,930	SPECIAL LIBRARIES ASSOCIATION, "Operation of the Translations Center," GN-469, 11/22/65
7,610	same as above, GN-469.1, 6/30/66
80,530	SPECIAL LIBRARIES ASSOCIATION, "Compilation of a Cumulative Index to Scientific and Technical Translations," GN-523, 5/13/66
6,890	STANFORD UNIVERSITY, "Support for Publication of 'Science in Switzerland'" GN-506, 3/10/66
47	Prior Year Adjustment: COMMERCE DEPT./PATENT OFFICE — additional charge re GN-4 (FY '64 award)

DATA COLLECTION AND PUBLICATIONS

$31,520	--	COMMERCE DEPT./CLEARINGHOUSE FOR FEDERAL SCIENTIFIC AND TECHNICAL INFORMATION, "Documentation Research Reports Center," AG-11, 1/19/66
4,353	--	HERNER AND COMPANY, "Survey and Study of Nonconventional Technical Information Systems," C-342.2, 1/6/66

PROGRAM/ACTIVITY SUMMARY
SCIENCE INFORMATION ACTIVITIES
FISCAL YEAR 1967

RESEARCH AND STUDIES

Communication Patterns

$55,450	AMERICAN CERAMIC SOCIETY, "Study of the Information Needs of Ceramists," GN-590, 11/18/66
33,727	AMERICAN PSYCHOLOGICAL ASSOCIATION, "Project on Scientific Information Exchange in Psychology," GN-547.1, 10/17/66
89,100	MASSACHUSETTS INSTITUTE OF TECHNOLOGY, "The Role of Information in Parallel R&D Projects," GN-597, 11/17/66
12,300	UNIVERSITY OF PENNSYLVANIA, "A Study of Patterns of Information Flow," GN-599, 11/28/66
24,950	UNIVERSITY OF PENNSYLVANIA, "Measurement of Information, Instruction and Motivation Conveyed by Messages," GN-608, 12/19/66
118,300	STANFORD UNIVERSITY, "Information Retrieval in High-Energy Physics," GN-600, 12/15/66

Information Sources and Services

$4,400	AMERICAN GEOLOGICAL INSTITUTE, "Liaison for Planning an Integrated Information Service in the Geological Sciences," GN-675, 6/21/67
14,175	AMERICAN INSTITUTE OF PHYSICS, "Committee Meetings and Seminars Looking Toward a Physics Information System," GN-629, 5/8/67
30	AMERICAN PSYCHOLOGICAL ASSOCIATION, Purchase of 30 copies of "The American Psychologist, Volume 21, No. 11, Nov. 1966 @ $1.00 per copy," P.O. 67-372, 12/23/66
50	AMERICAN PSYCHOLOGICAL ASSOCIATION, Purchase of 50 copies of "The American Psychologist, Volume 21, No. 11, Nov. 1966 @ $1.00 per copy," P.O. 67-456, 2/14/67
625	JOHN WILEY AND SONS, INC., Purchase of 50 copies of "Annual Review of Information Science and Technology, Volume I, @ $12.50 per copy," P.O. 67-375, 12/23/66

Organization and Searching

$238,900	AMERICAN MATHEMATICAL SOCIETY, "Research on Machine Aids to an Editor of Scientific Translations," GN-644, 6/27/67
85,175	UNIVERSITY OF CALIFORNIA, "Context Information Processing," GN-643, 6/28/67
154,700	UNIVERSITY OF CHICAGO, "A Study of Indexing and Retrieval Effectiveness," GN-654, 6/22/67
4,000	UNIVERSITY OF COLORADO, "Application of University of Illinois Library Serials System to the University of Colorado Libraries," GN-641, 6/14/67
227,950	NEW YORK UNIVERSITY, "Application of the String Program to Information Retrieval of Physics Texts," GN-659, 6/19/67
127,600	WESTAT RESEARCH, INC., "Development of Methods for the Evaluation and Analysis of Document Retrieval Systems," C-491, 11/4/66

INFORMATION SYSTEMS

Other Information Retrieval

$ 6,600	AMERICAN GEOLOGICAL INSTITUTE, "Interorganizational Liaison in Micropaleontology," GN-622, 2/17/67
18,400	AMERICAN GEOLOGICAL INSTITUTE, same as above, GN-622.1, 6/16/67
138,540	AMERICAN INSTITUTE OF PHYSICS, "Key Personnel Staffing for AIP Information Program," GN-646, 6/23/67
124,140	CENTER FOR APPLIED LINGUISTICS, "An Information System Program for the Language Sciences: Survey-and-Analysis Stage," GN-653, 6/30/67
30,000	ENGINEERING INDEX, INC., "Information System Development: Phase I, Management Planning," GN-635, 6/20/67
78,734	INFORMATION MANAGEMENT, INC., "Development of a Method of Describing Operational Discipline-oriented Science Information Systems," C-526, 6/27/67

Machine-Aided Translation

$ 3,648	NATIONAL ACADEMY OF SCIENCES, "Advisory Committee on Automatic Language Processing," C-310, T.O. 80.3, 9/13/66

Library Systems

$834,700	UNIVERSITY OF CHICAGO, "Development of an Integrated, Computer-based, Bibliographical Data System for a Large University Library," GN-556.2, 5/18/67
54,000	UNIVERSITY OF COLORADO, "Development of an Academic Libraries Cooperative Processing Center for all Colorado Colleges and Universities," GN-588, 10/17/66
27,500	UNIVERSITY OF COLORADO, same as above, GN-588.1, 6/16/67
51,300	HAMLINE UNIVERSITY, "Information Systems Management in a Small, Liberal Arts College," GN-624, 3/23/67
19,400	HARVARD UNIVERSITY, "Implementing the MARC Project Input System for Current Cataloguing in Academic Libraries," GN-598, 11/25/66
216,680	MASSACHUSETTS INSTITUTE OF TECHNOLOGY, "Technical Information System," GN-589, 10/27/66
69,300	WASHINGTON STATE UNIVERSITY, "On-line Automation of the Washington State University Library: Initial Phase," GN-625, 3/22/67

Publication Systems

$94,600	AMERICAN INSTITUTE OF PHYSICS, "Experiments with Computers for Primary Journal Composition and a Variety of Related Services," GN-601, 12/16/66
17,000	AMERICAN INSTITUTE OF PHYSICS, "Current Communication in Physics: Initial Phase," GN-623, 2/17/67

INFORMATION SERVICES

Abstracting and Indexing

A&I:

$861,000	AMERICAN GEOLOGICAL INSTITUTE, "Preparation and Publication of Bibliography and Index of Geology Exclusive of North America," GN-667, 6/22/67
243,200	AMERICAN METEOROLOGICAL SOCIETY, "Preparation and Publication, and Distribution of the 1967 Volume of Meteorological and GeoAstrophysical Abstracts (MGA), and a Cumulative Index Relating Thereto," G-507, 6/27/67
175,000	AMERICAN SOCIETY OF MECHANICAL ENGINEERS, "Publication of Applied Mechanics Reviews, 1967, 1968, and 1969," GN-626, 4/19/67
49,500	ASSOCIATION FOR COMPUTING MACHINERY, "Publication of Computing Reviews FY 1967," GN-607, 12/23/66
33,400	BIOLOGICAL ABSTRACTS, INC., "Publication of Abstracts of Mycology," GN-587, 10/17/66
5,000	BIOLOGICAL ABSTRACTS, INC., same as above, GN-587.1, 6/16/67
243,400	BIOLOGICAL ABSTRACTS, INC., "Conversion of Biological Abstracts into Machine Retrievable Form," GN-619, 2/17/67
358,000	ENGINEERING INDEX, INC., "Computerized Abstracting & Indexing Program in Plastics and Electrical-Electronics Engineering," GN-648, 6/30/67
-5,800	SOCIETY OF ECONOMIC GEOLOGISTS, "Preparation and Publication of Reviews of Economic Geology," GN-617, 2/2/67

Bibliographies and Specialized Indexes:

19,000	AMERICAN GEOLOGICAL INSTITUTE, "Preparation and Publication of a Bibliography of Theses in Geology for 1965-1967," GN-651, 6/27/67
27,000	AMERICAN MATHEMATICAL SOCIETY, "Compilation and Publication of Reviews of Algebraic and Differential Topology Since 1940," GN-621, 3/9/67
48,000	AMERICAN MUSEUM OF NATURAL HISTORY, "Support of a Bibliographic Service in Ichthyology," GN-658, 6/21/67
31,100	BOSTON UNIVERSITY, "Preparation of an International Bibliography and Trend Report on the Sociology of Marriage and Family Behavior," GN-575, 8/12/66
$ 4,450	CARNEGIE INSTITUTE, "Publication of A List of New North American Spiders, 1940-1966," GN-627, 4/18/67
18,050	HUMAN RELATIONS AREA FILES, "Preparation and Publication of a Korean Social Science Bibliography," GN-492.1, 6/19/67
19,550	NATIONAL ACADEMY OF SCIENCES, "Preparation and Publication of a Supplement to Island Bibliographies," C-310/T.O. #133, 6/20/67
65,700	SOCIAL SCIENCE RESEARCH COUNCIL, "Preparation and Publication of a Bibliography on Modern Chinese Society," GN-513.1, 6/16/67

Other Publications and Services

Research Journals:

$45,200	THE JOHN HOPKINS UNIVERSITY SCHOOL OF HYGIENE & PUBLIC HEALTH, "Publication of a Journal, Communications in Behavioral Biology," GN-636, 6/30/67
13,000	THE WISTAR INSTITUTE, "Publication of Journal of Morphology for Calendar Year 1966," GN-586, 11/2/66

	Monographs:
11,450	ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA, "Preparation and Publication of Catalogue of Fossil Invertebrate Types in the Academy's Collection," GN-577, 9/26/66
7,000	ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA, "Publication of Revision of the Classification of the Oscillatoriaceae," GN-649, 6/26/67
1,855	UNIVERSITY OF CALIFORNIA PRESS, "Publication of Ecology of Soil-Borne Plant Pathogens," GN-261.1, 12/22/66
3,700	CATHOLIC UNIVERSITY OF AMERICA, "Publication of The Higher Classification, Phylogency and Zoogeography of the Satyridae," GN-652, 6/26/67
12,200	FARMINGTON STATE COLLEGE, "Publication of a Monograph, Ichneumoninae of Africa South of the Sahara," GN-561.1, 5/18/67
9,450	UNIVERSITY OF HAWAII, "Publication of Monogenetic Trematodes of Hawaiian Fishes," GN-650, 6/16/67
11,500	UNIVERSITY OF KANSAS, "Publication of The Hylid Frogs of Middle America," GN-640, 6/14/67
3,600	THE JOHN HOPKINS UNIVERSITY, "Publication of A Stereotaxic Atlas of the Pigeon Brain," GN-594, 11/7/66
13,400	THE NEW YORK BOTANICAL GARDEN, "Publication of Two Issues of Memoirs of the New York Botanical Garden," GN-595, 11/2/66
127,000	THE NEW YORK BOTANICAL GARDEN, "Publication of Memoirs of the New York Botanical Garden and North American Flora," GN-671, 6/30/67
$17,640	TEXAS A & M RESEARCH FOUNDATION, "Editing of Scientific Results of the R/V ANTON BRUUN Program in the Southeastern Pacific Ocean," GN-662, 6/16/67
5,850	WASHINGTON STATE UNIVERSITY, "Publication of a Monograph on North American Indian Sorcery," GN-613, 1/5/67
81,600	WASHINGTON UNIVERSITY, "Publication of Studies in Comparative International Development," GN-665, 6/27/67
5,900	YALE UNIVERSITY, "Publication of Arminna West I: The Late Nubian Settlement (The Northern Sector)," GN-585, 10/17/66
	Conference Proceedings:
5,900	AMERICAN PHYTOPATHOLOGICAL SOCIETY, "Publication of the Proceedings, The Dynamic Role of Molecular Constituents in Plant-Parasite Interaction," GN-574, 8/15/66
10,350	UNIVERSITY OF MINNESOTA, "Editing of Proceedings of the VII Congress of the International Quaternary Association (INQUA)," GN-616, 1/26/67
	Other Services:
19,600	AMERICAN METEOROLOGICAL SOCIETY, "Management and Operations Study of Meteorological and GeoAstrophysical Abstracts," GN-628, 4/25/67
51,520	CENTER FOR RESEARCH LIBRARIES, "Continued Partial Support of the Scientific Journals Center," GN-567, 7/25/66

SPECIAL PROJECTS

$94,800	AMERICAN INSTITUTES FOR RESEARCH, "Study of Information Requirements of Scientists," C-492, 11/23/66
8,928	AMERICAN LIBRARY ASSOCIATION, "A Study of Acquisition of Science Materials for College and University Libraries," GN-541.1, 11/17/66
287,500	UNIVERSITY OF COLORADO, "Development of a Prototype System for Storage and Retrieval of Biological Information," GN-656, 6/20/67
449,825	GEORGIA INSTITUTE OF TECHNOLOGY, "A Research Program in Information Science and Engineering," GN-655, 6/22/67
19,800	WHITTENBURG, VAUGHAN ASSOCIATES, INC., "Preliminary Study of the Economic Aspects of Specialized Information Services," C-509, 3/16/67

CHEMICAL INFORMATION

$60,950	AMERICAN CHEMICAL SOCIETY/CHEMICAL ABSTRACTS SERVICE, "Experimental Development of a Mechanized Registry System for Chemical Compounds and for Research and Development in Selected Information Handling Problems," C-414.4, 11/25/66
59,700	AMERICAN CHEMICAL SOCIETY/CHEMICAL ABSTRACTS SERVICE, same as above, C-414.6, 1/20/67
214,900	AMERICAN CHEMICAL SOCIETY/CHEMICAL ABSTRACTS SERVICE, same as above, C-414.8, 6/19/67
498,700	AMERICAN CHEMICAL SOCIETY/CHEMICAL ABSTRACTS SERVICE, "Research and Development Related to the National Chemical Information Program," C-521, 6/26/67
117,600	COMMERCE DEPT./NATIONAL BUREAU OF STANDARDS, "NBS Research on a Generalized Computer File Organization and Search of Generic Chemical Structure," AG-69, 11/30/66
99,680	IIT RESEARCH INSTITUTE, INC., "Feasibility Study of the Development of a Specialized Computer System of Organic Chemical Signatures of Spectral Data," C-514, 4/17/67
10,769	JOHN I. THOMPSON & CO., "Planning Support and Services for the Chemical Information Program," C-447.2, 11/17/66
40,808	SCIENCE COMMUNICATION, INC., "Analysis of Current Chemical Data Compilations for Basic Information-Communication Units and Combinations," C-478, 7/6/66

DOMESTIC SCIENCE INFORMATION

Science Information Exchange

$350,000	SMITHSONIAN INSTITUTION, "Operation of the Science Information Exchange," C-473.3, 3/31/67

National Referral Center

$125,500	LIBRARY OF CONGRESS, "National Referral Center for Science and Technology," AG-1.2, 11/7/66
135,000	LIBRARY OF CONGRESS, same as above, AG-1.3, 6/19/67

Other Federal Projects

$140,000	U. S. DEPT. OF HEALTH, EDUCATION & WELFARE/OFFICE OF EDUCATION, "Partial Support of the University of Maryland Manpower Requirements Study," AG-90, 6/7/67
60	DEPT. OF COMMERCE/CLEARINGHOUSE, Purchase Order for Report by the Battelle Memorial Institute: "A Survey of Scientific-Information Manpower in Engineering and the Natural Sciences, 20 Copies," S-67-4, 5/8/67

Non-Federal Projects

$ 6,800	AMERICAN DOCUMENTATION INSTITUTE, Development of Seminar Tutorial Programs in Information Science," GN-657, 6/26/67
12,700	THE GEORGE WASHINGTON UNIVERSITY, "A Study of Scientific Journal Page Charge Practices," C-500, 4/12/67
50,000	NATIONAL ACADEMY OF SCIENCES/NATIONAL RESEARCH COUNCIL "General Support of a Council on Biological Sciences Information," C-310, T.O. 127, 1/6/67
15,900	SPECIAL LIBRARIES ASSOCIATION, "Current Literature Display on Information Science and Technology," GN-637, 6/19/67
18,700	SYRACUSE UNIVERSITY, "Study the Coverage of Chemistry Journals in <u>Nuclear Science Abstracts</u> and <u>Chemical Abstracts</u>," GN-612, 12/23/66
454	SYSTEM DEVELOPMENT CORPORATION, Purchase Order for 200 Copies @ $2.27 ea. of a Report Resulting from NSF/OSIS C-464, "A System Study of Abstracting and Indexing in the United States, TM-WD-394, 12/16/66," P.O. S-67-3, 2/3/67

FOREIGN SCIENCE INFORMATION

Translations

	Domestic/Slavic:
$15,100	AMERICAN GEOGRAPHICAL SOCIETY, "Selected Translation Journal, Soviet Geography: Review and Translation," GN-579, 10/17/66
47,000	AMERICAN GEOLOGICAL INSTITUTE, "Selective Translation Journal, Geochemistry International, Vol. IV (1967)," GN-580-10/17/66
119,200	AMERICAN GEOLOGICAL INSTITUTE, "Translation Journals: International Geology Review, Vol. IX (1967); and Doklady of the Academy of Sciences, USSR: Earth Science Sections, Vols.172-177," GN-581, 10/18/66
20,665	AMERICAN GEOLOGICAL INSTITUTE, "Support for Publication of Two Translations Entitled: Deep Seismic Sounding of the Earth's Crust in the USSR and Ore Deposits," GN-669, 6/19/67
17,100	AMERICAN GEOLOGICAL INSTITUTE, "Translation and Publication of Russian Journal, Paleontologicheskiy Zhurnal, Vol. 1967," GN-638, 6/26/67
20,500	AMERICAN GEOLOGICAL INSTITUTE, "Translation of Russian Monograph Chetvertichnyy period (Quaternary Period), Moscow 1965, Vols. I and II," GN-666, 6/20/67
109,300	AMERICAN GEOPHYSICAL UNION, "Translation Journals: Geodesy and Aerophotography; Geomagnetism and Aeronomy, Oceanology, Izvestiya of the Academy of Sciences USSR: Physics of the Solid Earth Series, Vols. 1967" GN-605, 12/22/66
21,000	AMERICAN GEOPHYSICAL UNION, "Selective Translation Journal, Soviet Hydrology: Selected Papers, Vol. 1967," GN-602, 1/16/67
7,000	AMERICAN GEOPHYSICAL UNION, "Production and Distribution of Soviet Hydrology: Selected Papers, Vol. 1966," GN-486.1, 2/8/67
30,000	AMERICAN GEOPHYSICAL UNION, "Translation and Publication of Russian Journal, Geotektonika, Vol. 1967," GN-639, 6/23/67
42,000	AMERICAN INSTITUTE OF CHEMICAL ENGINEERS, "Support for Selected Translation Journal, International Chemical Engineering, Vol. VII (1967)," GN-584, 10/17/66
10,100	AMERICAN MATHEMATICAL SOCIETY, "Support for Translation Journal, Soviet Mathematics--Doklady, Vol. VIII (1967)," GN-582, 10/17/66
24,000	AMERICAN SOCIETY OF CIVIL ENGINEERS, "Translation Journal, Hydrotechnical Construction, Vol. 1967," GN-596, 11/17/66
19,100	ENTOMOLOGICAL SOCIETY OF AMERICA, "Translation Journal, Entomological Review, Vol. 46 (1967)," GN-578, 10/17/66
42,200	INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC., "Translation Journals: Radio Engineering and Electronic Physics and Telecommunications and Radio Engineering, (1967)," GN-610, 12/23/66
19,000	INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC., "Translation Journal, Engineering Cybernetics, Vol. 1967," GN-611, 1/9/67
24,900	INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC., "Translation and Production of 1964 Issues of Three Russian Journals Under Two English Titles: Radio Engineering and Electronic Physics, and Telecommunications and Radio Engineering," GN-290.1, 6/29/67
10,600	INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC., "Support for Translation Journals: Radio Engineering and Electronic Physics and Telecommunications and Radio Engineering, Vols. 1967," GN-610.1, 6/27/67
21,400	THE OHIO STATE UNIVERSITY RESEARCH FOUNDATION, "Preparation and Translation of a Volume of Readings in Soviet Economic Geography," GN-593, 11/2/66
13,250	OPTICAL SOCIETY OF AMERICA, "Russian Translation Journal, Optics and Spectroscopy, Vol. XX (1967)," GN-614, 1/16/67
25,300	OPTICAL SOCIETY OF AMERICA, "Translation Journal, Optical-Mechanical Industry, Vols. 1966 and 1967," GN-620, 2/13/67
10,000	SOCIETY FOR INDUSTRIAL AND APPLIED MATHEMATICS, "Translation Journal, Theory of Probability and Its Applications, Vol. XII, 1967," GN-592, 11/17/66

14,100	SOCIETY FOR INDUSTRIAL AND APPLIED MATHEMATICS, "Translation and Publication of Selected Articles on Control Theory in the SIAM Journal on Control," GN-673, 6/20/67
43,[illegible]	SOIL SCIENCE SOCIETY OF AMERICA, "Support for Translation Journal, Soviet Soil Science, Vol. 1967," GN-603, 12/19/66
	Domestic/Oriental:
35,000	AMERICAN GEOLOGICAL INSTITUTE, "Translation and Publication of Selected Papers from Acta Geologica Sinica, Vols. 44, 45, 46, (1964, 1965, 1966)," GN-663, 6/22/67
66,170	AMERICAN INSTITUTE OF PHYSICS, "Translation, Publication and Distribution of Acta Physica Sinica, (1966)," GN-568, 8/2/66
19,000	AMERICAN MATHEMATICAL SOCIETY, "Support for Translation Journal, Chinese Mathematics--Acta, Vol. IX (1967)," GN-583, 10/17/66
33,000	BIOLOGICAL ABSTRACTS, INC., "Translation of three Japanese Monographs: Marine Aquiculture of 60 Species; Fresh Water Aquiculture; and Marine Aquiculture," GN-672, 6/26/67
26,000	ENTOMOLOGICAL SOCIETY OF AMERICA, "Translation, and Publication of Chinese Journal, Acta Entomologica Sinica," GN-645, 6/19/67
98,700	INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC., "Translation Journals: Electrical Engineering in Japan and Electronics and Communications in Japan, (1967)," GN-609, 12/23/66
25,650	INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC., "Production and Distribution of English Editions of Two Japanese Journals: Electronics and Communications in Japan, Vol. 49 (1966), and Electrical Engineering in Japan, Vol. 86 (1966)," GN-491.1, 6/26/67
$22,100	INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC., "Support for Translation Journals: Electrical Engineering in Japan, Vol. 87, (1967), and Electronics and Communications in Japan, Vol. 50, (1967)," GN-609.1, 6/27/67
12,300	INSTRUMENT SOCIETY OF AMERICA, "Translation Journal, Acta Automatica Sinica, Vol. 1966," GN-604, 12/19/66

Special Foreign Currency Translation Program

$685,000	ISRAEL:	C-244.12, 7/11/66 @ $20,000
		C-503 4/26/67 @ 665,000
180,000	YUGOSLAVIA:	C-251.15, 12/17/66 @ 80,000
		C-502.1, 6/29/67 @ 100,000
100,000	POLAND	C-250.15, 1/10/67
55,000	INDIA	C-466.2, 12/17/66
15,000	UNITED ARAB REPUBLIC,	C-474, 6/30/66 [Aug. '66 obligation/per C/FO]

Foreign Science Services and Publications

$3,300	AMERICAN INSTITUTE OF PHYSICS, "Conference of Editors of Primary Journals in Physics," GN-630, 5/8/67
11,430	CENTER FOR APPLIED LINGUISTICS, "Support of the Secretariat of the Committee on Linguistics in Documentation of the International Federation for Documentation," GN-618, 2/21/67
4,000	INTERNATIONAL ASSOCIATION OF TECHNOLOGICAL UNIVERSITY LIBRARIES, "Support of the Secretariat of the International Association of Technological University Libraries," GN-632, 5/15/67
60,800	COMMERCE DEPT./CLEARINGHOUSE, "Operational Functions of NSF's Special Foreign Currency Science Information Program, AG-59, 8/25/66
10,000	INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS, "Continued Partial Support of the ICSU Abstracting Board," GN-606, 1/10/67
16,000	LIBRARY OF CONGRESS, "Partial Support of the Publication of the World List of Future International Meetings," AG-84, 3/24/67
450	LIBRARY OF CONGRESS, same as above, Part I, World List..., AG-43.1,
46,450	NATIONAL ACADEMY OF SCIENCES/NATIONAL RESEARCH COUNCIL, "Support of the U. S. National Committee for the International Federation for Documentation (FID)," C-310, T.O. 41.5, 11/8/66
62,200	NATIONAL ACADEMY OF SCIENCES/NATIONAL RESEARCH COUNCIL, "Partial Support of the Central Office of the International Committee on Data for Science and Technology," C-310, T.O. 124, 12/13/66
32,200	NATIONAL FEDERATION OF SCIENCE ABSTRACTING AND INDEXING SERVICES, "Acquisition and Announcement of Journals from Mainland China," GN-642, 6/19/67
3,100	UNIVERSITY OF NORTH CAROLINA, "The American Standards Association, Sectional Subcommittee Z-39," GN-473.2, 3/13/67
48,915	SPECIAL LIBRARIES ASSOCIATION, "Operation of the Translation Center," GN-591, 10/17/66
32,215	SPECIAL LIBRARIES ASSOCIATION, "Translations Register-Index," GN-670, 6/26/67
16,215	SURVEYS AND RESEARCH CORPORATION, "Contract for Preparation of a Directory of Communist Chinese Research Institutes and Key Personnel," C-406.1, 6/29/67

PROGRAM/ACTIVITY SUMMARY
SCIENCE INFORMATION ACTIVITIES
FISCAL YEAR 1968

RESEARCH AND STUDIES

Communication Patterns

$29,100	AMERICAN INSTITUTE OF PHYSICS, "Studies of Elements of a Physics Information System," GN-549.1, 10/5/67
31,450	AMERICAN MATHEMATICAL SOCIETY, "A Conference on Communication Problems in the Mathematical Sciences," GN-702, 11/15/67, 12 mos.
73,300	UNIVERSITY OF MICHIGAN, "Integrative Mechanisms in Literature Growth," GN-716, 2/15/68, 12 mos.
5,500	NEW YORK UNIVERSITY, "Synthesis of Research on the Flow and Use of Scientific and Technical Information," GN-454.1, 8/1[illegible]/67, 14 mos.

Information Sources and Services

$ 2,379	AMERICAN INSTITUTE OF PHYSICS, "Committee Meetings and Seminars Looking Toward a Physics Information System," GN-629.1, 10/5/67
7,325	HUMAN RELATIONS AREA FILES, INC., Support of a Conference Entitled "Toward an Automated, Comprehensive, East Asian Bibliographic System" to be Held in New Haven, Conn. During Jan. 1968, GN-712, 12/26/67, 12 mos.
419	JOHN WILEY & SONS, INC., "Purchase of 31 copies of <u>Annual Review of Information Science and Technology</u>, Volume II," P. O. 68-426, 1/30/68
18,775	PITTSBURGH REGIONAL LIBRARY CENTER, "Evaluation of a Union List of Serials," GN-697, 1/8/68, 18 mos.
88,700	PURDUE RESEARCH FOUNDATION, "Operational Analysis of Information Systems," GN-759, 4/30/68, 24 mos.
9,400	STATE UNIVERSITY OF NEW YORK AT BUFFALO, "Demand Models for Books in Library Circulation Systems," GN-706, 3/20/68, 24 mos.

Organization and Searching

$142,100	CORNELL UNIVERSITY, "Automatic Document Retrieval System Procedures," GN-750, 5/22/68, 24 mos.
340,000	MASSACHUSETTS INSTITUTE OF TECHNOLOGY, "The Continuation of the Design, Development and Evaluation of an Unconventional Library Catalog," GN-774, 6/28/68, 24 mos.
96,250	UNIVERSITY OF PENNSYLVANIA, "Real-Time Video Console Indexing," GN-682, 8/25/67, 18 mos.
158,775	PRINCETON UNIVERSITY, "Research on the Improvement of Automatic and Computer-Aided Indexing and Related Means of Information A[illegible]," GN-709, 2/13/68, 24 mos.
137,400	SYSTEM DEVELOPMENT CORP., "Document Representation Techniques," GN-708, 1/24/68, 24 mos.

INFORMATION SYSTEMS

Other Information Retrieval

$15,000	AMERICAN GEOLOGICAL INSTITUTE, "Interorganizational Liaison in Micropaleontology," GN-622.2, 4/4/68, 14 mos.
92,800	AMERICAN INSTITUTE OF PHYSICS, "Additional Prerequisites for Development of a National Information System for Physics," GN-686, 9/13/67, 6 mos.
23,260	AMERICAN INSTITUTE OF PHYSICS, "Key Personnel Staffing for AIP Information Program," GN-646.1, 11/3/67
239,300	AMERICAN INSTITUTE OF PHYSICS, "Toward Development of a National Physics Information System," GN-710, 12/29/67, 6 mos.
55,000	AMERICAN INSTITUTE OF PHYSICS, same as above, GN-710.2, 6/24/68, 2 mos.
300,000	AMERICAN INSTITUTE OF PHYSICS, same as above, GN-710.3, 6/28/68, 10 mos.
143,300	AMERICAN INSTITUTE OF PHYSICS, "Maintenance of a Computer Store of Physics Information," GN-713, 12/29/67, 12 mos.
1,400	AMERICAN INSTITUTE OF PHYSICS, same as above, GN-713.1, 2/21/68
23,500	AMERICAN MATHEMATICAL SOCIETY, "Committee to Monitor Problems in Communication," GN-731, 1/29/68, 12 mos.
450,950	AMERICAN PSYCHOLOGICAL ASSOCIATION, "Development of a National Information System for Psychology: Definition Phase," GN-772, 6/10/68, 9 mos.
46,000	BIOLOGICAL ABSTRACTS, "Preparation of a Guide to the Vocabulary of Biological Information," GN-751, 4/30/68, 12 mos.
40,000	CENTER FOR APPLIED LINGUISTICS, "An Information-System Program for the Language Sciences, Stage Two: System Design," GN-771, 6/28/68, 4 mos.
19,000	THE ECONOMETRIC SOCIETY, "Development of Mechanization System for Biographical and Bibliographical Indexing," GN-734, 2/28/68, 24 mos.
42,950	ENTOMOLOGICAL SOCIETY OF AMERICA, "A System-Designed Entomological Data Center—A Feasibility Study," GN-773, 6/28/68, 12 mos.
168,500	UNITED ENGINEERING TRUSTEES, INC., "Preparation of an Engineered Plan for an Engineering Information and Data System," GN-760, 5/15/68, 10 mos.

Library Systems

$200,000	COLUMBIA UNIVERSITY, "Library System Development for a Large Research Library," GN-694, 1/22/68, 18 mos.
60,700	COLUMBIA UNIVERSITY, "Support of a Collaborative Program in Library System Development," GN-724, 3/15/68, 18 mos.
125,150	MASSACHUSETTS INSTITUTE OF TECHNOLOGY, "Technical Information System," GN-589.1, 1/31/68, 12 mos.
39,450	UNIVERSITY OF TEXAS, "Automation of Selected Library Reference Activities," GN-733, 2/8/68, 12 mos.
119,250	WILLIAM MARSH RICE UNIVERSITY, "A Science Improvement Program for the Gulf Coast Region," GN-758, 5/15/68, 17 mos.

Publication Systems

$15,600	AMERICAN INSTITUTE OF PHYSICS, "Experiments with Computers for Primary Journal Composition and a Variety of Related Services," GN-601.1, 11/3/67
2,800	AMERICAN INSTITUTE OF PHYSICS, "Current Communication in Physics: Initial Phase," GN-623.1, 11/3/67
152,000	AMERICAN MATHEMATICAL SOCIETY, "Implementation, Test, and Refinement of a Computer-Aided Journal Composition System for Mathematics," GN-690, 11/1/67, 14 mos.

INFORMATION SERVICES

Abstracting and Indexing

	A&I:
$78,000	AMERICAN MATHEMATICAL SOCIETY, "Preparation and Publication of Mathematical Reviews, Calendar Year 1967," GN-680, 8/4/67, 12 mos.
(78,000)	CYA/April 1968
43,000	AMERICAN MATHEMATICAL SOCIETY, "Preparation and Publication of a Cumulative Subject/Author Index for the Journal, Mathematics of Computation," GN-691, 12/28/67, 18 mos.
200,000	AMERICAN METEOROLOGICAL SOCIETY, "Preparation, Publication and Distribution of the 1968 Volume of Meteorological and GeoAstrophysical Abstracts (MGA) and a Cumulative Annual Index Relating Thereto," C-549, 5/31/68, 18 mos.
(63,120)	ESSA transfer for above @ $40,000, and $23,120 from DoD
108,900	AMERICAN PSYCHOLOGICAL ASSOCIATION, "Preparation and Publication of Psychological Abstracts for Calendar Year 1968," GN-743, 4/24/68, 12 mos.
26,900	AMERICAN SOCIETY FOR TESTING AND MATERIALS, "Preparation of a CODEN of Periodical Titles," GN-552.2, 2/13/68, 12 mos.
102,600	ASSOCIATION FOR SYMBOLIC LOGIC, "Preparation and Processing of Accumulated Review Materials for Publication in the Journal of Symbolic Logic," GN-280.1, 10/6/67, 36 mos.
145,000	ENGINEERING INDEX, INC., "Computerized Abstracting and Indexing Program in Plastics and Electrical/Electronics Engineering," GN-762, 5/23/68, 8 mos.
	Bibliographies and Specialized Indexes:
88,000	AMERICAN DOCUMENTATION INSTITUTE, "Preparation and Publication of the Annual Review of Information Science and Technology, Vols. III, IV, and V," GN-692, 11/3/67, 36 mos.
157,000	AMERICAN MUSEUM OF NATURAL HISTORY, "Bibliographic Service in Herpetology," GN-707, 1/8/68, 24 mos.
12,900	BOSTON UNIVERSITY, "Preparation of an International Bibliography and Trend Report on the Sociology of Marriage and Family Behavior," GN-575.1, 2/13/68
158,800	UNIVERSITY OF CALIFORNIA, SAN DIEGO, "Preparation of a Catalogue of Radiolaria," GN-687, 9/26/67, 36 mos.
6,000	INTERNATIONAL ASSOCIATION FOR PLANT TAXONOMY, "Publication of a Biosystematic Literature Survey 1945-64," GN-631, 7/24/67, 12 mos.
92,500	NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY, "Compilation and Publication of an Indexed-Annotated Bibliography of Geothermal Phenomena," GN-764, 5/24/68, 24 mos.
7,650	THE WILDLIFE SOCIETY, "Publication of a Third Ten-Year Index to the Journal of Wildlife Management," GN-684, 9/28/67, 12 mos.

Other Publications and Services

	Research Journals:
$26,000	AMERICAN ANTHROPOLOGICAL ASSOCIATION, "Publication of Basic Research Documents and of Book Reviews in Anthropology," GN-737, 3/19/68, 24 mos.
2,500	AMERICAN SOCIETY OF BIOLOGICAL CHEMISTS, INC., "Xographic Illustration of Lysozyme Model," GN-736, 3/8/68, 6 mos.
15,000	CLARK UNIVERSITY, "Publication of the Journal, Economic Geography," GN-683, 9/13/67, 36 mos.
480,000	GEOLOGICAL SOCIETY OF AMERICA, "Accelerated Publication Program of the Geological Society of America," GN-693, 2/9/68, 24 mos.
13,200	REGIONAL SCIENCE RESEARCH INSTITUTE, "Publication of the Journal of Regional Science," GN-730, 2/15/68, 36 mos.
14,400	WILLIAM MARSH RICE UNIVERSITY, "Publication of a Journal, Public Choice," GN-721, 2/20/68, 36 mos.

Monographs:

38,700 AMERICAN GEOGRAPHICAL SOCIETY, "Publication of American Activities in the Antarctic, 1775-1948," GN-741, 4/15/68, 18 mos.

9,480 BERNICE P. BISHOP MUSEUM, "Publication of Three Pacific Insects Monographs," GN-745, 5/16/68, 12 mos.

18,500 BERNICE P. BISHOP MUSEUM, "Partial Publication Support for the Insects of Micronesia Series," GN-160.2, 6/28/68, 12 mos.

8,800 UNIVERSITY OF CHICAGO, "Publication of Spectroscopic Astrophysics," GN-703, 1/17/68, 12 mos.

8,000 CORNELL UNIVERSITY, "Publication of Faunal Adjustments in the Naturalization of Malus," GN-749, 6/28/68, 15 mos. (excludes the $5,000 contributed by BMS)

2,375 HARVARD UNIVERSITY, "Publication of Fish, Amphibian and Reptile Remains from Archaeological Sites: Part I," GN-685, 9/12/67, 12 mos.

6,950 UNIVERSITY OF IDAHO, "Publication of a Monograph on North American Indian Sorcery," GN-728, 1/23/68, 12 mos.

3,840 LOS ANGELES COUNTY MUSEUM OF NATURAL HISTORY FOUNDATION, "Publication of a Monograph on Early Miocene Faunas," GN-757, 6/10/68, 12 mos.

6,450 UNIVERSITY OF MIAMI, "Publication of Dinoflagellates of the Caribbean Region," GN-717, 2/7/68, 12 mos.

6,360 UNIVERSITY OF MIAMI, "Publication of A Revision of the Genera Brissopsis, Plethotaenia, Palaeopneustes, and Savinlaster," GN-718, 2/7/68, 12 mos.

9,430 UNIVERSITY OF MIAMI, "Publication of Stomatopod Crustacea of the Western Atlantic," GN-719, 1/23/68, 12 mos.

$1,000 UNIVERSITY OF MINNESOTA, "Publication of A Review of Mutillid Genus Glyphotes Blake," GN-678, 7/27/67, 12 mos.

22,300 THE NEW YORK BOTANICAL GARDEN, "Publication of The Hepaticae and Anthocerotae of North America, Volume II," GN-679, 10/5/67, 12 mos.

18,000 PENNSYLVANIA STATE UNIVERSITY, "Preparation of a Critical Review on the Crystal Chemistry of Non-Metallic Materials," GN-744, 4/14/68, 24 mos.

40,300 TEXAS A & M RESEARCH FOUNDATION, "Publication of Scientific Results of the R/V ANTON BRUUN Program in the Southeastern Pacific Ocean," GN-662.1, 6/24/68, 15 mos.

Other Services:

190,000 AMERICAN GEOLOGICAL INSTITUTE, "Planning an Information System Program for the Geological Sciences, Phase I: Staffing and Communications Support," GN-752, 6/3/68, 24 mos.

76,800 AMERICAN MATHEMATICAL SOCIETY, "Mathematical Offprint Service," GN-747, 5/15/68, 12 mos.

12,700 AMERICAN MUSEUM OF NATURAL HISTORY, "Preparation of a Procedural Manual for Micropaleontological Data Projects," GN-766, 5/22/68, 6 mos.

50,000 CENTER FOR RESEARCH LIBRARIES, "Partial Support of the Scientific Journals Center," GN-746, 4/26/68, 12 mos.

SPECIAL PROJECTS

$55,200	UNIVERSITY OF ARIZONA, "Preparation of a Prototype Machine-Readable Subject Index for Desert Environments Information," GN-735, 2/28/68, 18 mos.
268,150	LEHIGH UNIVERSITY, "Prototype Retrieval System Development Within an Information Resource Laboratory," GN-668, 9/19/67, 24 mos.
365,800	OHIO STATE UNIVERSITY RESEARCH FOUNDATION, "Computer and Information Science Research Center," GN-534.1, 4/10/68, 12 mos.
274,600	STANFORD UNIVERSITY, "Development of a Physics Information Retrieval System," GN-742, 5/16/68, 12 mos.
32,786	WHITTENBURG, VAUGHAN ASSOCIATES, INC., "A Preliminary Study of the Economic Aspects of Specialized Information Services," C-509.1, 11/15/67, 12 mos.
1,290	WHITTENBURG, VAUGHAN ASSOCIATES, INC., same as above, C-509.2, 6/7/68

CHEMICAL INFORMATION

$ 3,242	AMERICAN CHEMICAL SOCIETY, "Systems Requirements Analysis for Disseminating Primary Literature," GN-563.1, 8/18/67
152,000	AMERICAN CHEMICAL SOCIETY, "Implementation of the Role of the Computer in Scientific Publication," GN-740, 4/10/68, 9 mos.
655,000	AMERICAN CHEMICAL SOCIETY/CHEMICAL ABSTRACTS SERVICE, "Experimental Development of a Mechanized Registry System for Chemical Compounds and for Research and Development in Selected Information Handling Problems," C-414.10, 11/2/67
33,000	ACS/CAS, same as above, C-414.11, 11/17/67
754,600	ACS/CAS, same as above, C-414.12, 6/7/68, 9 mos.
520,600	ACS/CAS, same as above, C-414.13, 6/7/68, 6 mos.
1,119,564	ACS/CAS, same as above, C-414.14, 6/21/68, 4 mos.
310,000	AMERICAN CHEMICAL SOCIETY/CHEMICAL ABSTRACTS SERVICE, "Research and Development Related to the National Chemical Information Program," C-521.1, 8/28/67
96,800	ACS/CAS, same as above, C-521.2, 4/30/68
136,900	ACS/CAS, same as above, C-521.3, 5/13/68, 4 mos.
162,180	ACS/CAS, same as above, C-521.4, 6/27/68, 3 mos.
150,281	IIT RESEARCH INSTITUTE, "Establishment of a Chemical Information Center in Order to Develop a Capacility to Educate and Assist Industry in such a Manner so as to Link Industry (and to a lesser degree, academia) to Chemical Information," C-554, 6/26/68, 12 mos. (excludes the $10,615 contributed by GES)
1,650	INFORMATION MANAGEMENT, INC., "Preparation of a Precis of the Study An Overview of Worldwide Chemical Information Facilities and Resources," C-538, 10/4/67, 1 mo.
45,000	JOHN I. THOMPSON & COMPANY, "The Producing of Expository Information on the Discipline-Oriented, Computer-Based Chemical Information System Being Developed Primarily by the Chemical Abstracts Service of the American Chemical Society," C-551, 5/1/68, 12 mos.
145,218	UNIVERSITY OF PENNSYLVANIA, "A Study of Large Scale Chemical File Organization and Programs for Display of Structural Formulas," C-547, 4/23/68, 13 mos.
120,000	UNIVERSITY OF PITTSBURGH, "A Chemical Information Center Experimental Station," GN-738, 3/20/68, 6 mos.

DOMESTIC SCIENCE INFORMATION

Science Information Exchange

$ 310,000	SMITHSONIAN INSTITUTION, "Operation of the Science Information Exchange," C-437.4, 8/28/67, 2 mos.
1,540,000	SMITHSONIAN INSTITUTION, same as above, C-437.5, 11/17/67, 10 mos.
150,000	SMITHSONIAN INSTITUTION, same as above, C-437.6, 3/8/68

Other Federal Projects

$45,000	GENERAL SERVICES ADMINISTRATION, Oceanographic Management Data Studies," MOR 68-27, 9/15/67
30,500	COMMERCE DEPT./National Bureau of Standards, "Sherwin Task Group," AG-132, 12/29/67, 5 mos.
8,000	ROSENBLUM, Marcus (individual), "Preparation of the Text for the Brochure Entitled Science Information: Yesterday, Today and Tomorrow," C-555, 6/7/68, 5 mos.
174,687	PEAT, MARWICK, LIVINGSTON AND COMPANY, "A Study of Government-Wide Scientific and Technical Research Project Reporting Systems," C-563, 6/19/68, 6 mos.
25,000	ROME AIR DEVELOPMENT CENTER, "Publication of Third Edition of COSATI Inventory of R&D in Information Sciences Technology," AG-162, 6/10/68, 12 mos.

Non-Federal Projects

$2,000	AMERICAN GEOLOGICAL INSTITUTE, "Partial Support for the First Meeting of the Association of Earth Science Editors," GN-688, 9/26/67, 6 mos.
26,700	ASSOCIATION OF AMERICAN UNIVERSITY PRESSES, INC., "Conference on Future Documentation and Information Handling Techniques," GN-700, 3/19/68, 9 mos.
26,135	HERNER AND COMPANY, "The Preparation of Current Research and Development in Scientific Documentation, No. 15," C-536, 1/3/68, 13 mos.
37,000	JOINT COMMITTEE ON THE UNION LIST OF SERIALS, INC., "Serials Data Program," GN-704, 1/8/68, 11 mos.
42,020	NATIONAL ACADEMY OF SCIENCES, "Support of the Office of Critical Tables," C-310/T.O. #146, 4/8/68, 5 mos.
21,900	WOLF RESEARCH AND DEVELOPMENT CORPORATION, "Survey of Professional Scientific Societies," C-550, 5/3/68, 5 mos.

FOREIGN SCIENCE INFORMATION

Translations

Domestic/Slavic:

$15,955	AMERICAN FISHERIES SOCIETY, "Translation Journal, Problems of Ichthyology (1968 Vol.)," GN-715, 1/24/68, 18 mos.
8,071	AMERICAN FISHERIES SOCIETY, same as above, GN-715.1, 5/16/68
17,300	AMERICAN GEOGRAPHICAL SOCIETY, "Selected Translation Journal, Soviet Geography: Review and Translation, Vol. IX, (1968)," GN-695, 12/27/67, 18 mos.
102,066	AMERICAN GEOLOGICAL INSTITUTE, "Translation Journals: International Geology Review, Doklady--Earth Sciences Section, Paleontology, and Geochemistry International (Vols. 1968)," GN-726, 2/8/68, 18 mos.
9,290	AMERICAN GEOLOGICAL INSTITUTE, "Translation of Russian Monograph Chetvertichnyy Period (Quaternary Period), Moscow 1967 (Vol. III)," GN-767, 6/28/68, 12 mos.
136,800	AMERICAN GEOPHYSICAL UNION, "Translation Journals: Soviet Hydrology, Atmospheric and Oceanic Physics, Physics of the Solid Earth, Geomagnetism and Aeronomy, Geodesy and Aerophotography, Oceanology, and Geotectonics (Vols. 1968)," GN-725, 2/13/68, 24 mos.
18,400	AMERICAN INSTITUTE OF CHEMICAL ENGINEERS, "Selected Translation Journal, International Chemical Engineering, Vol. VIII (1968)," GN-696, 1/5/68, 18 mos.
233	AMERICAN INSTITUTE OF PHYSICS, "Scientific Editing of an English Translation of D. Ya. Martynov's Book, A Course in Practical Astrophysics," GN-397.1, 11/15/67
22,600	AMERICAN SOCIETY OF CIVIL ENGINEERS, "Translation Journal, Hydrotechnical Construction, Vol. 1968," GN-701, 1/9/68, 24 mos.
19,175	AMERICAN SOCIETY OF MECHANICAL ENGINEERS, "Selected Translation Journal, Heat Transfer Bimonthly - Soviet Research," GN-754, 6/6/68, 18 mos.
12,600	ENTOMOLOGICAL SOCIETY OF AMERICA, "Translation Journal, Entomological Review, Vol. 47 (1968)," GN-699, 1/9/68, 18 mos.
11,800	INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC., "Translation Journal, Soviet Automatic Control (Vol. 1968)," GN-720, 5/24/68, 18 mos.
6,500	OHIO STATE UNIVERSITY RESEARCH FOUNDATION, "Preparation and Translation of a Volume of Readings in Soviet Economic Geography," GN-593.1, 4/4/68, 8 mos.
24,600	SOCIETY FOR INDUSTRIAL AND APPLIED MATHEMATICS, "Monograph, Problems of Hydrodynamics and Continuum Mechanics," GN-711, 1/3/68, 12 mos.
9,700	SOCIETY FOR INDUSTRIAL AND APPLIED MATHEMATICS, "Translation Journal, Theory of Probability and Its Applications, Volume 13, 1968," GN-733, 2/1/68, 18 mos.
45,008	SOIL SCIENCE SOCIETY OF AMERICA, "Translation Journal, Soviet Soil Science, Vol. 1968," GN-705, 1/4/68, 18 mos.
5,750	SOIL SCIENCE SOCIETY OF AMERICA, same as above, GN-705.1, 2/12/68
9,500	SOIL SCIENCE SOCIETY OF AMERICA, "Support for Translation Journal, Soviet Soil Science, Vol. 1967," GN-603.1, 2/15/68, 6 mos.

	Domestic/Oriental:
$21,400	AMERICAN MATHEMATICAL SOCIETY, "Translation Journal, Chinese Mathematics — Acta, Vol. X, (2 issues 1956, and 4 issues 1957)," GN-748, 4/30/68, 24 mos.
100,500	INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC., "Translation Journals: Electrical Engineering in Japan, and Electronics and Communications in Japan," GN-698, 5/24/68, 18 mos.
15,200	INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC., "Four-Part Monograph: Electronics in Mainland China," GN-714, 5/24/68, 18 mos.

Special Foreign Currency Translation Program

$525,000	ISRAEL	C-503.3, 1/26/68
225,000	POLAND	C-501.2, 1/26/68
175,000	YUGOSLAVIA	C-502.3, 2/2/68
50,000	INDIA	C-466.4, 2/2/68
25,000	TUNISIA	C-504.1, 1/23/68

Foreign Science Services and Publications

$3,542	AMERICAN CHEMICAL SOCIETY, "Symposium on Notation Systems," to be held in San Francisco, Calif. during March and April 1968, GN-723, 1/18/68, 6 mos.
20,000	BERNICE P. BISHOP MUSEUM, "Partial Support of the Permanent Secretariat of the Pacific Science Association," GN-681, 8/15/67, 60 mos.
200	CALIFORNIA INSTITUTE OF INTERNATIONAL STUDIES, "Preparation of a Report on Science Information in Middle and South America," GN-438.1, 5/16/68
15,423	CENTER FOR APPLIED LINGUISTICS, "Support of the Secretariat of the Committee on Linguistics in Documentation of the International Federation for Documentation," GN-761, 6/10/68, 12 mos.
54,000	COMMERCE DEPT./Clearinghouse for Federal Scientific and Technical Information, "Operational Functions for NSF's Special Foreign Currency Science Information Program, FY 1968," AG-117, 8/28/67, 12 mos.
54,200	COMMERCE DEPT./Clearinghouse for Federal Scientific and Technical Information, "Operational Functions for NSF's Special Foreign Currency Science Information Program, FY 1969," AG-152, 6/24/68, 12 mos.
479	INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC., "IEE International Convention," New York City, March 18-21, 1968, GN-722, 1/17/68, 6 mos.
5,695	INTERNATIONAL BUSINESS MACHINES CORP., "Purchase of Eight IBM Electric Typewriters and Shipment of Same to NSF/New Delhi, India for Loan to the Indian National Scientific Documentation Centre (INSDOC), NSF Contractor under C-466," P.O. 68-639, 5/17/68
10,000	INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS, "Continued Partial Support of the ICSU Abstracting Board," GN-727, 2/1/68, 12 mos.
21,280	LIBRARY OF CONGRESS, "Partial Support of the Publication of the World List of Future International Meetings," AG-135, 2/28/68, 12 mos.
54,050	NATIONAL ACADEMY OF SCIENCES, "Support of the U. S. National Committee for the International Federation for Documentation (FID)," C-310/T.O. #41.6, 12/1/67, 12 mos.
3,000	NATIONAL ACADEMY OF SCIENCES, same as above, C-310/T.O. #41.7, 6/26/68
55,783	SPECIAL LIBRARIES ASSOCIATION, "Operation of the Translation Center," GN-729, 1/22/68, 12 mos.
4,650	SPECIAL LIBRARIES ASSOCIATION, same as above, GN-729.1, 5/24/68
9,952	SPECIAL LIBRARIES ASSOCIATION, "Compilation and Publication of a Cumulative Index to Scientific and Technical Translations," GN-523.1, 5/24/68

Mr. PUCINSKI. Do you think that by paying for the travel of scientists to meetings that this is what the Congress intended when it said to foster the interchange of scientific information among scientists in the United States and foreign countries? Do you think that the junkets that you are paying for is what the Congress intended?

Mr. BELL. May I interrupt just a second. Although your concern is directly under the National Science Foundation, do you have an independent capacity?

Dr. ADKINSON. No, I don't.

Mr. BELL. Are all the people you send on trips sent for the National Science Foundation or does the National Science Foundation send some and you send some?

Dr. ADKINSON. The Office of Science Information Service is a unit of the National Science Foundation. When you ask how many people have been sent I gave the total number for the whole National Science Foundation.

Mr. BELL. Mr. Chairman, I must object on behalf of the witness for the use of the word junket. I think the reference to junkets is a bit unfair as though these were pleasure trips. There is obviously good need for many of these trips and I don't think we ought to use the word junket.

Mr. PUCINSKI. I think that because it has been so popularly accepted that every time a Member of Congress takes an investigation trip it is called a junket, that I don't know why we should——

Mr. BELL. These are people of the Government and we are not a newspaper organization interviewing them.

Mr. PUCINSKI. Let's strike the word junket.

As I understand the Science Information Service was established as part of the great awakening of this country to the lack of our scientific pursuits, especially when Sputnik was launched.

This Agency of yours, the Science Information Service, was created to perform a specific service, not to duplicate the National Science Foundation.

Now, the National Science Foundation had been in business for a long time before that, hadn't it?

Dr. ADKINSON. It started in 1950, but it had a unit which was known as the Office of Scientific Information, and that is what I moved to the Foundation in 1957 to head. Then that unit's name was changed and the assignment of NDEA title 9 was more specific.

Mr. PUCINSKI. What percentage of your annual budget, Dr. Adkinson, would go for the payment of these trips by the scientists? You say you received approximately $11 million a year. What percentage of your budget goes for the payment of these 700 or so scientists whom you assist in making these trips?

Dr. ADKINSON. Let me make sure that we understand one another. The Office of Science Information Service' budget alone paying for trips related to scientific information activities will represent way less than 1 percent of the budget. For the 750 that I mentioned, for the whole Foundation, that runs in the neighborhood of around $450,000 out of a budget of $450-some million.

Mr. PUCINSKI. You said in your testimony that you do not believe that it is desirable at present to establish by legislation a formal national information system?

Dr. ADKINSON. Yes.

Mr. PUCINSKI. The reason for this legislation is to try to get your agency to do what you should have been doing the last 10 years or 11 years and apparently have not been doing.

Section 3 of the act, title 9, setting up a Science Information Service, section 901 says:

The National Science Foundation shall establish a Science Information Service. The Foundation, through such service, shall, one, provide or arrange for the provision of indexing, abstracting, translating, and other services leading to a more effective dissemination of scientific information; and, two, undertake programs to develop new or improved methods including mechanized systems for making scientific information available.

Where, under section 901, Dr. Adkinson, is there any authority in your judgment to subsidize these trips by scientists? Where does that come into the language of 901?

Dr. ADKINSON. It doesn't. It comes into the enabling legislation of the Foundation to foster the interchange.

Mr. PUCINSKI. What I would like to know at this time is what percentage of your $11 million goes for the subsidizing of these trips?

Dr. ADKINSON. $5,000, roughly.

Mr. PUCINSKI. $5,000?

Dr. ADKINSON. Yes.

Mr. PUCINSKI. A total of $5,000?

Dr. ADKINSON. Out of the $11 million.

Mr. PUCINSKI. For the 700 scientists?

Dr. ADKINSON. I said that is for the total Foundation.

Mr. PUCINSKI. In other words, we are not correct in assuming that you are subsidizing these trips?

Dr. ADKINSON. We use about $5,000 a year to subsidize trips of scientists going to meetings whose subject in scientific information. The Foundation subsidizes around 700 to go to scientific meetings.

Mr. PUCINSKI. All right. Would you tell the committee what provisions you have in the Science Information Service for providing indexing and abstracting and translating and other services leading to a more effective dissemination of scientific information? You talked about translation. What part of your budget goes for translation?

Dr. ADKINSON. About 10 percent.

Mr. PUCINSKI. About a million dollars.

Dr. ADKINSON. Yes.

Mr. PUCINSKI. And this is translation of what, Dr. Adkinson?

Dr. ADKINSON. Translation of scientific and technical materials from Russian, Chinese and from Japanese. This translation is done by scientific societies. We furnish funds to them on a deficit basis. In other words, we ask them to sell this product and we agree to pick up the deficit. A large number of the journals that have been started are self-supporting now and we don't have to support them. We have started additional ones where the societies felt they were necessary. So that in total we have stimulated the publication of about 65 translation journals.

Mr. PUCINSKI. What happens to these translations after you get them? Are these translations into English?

Dr. ADKINSON. Yes.

Mr. PUCINSKI. What happens after that?

Dr. ADKINSON. They are sold to the people who wish them, to libraries and scientists and research institutions. They are sold overseas. A lot of the translations from Russian that is done in the United States is purchased in Great Britain, France, and Japan, for the use of the scientists there.

Mr. PUCINSKI. How do you decide which materials are to be translated?

Dr. ADKINSON. The scientific societies have committees that make that selection. We do not. For the Public Law 480 program where we have foreign credits, scientists within the Government make that selection.

Mr. PUCINSKI. You say you translated about 65 documents last year?

Dr. ADKINSON. 65 journals.

Mr. PUCINSKI. 65 journals at a cost of a million dollars?

Dr. ADKINSON. I have forgotten how many pages we supported in translation in both of our programs, but it is over 100,000.

Mr. PUCINSKI. Now these 65 journals and the $1 million, does that also include the Public Law 480 funds or is this in additi[illegible] Public Law 480 funds?

Dr. ADKINSON. The Public Law 480 funds would be anot[illegible] [illegible]hly $900,000.

Mr. PUCINSKI. So you spent, roughly, $2 million on translating 65 documents?

Dr. ADKINSON. No; I said they were journals that were translated, there were a lot of books, that were translated, there were patents that were translated, there were abstracts that were translated, there was a lot of materials that were translated.

Mr. PUCINSKI. How many documents do you think you translated last year?

Dr. ADKINSON. I cannot give you the figure, but I can furnish it for the record.

Mr. PUCINSKI. Take a stab in the dark.

Dr. ADKINSON. Let me look, maybe I can get you a little better picture than that by not stabbing.

Mr. DUBESTER. Mr. Chairman, I think it is important to recognize that every translated journal has on the average about eight articles in an issue. Each journal has about four or five issues each year. If you multiply the 10 articles by the four issues, and by the 65 journals, you come out with a significant number of articles which I think is what you mean by documents. It comes to quite a number of hundreds of documents. The same thing is true in the foreign area where our best standard count is one of pages, because there are many different kinds of materials—some are books, some are articles, some are documents, and a common denominator is a page count. Here we count in the thousands of pages each year.

Actually, this has been a very important way of getting foreign information to our scientists and on that score we have evidence of appreciation of the agencies and the scientific community.

Mr. PUCINSKI. You did all that for a million American dollars and $900,000 counterpart?

Mr. DUBESTER. Exactly.

Mr. PUCINSKI. Do you think you could get very much done for that kind of money?

Dr. ADKINSON. We hope to get more in our next appropriation request. We have asked for an additional $2 million of counterpart funds.

Mr. PUCINSKI. You heard Dr. Seaborg testify this morning about the mountain of material that is now being generated throughout the world. Do you really think that you are making any kind of contribution other than just absolute abstract tokenism in the field of translation when you come before this committee and try to tell us that your system now is sufficient to do the job in its present form, when we have testimony of witness after witness as to the enormity of the challenge and problem ahead of us?

Dr. ADKINSON. On the side of translation, sir, our translation program does not fill all of the needs, but it certainly has filled many of the important needs of the scientists. There are requests standing in line, but it is a significant program.

Now, I have said nothing about our support to the abstracting services and the mention was made here this morning of the American Chemical Society. We have been working with the American Chemical Society since 1959 and we put in half of the development funds at the present time for that big system, and we have helped them to develop this relationship with Great Britain.

Mr. PUCINSKI. What role did your agency play in developing that agreement between the American Chemical Society and the British society?

Dr. ADKINSON. It happened to be that I was in Europe several times discussing this with the British Government, because the British had to assist the chemists in Great Britain. I discussed the American program with them and showed them it was to their advantage to assist in it.

We have also encouraged the American Chemical Society to participate in the OECD that I mentioned earlier where they are talking to many of the countries and beginning to formulate plans so they can have interaction between many countries and the American Chemical Society.

Mr. PUCINSKI. How much did you spend last year on abstracting?

Dr. ADKINSON. Roughly about a million dollars.

Mr. PUCINSKI. How much did you spend on indexing?

Dr. ADKINSON. We spent $600,000 last year in support of abstracting and indexing services. That would have gone to places like biological abstracts, engineering index, services of that type, so they could do a better and faster job.

Mr. PUCINSKI. What new programs have you developed to make scientific information more available?

Dr. ADKINSON. It is a little hard to answer. Let me put it this way: We have furnished support to places like chemical abstract service to start their new chemical titles which is a very popular thing; it became a computerized service as well as a published service.

We have assisted and are assisting the American Institute of Physics right now in their advanced indexing system. We have assisted the engineering index in developing a new system that speeded up their service by not a few weeks but by months and months. We have helped biological abstract to come out with several new services and I could go on and mention others.

Mr. PUCINSKI. Specifically, what was the nature of that help?

Dr. ADKINSON. Financial help.

Mr. PUCINSKI. How much?

Dr. ADKINSON. I can't give you the exact amount for each one of those because I have given you the total for 1 year, the previous year for abstracting and indexing we had $400,000, but in 1966 it was a million dollars.

Mr. PUCINSKI. I have a series of other questions, but I would like to yield to my colleague at this point, Mr. Bell.

Mr. BELL. Thank you, Mr. Chairman.

Mr. Chairman, I regret that I was not present at the beginning and I don't know yet just how I feel about this bill. I have an open mind on it. But did Dr. Seaborg endorse this bill?

Mr. PUCINSKI. Well, Dr. Seaborg's statement is here. He does not endorse the bill. He said, "In conclusion, Mr. Chairman, I would like to state my opinion that the pending bill is on sound ground in calling for cooperative efforts."

Mr. BELL. He endorses the philosophy of it.

Mr. PUCINSKI. Dr. Seaborg's testimony was that he showed us, rather than addr himself to the bill, the problems that exist and the various things t have to be done before we could effectively get into an information stem like this.

Mr. BELL. I would like to ask Dr. Adkinson something. In summary, why are you opposed to this bill?

Dr. ADKINSON. The National Science Foundation and the Bureau of the Budget's position is that we have all the authority that is necessary, legal authority, at the present time to do the things that are necessary under the act. It doesn't extend the authority, it emphasizes certain particular things and so the Foundation's position and the Bureau of the Budget's position is that it isn't necessary. I think I am stating them correctly. Legal counsel can correct me.

Mr. BELL. You have that authority to do this?

Dr. ADKINSON. Yes.

Mr. BELL. Have you been working in the direction of doing this?

Dr. ADKINSON. Yes, with the resources we have.

Mr. BELL. Do you think it is possible to achieve the requests of this bill?

Dr. ADKINSON. I think it will be possible but it is an evolutionary process that will take a long time, several years.

Mr. BELL. Let me ask you another type of question, Doctor. Do you think the scientists, the American scientists, actually have time to take a lot of trips?

Dr. ADKINSON. I think it is——

Mr. BELL. Unnecessary trips?

Dr. ADKINSON. You have changed the question.

Mr. BELL. Questionable trips, put it that way.

Dr. ADKINSON. I would like to put it this way, Mr. Bell, that scientists need to travel to other countries where good research is going on and to discuss what their counterparts are doing in other countries, so there is a necessity for that travel for that purpose; also, to go to meetings where they can exchange advanced ideas, where scientists from several countries meet. These trips have accrued to the advantage of U.S. scientists.

Mr. BELL. The principle, as I understand it, of both this bill, which the chairman espouses, and of what you were all driving for basically is to try to develop a central knowledge of the problems that exist in science throughout the world, so that they can be analyzed and digested. Having scientists travel to attend scientific meetings where such problems are discussed, seems basically a move in the direction of accomplishing the very thing that the chairman wants to see accomplished.

Dr. ADKINSON. It is one of the things and one of the things that Dr. Seaborg mentioned, it is one of the mechanisms.

Mr. BELL. And don't misunderstand me, Mr. Chairman, I am not taking issue with you on this.

Mr. PUCINSKI. Will you yield at this point?

Mr. BELL. Yes.

Mr. PUCINSKI. I would be the last man in the world to ever deny a scientist a trip; of course they are necessary. I think trips are necessary for Members of the Congress, I think they are necessary for scholars, I think they are necessary for scientists. And if the National Science Foundation wants to fund or assist these scientists in their travels, I am all for it. I think that the exchange of ideas is the very lifeblood of our scientific community.

The point that I made here, if my colleague will bear with me, was that it is not the function of the Science Information Service, as its functions are spelled out rather concisely and clearly in section 901.

Mr. BELL. Is it the function of the National Science Foundation?

Mr. PUCINSKI. Yes; of course it is. This whole discussion is now academic because apparently we misunderstood each other. If I understand the witness now, Office of Science Information Service really didn't support any extensive trips. I think he said 11 scientists at a cost of some $5,000 or something like that and I presume it was in connection with some of the duties spelled out in section 901. We had originally understood the witness to say that the Science Information Service had funded some 700.

Mr. BELL. That was the National Science Foundation.

Mr. PUCINSKI. You see the Science Information Service is an adjunct, an agency of the National Science Foundation. And I stress here that I have no criticism of the National Science Foundation sending all the scientists they want wherever they think they can be of any value to themselves or their country or their profession.

But the discussion on trips apparently came up from a misunderstanding in that the Science Information Service, we thought, was funding these various trips and I merely made the point that that was not the function of S.I.S. It is the function of the National Science Foundation.

Mr. BELL. You are splitting this on the basis of my question a few moments ago as to whether or not the Science Information Service should do it or whether the National Science Foundation should do it.

Mr. PUCINSKI. Yes.

Mr. BELL. Now, the witness, as I understand it, was speaking for the National Science Foundation when he made that comment. He wasn't speaking for the information organization.

Mr. PUCINSKI. We have no quarrel with the National Science Foundation sending scientists. We would be very critical if the Science Information Service were depleting its very limited funds spelled out for specific purposes in section 901. If SIS were using these funds for these trips, then I must say I would be very, very critical.

Mr. BELL. Would you care to comment on that?

Dr. ADKINSON. May I add one thing?

If you will turn to section 903 of NDEA, title 9, it says, "In carrying out its functions under this title," that is title 9, "the National Science Foundation shall have the same power and authority it has under the National Science Foundation Act of 1950 to carry out its functions under that act."

In other words, it also gives the Foundation and the Office of Science Information the authority of the whole Foundation.

Mr. BELL. So you were actually speaking for the National Science Foundation as a total organization. So you have no quarrel at all.

Mr. ADKINSON. I have no quarrel at all with the question. It was a misunderstanding.

Mr. BELL. All I am trying to do is clear that up.

Mr. PUCINSKI. I think that we ought to have clear in this record the relationship of the Science Information Service with the National Science Foundation. I don't know, Mr. Adkinson, whether you have been authorized by the Chairman of the National Science Foundation to speak for the Foundation.

Mr. ADKINSON. I have, sir.

Mr. PUCINSKI. You are, as far as I know, a satellite of the Science Foundation. The National Science Foundation has many agencies and you are subordinate to the National Science Foundation. You are an agency of the National Science Foundation.

So I don't see where calling our attention to 903 in any way alters your position. Your function as the Science Information Service is specifically and categorically spelled out in section 901. You do not have the broad functions of the National Science Foundation and the language is very clear in the bill. And I think record should show it.

If the National Science Foundation wants to send scientists all over the world, fine, I am for it. I support it. I think they ought to do it. I think it helps the interchange and exchange of information.

But I want to address myself this afternoon to your functions as the Director of the Science Information Service and to your functions as spelled out in the section 901. I am not interested at this point in what the National Science Foundation, itself, is doing. We will have ample opportunity for that testimony at some later date.

I will continue to yield to my colleague from California.

Mr. BELL. Let Mr. Adkinson answer.

Dr. ADKINSON. I would rather turn that over to my legal counsel.

Mr. MAECHLING. The Science Information Service is an integral part of the National Science Foundation. Dr. Adkinson and his Service derive their authority just as much from section 3(a)3 of the National Science Foundation Act as from the National Defense Education Act. And if the National Science Foundation had acted in 1957 when Dr. Adkinson arrived, it could have set up the Science Information Service in much the same form as it is set up now and it could have performed precisely the same functions as it is performing now.

When I say "now," I also mean for the foreseeable future. This does not mean, however, that if the Science Information Service were to go off and embark on a really large-scale program of subsidizing a national information system, and so forth, that additional legislation would not be desirable. Because, after all, the Science Foundation has been set up to support basic research and education in the sciences. Today the Foundation's authority has been expanded to include applied research, but generally the mission of the Foundation remains fairly set and we consider Science Information as an integral part of that mission.

Mr. PUCINSKI. Just for the point of clarification here so that we know what we are talking about.

Now, the present law reads, section 901:

> The National Science Foundation shall establish a Science Information Service. The Foundation, through such service, shall, one, provide or arrange for the provision of indexing and abstracting and other services leading to a more effective dissemination of scientific information; and, two, undertake programs to develop new or improved methods, including mechanized systems for making scientific information available.

Now, the bill before us reads, we would provide here, to amend by striking out the words "a Science Information Service," and including in that place the words, "a National Science Research Data Processing and Information Retrieval System." So that the bill would now read, assuming it were adopted, "the National Science Foundation shall establish a National Science Research Data Processing and Information Retrieval System."

Now, I merely want the record to be clear as to the relationship of the Science Information Service to the National Science Foundation and the relationship of the proposed National Science Research Data Processing and Information Retrieval System.

This legislation spells out more precisely what an Information Retrieval System would do and what it would not do so that we could give greater meaning to what you people should have been doing for the last 11 years and have been doing only in a token form. That is the only point I make here.

Mr. DELLENBACK. If I may make a brief comment on this point.

I think we are over into technicalities that may or may not be important. But if I may speak for just a moment to the technicality. Unless you follow the concept, Mr. Chairman, to include one is to exclude all else, I don't read those sentences that you have talked to as to the authority of the Science Information Service in any way blocking the basic authority of the National Science Foundation to do more through the Information Service than merely those couple of points if it makes the policy decision within its broad scope of authority which is elsewhere in the language to do other things. It merely places upon it a mandate to do those particular things.

Now, if the National Science Foundation, of which the Science Information Service is one subdivision, is meeting the statutory requirements that we have set out as to what that office of Science Information shall do, and if the National Science Foundation, the parent organization, wants to do other things through that instrumentality, it may look elsewhere in its authority and find it has the statutory authority to do those things and proceed to use the Office of Science Information Service to do those very things.

So unless we are splitting hairs, I think we are off on a tangent whereas the real fundamental question is the type of thing which basically Dr. Adkinson's testimony directs itself and Dr. Seaborg's testimony directs itself. I think everybody agrees on this; you agree on this; Mr. Bell agrees on this; Dr. Adkinson agrees on this; Dr. Seaborg agrees; and I agree on this.

And I assume that since all of this is under the authority of the Board of the National Science Foundation, which includes some of the leading scientists of this Nation, and they have authorized these instrumentalities to do what they are expected to do, I assume they agree that what we are talking about is a very necessary gathering of information together, putting it in usable form and then proceeding to make it broadly available.

We are not quarreling, I don't think, with that basic underlying premise. That is exactly what Dr. Seaborg testified to and that is exactly what Dr. Adkinson testified to. This is what your bill seeks to do, Mr. Chairman, and this is what every man on this committee who has made comment this morning agrees ought to be done.

Am I speaking correctly, Dr. Adkinson, as to the impact of your testimony on this?

Dr. ADKINSON. Yes; that is correct.

Mr. PUCINSKI. If my colleague would yield. I have no quarrel with anything that my colleague has said.

Mr. DELLENBACK. I think the record ought to be clear on that particular. I don't think we ought to leave the witness with the misapprehension that we are trying to tear him apart or quarrel with him on what he said, nor should the record be left with that implication.

If you agree with what I have said, then I think that is the base from which we start and then let's go on from there to other things that we may talk about.

Mr. PUCINSKI. If the gentleman will yield.

I do not quarrel nor do I question anything that the gentleman has said in trying to put this in perspective. But I do have a serious disagreement with the witness' testimony when, on behalf of the Bureau of the Budget, he comes in here and says that he does not believe that this legislation is desirable or necessary.

The only reason why we introduced H.R. 8809 and the reason why this legislation is before us is because witness after witness has been before this committee, including the most recent witness, Dr. Seaborg, and told us of the enormity of the problem that confronts the scientific community of this country. Yet even though the Science Information Service has, and has had since the passage of this legislation in 1957, I believe, has had the authority to start addressing itself to the problems that witness after witness has described before this committee, and that I have described. The record is very clear that whatever the Science Information Service has been doing up to now has been mere tokenism. The best proof of that is that they are only spending a million dollars on translation, $1,600,000 on abstracting and indexing, when the testimony of Dr. Seaborg showed the enormity of the challenge.

When I introduced H.R. 8809 it was merely to amplify the provisions of section 901. This is why this is an amendment to 901.

I said earlier this morning that after listening to the testimony of witnesses, I have some serious doubt now whether the Science Information Service is capable of taking on these jobs. A national scientific and technical information system is such a vast undertaking that I am not too sure that we shouldn't really repeal 901 and turn the responsibility over to NASA or some agency capable of doing the job. The Science Information Service for 10 years now has made nothing more than a token effort. Six years ago Dr. Adkinson was before this committee and he heard the witnesses then—and the record is available to him—eminent scientists who spoke out that SIS is not doing the job sufficiently. I have heard in this testimony presented by Dr. Adkinson no great, startling progress made in the last 6 years to address his office to this problem. The same snail's pace that they used in the first 4 years of their existence they are using now.

And so, if my colleague will bear with me, what H.R. 8809 attempts to do is to bring this agency into tune with the needs of the times. And all I see here in the statement by Dr. Adkinson today is a lot of platitudes that haven't moved us an inch forward in dealing with the problems that are before the country.

Mr. DELLENBACK. I think it is important that we clearly distinguish between two different things as we make comment on 8809 or on this general problem. Now, each one of us on the committee is entitled to his own opinion and is subject to analysis as to whether enough has been done and whether we ought to modify it. But I think we ought not to interweave this too far as if they were made of the same fabric, the question of what Dr. Seaborg said, of what Dr. Adkinson said, of what other witnesses have said, and by tying them together in the same phrase and sentence, make them sound like they were the same thing.

Dr. Seaborg has clearly alluded to the immensity of the problem that is before us. Dr. Adkinson's testimony clearly alluded to the immensity of the problem that is before us. Dr. Seaborg does not go beyond the general concept of the immensity of the problem, the need to do a very great many things and approving of the basic concept of doing this thing on a basis of cooperative efforts rather than a more centralized system. He, as you pointed out in your prior remarks, does not specifically back this particular bill, nor do I specifically back it or attack it, but let's be sure what Dr. Seaborg said.

Now, let's go on to Dr. Adkinson. He has, I think, made a good comparison between the situation that existed some 6 years ago and that which exists now. He has commented about what has been done during this time—and I keep in the back of my mind thinking in terms of the fact that this is a part of the National Science Foundation and if we are attacking this we are saying something very significant

31-464 O—69——10

about the National Science Foundation and its Board. You are either saying it is disregarding and it is itself proving inadequate to deal with this problem which is essentially a scientific problem. The chairman has said that the scientists who are on this Board and citizenry on this Board have failed to police themselves and establish themselves the system which they want, when that is what the chairman and others said that the scientists ought to themselves say what they want instead of our attempting to control it with an overall system; or else we are saying that we don't know what they want and we ought to move in and tell them and if we have to, let's take it away from them and put it somewhere else. Maybe we should. I am not commenting on that.

But I think the chairman's comment or any other comment or opinion on our part ought to be clearly divorced on the scientific testimony of the experts who have said a great many things about [illegible]ation and the progress that has been made.

Now, let me shift to f[illegible] subject remarks. I don't think there has been only token progress. I don't read any of the testimony of Dr. Aikinson as saying that all that has happened over the past 6 years is a snail's pace progress and token advance. I was struck by one of the points that is extremely significant and this comes out of Dr. Seaborg's testimony too; namely, that the state of the art has not yet reached the point of perfection. We are learning. We know a good deal more today than we knew 6 years ago. We know a great deal more than we knew before that.

Now, Dr. Adkinson, do you think the state of the art has reached perfection so that we can put it in a form that will serve indefinitely what needs to be done in this field?

Dr. ADKINSON. There are two aspects to that I would like to speak to. There is, first, as we say in our trade, the hardware, the computers, the microforms, the ability to transmit messages over lines——

Mr. DELLENBACK. If I may break in for just a second, the state of the hardware today is infinitely advanced over what it was 6 years ago?

Dr. ADKINSON. Yes.

Mr. DELLENBACK. And had we produced the system 6 years ago we would have had to modify it very extensively today to bring it up to the present state of the art; am I correct?

Dr. ADKINSON. Yes.

Mr. DELLENBACK. Go ahead with what you were saying.

Dr. ADKINSON. On the hardware side of it today, there are places where the state of the art is not far enough; it is handicapping us. But in general, on the soft hardware side, we are not using the full capabilities of the computer and the other technological innovations that have come down the road in the last 6 years.

In other words, our intellectual ability to organize these large files which are a new phenomenon in computers has lagged. As you heard today, the compound registry has a million compounds in it. You can search that by every atom in the computer. It took us several years to learn to do this, and we are adding several thousand every week and we estimate that before we get through in another year or two or three we will have 3 million compounds in our file and so all the literature and we will be able to take a look at the fantastic progress that has happened this year.

It is the software where we have a lot of work to do. The hardware we haven't learned to use in all of its capability.

Mr. DELLENBACK. You made the other point in your testimony which I thought was very significant that when you have once started on a system, that is at a given level of the state of the art, if you make a radical change to another system it becomes necessary to keep both systems going for a period of time, thus increasing markedly the expense of what must be done. And until you have the new system fully operative and can transfer from the old system into the new system, you must both move forward in the actual system and fully fund the other.

Dr. ADKINSON. That is correct.

Mr. DELLENBACK. And if that new system is not really the final word, all it is is a weighing station which is going to multiply expenses and duplicate expenses because when we are ready to move on to the next system we must go through that system.

Mr. PUCINSKI. May I make a point?

Mr. DELLENBACK. Let me make this point; if I may.

If that is in truth the case then one of the significant points that I think you have made is the comment on the present state of the art and the comment that the advance is still so slow that we ought not to precipitously jump in over our heads unless we have pretty well determined the future course of the things that have arrived as a system.

Do I correctly reflect your thinking in this regard?

Dr. ADKINSON. Let me respond to that with an illustration. I think this can illustrate the problem.

Mr. DELLENBACK. Which will reflect general concurrence with what I say or disapproval?

Dr. ADKINSON. I think it will clarify it also.

Mr. DELLENBACK. But approval rather than disapproval. We are building the record and I would like to know whether I am correct or incorrect.

Dr. ADKINSON. You are correct.

Now, let me illustrate and I will use a Government service. It is known as Medlars. It is the indexing computerized system of the National Library of Medicine. They started operating that system in 1961. It has many handicaps but it was an innovation, tremendous innovation in 1961. They are right now in the process, at the cost of several millions of dollars, of building a new system, of updating that old system of 1961. Because of the innovations coming along and having to rebuild another system, they have gone outside and got competence outside to design this system and now they are acquiring it through the several million. And I am sure that the American Chemical Society now wants to use that system they are building today.

Mr. PUCINSKI. After all of this conversation, assuming that we were to accept the statement made by the witness, then we would really have to discredit the testimony of Dr. Seaborg, because on page 5 he says:

So it is also necessary to make sure that these systems continue to be aided individually as well as tied into any national system that may be developed. As one example of such a system I might point out the American Chemical Society's

Chemical Abstracts Service. This computer-based registry, begun in 1960, has already registered more than one million chemical compounds and continues to add them at a rate of 4000 to 5000 per week. It already works closely with such government organizations as the National Science Foundation, the National Library of Medicine and the Food and Drug Administration.

Dr. Seaborg points out, and I congratulate the American Chemical Society for not waiting, the whole story of American technology is progress. I think that the problem here, Mr. Witness—and we will take this up in the afternoon session—is that while organizations like Medlars and the American Chemical Society have been moving forward making the best use of the equipment available, your own organization has been sitting around waiting for utopia.

Now, we are going to stand in recess until 1:30.

Dr. ADKINSON. May I respond?

Mr. PUCISKI. You will be the first one to respond when we come back at 1:30.

(Whereupon, at 12:30 p.m., the subcommittee recessed to reconvene at 1:30 p.m. the same afternoon.)

AFTERNOON SESSION

Mr. PUCINSKI. The meeting will come to order.

Dr. Adkinson, when we recessed for the lunch hour, you were about to respond to a statement that I had made quoting Dr. Seaborg's statement today that the American Chemical Society Chemical Abstract Service has a computer-based registry which it has been operating since 1960 and has already registered more than one million chemical compounds and continues to add them at a rate of 4,000 to 5,000 per week.

Medlars is continuing to operate. There are other scientific communities that have gone into information retrieval through the use of computers. The whole story of American technology has been changing capabilities. If we were to take the position that we can not move forward because tomorrow there will be a better idea, then this country would come to a grinding halt. Progress would end.

I do not agree with your statement. Obviously by citing the American Chemical Society's successful program, Dr. Seaborg does not agree with your statement. You wanted to comment on that, so please do.

Dr. ADKINSON. There were two points that I wanted to make.

One was that I think my statement as I made it may have been misunderstood. First of all, the chemical registry system that was mentioned by Dr. Seaborg is one in which the National Science Foundation has been heavily involved, but that is only one component of a large system that they are developing there and I thought that you would be interested in knowing that last year, 1968, in the system's development and improvement, my office supported over $4 million worth of development in that field leading toward an improved chemical information system and for developing new systems in many disciplines; physics, mathematics, psychology, the social sicences, and engineering.

During that same year we spent over $8 million in assisting the societies to develop new and improved systems. There is not a major abstract indexing service in the societies that do not have computers and that we have not helped to get them.

I wanted to make that clear.

Mr. PUCINSKI. How do you reconcile the statement that you are making now with your reply to Mr. Dellenback when he asked you if we had proceeded with the establishment of a national system in 1960 or 1963, you would today have to completely revamp it because of new technology.

Dr. ADKINSON. I think that statement is not at variance with what we are talking about, because 5 or 7 years from now the systems we are developing will have to be revamped again.

Mr. PUCINSKI. But you are developing them anyhow?

Dr. ADKINSON. Because of new technology, but we are developing them. You just cannot wait for the ultimate.

Mr. PUCINSKI. There appears to be a conflict in your statement. On the one hand you say we should not have proceeded 6 years ago because we would have been financing an obsolete system. But on the other hand you say we are doing it anyway. We are spending $4 million on development and purchase of equipment.

Which is correct? Is it your idea to move forward with whatever equipment we have at this point in time, or is it your idea to just do anything until we reach a stage of technical perfection?

Dr. ADKINSON. Mr. Chairman, I think that when I said if we had moved in 1961, you must remember the state of the computer and the other devices were not as sophisticated as they are today and we can do a great many more things with our present hardware and software, and it makes a great deal of sense to push it today, where in 1961, we could do very little with it in the form of automation.

We did support experiments in 1961 with the computer.

Mr. PUCINSKI. Suppose NASA took that attitude in 1961. Do you think we would have a man reaching for the moon today, if they decided they were not going to go into any kind of computer technology in 1961 because we were going to make great strides in ensuing years?

We just installed a multimillion dollar computer system in our Revenue Service. Now, should we have told the Revenue Service not to put that equipment in because better equipment will be developed? This Congress has authorized substantial computer investments in the Government. Should we have adopted your philosophy, "Don't do it because better equipment will be developed"?

Dr. ADKINSON. I will restate it. I do not think we are at variance at all. I am saying that we definitely are supporting the development of new systems, based on the present knowledge and what we see coming down the road at the present time. In 1961, however, to try to have developed a national system based on computers at the state of development they were then, we would have been in trouble.

Mr. PUCINSKI. Did you spend any money in 1961 in helping these scientific societies buy any computers?

Dr. ADKINSON. No, but we spent money experimenting with computers, in indexing, in translation, computational linguistics and a lot of others, to learn what they could and could not do.

Mr. PUCINSKI. In other words, what you are saying is you do not stop simply because you do not reach perfection. You move and work with what you have, and adapt to changes as they occur.

Dr. Adkinson. That is correct.

Mr. Pucinski. Then how can you reconcile that conclusion with your statement that you do not believe a national system is desirable at the present? You say that constraints imposed by such a formal system might well inhibit rather than assist the productive evolution of these services.

How does this particular technical straitjacket that you profess in that statement subscribe to what you have said on three different occasions about working with what is available?

Dr. Adkinson. I think that my remark on page 15 is addressed to a formal legislative system. I do not think it says that we are not supposed to go ahead and work toward a national system. And I mentioned in my testimony several times where we will interconnect things like chemical abstracts with other systems and we are helping to pay for experiments to do that now.

Mr. Pucinski. On page 21 you say, "I hope my remarks have reflected the belief that it would be neither practical nor desirable to centrally direct or manage our national array of information services." Of course I agree with that.

You then go on to say, "Nor does it appear desirable at present to establish by legislation a formal national system. The constraints imposed by such a formal system might well inhibit rather than assist a productive evolution of these services." Now, what does that mean, in light of what you have just told the committee regarding the necessity to work with the material that you have in hand and then adjust yourself as you move ahead to new and improved technologies.

Dr. Adkinson. I think the two sentences that you read there are addressing themselves only to the legislation. They are not addressing themselves to the technical development of the system but to legislation—it says by legislation—for a formal national system.

And that is all it is addressing itself to. I think that you and I both agree that we have to work toward making better systems and connecting these are rapidly as we can.

Mr. Pucinski. I am not sure that we do, Mr. Adkinson. I know I believe that. I have believed in it since I introduced this legislation. I have believed in it very fervently for many years because testimony has been overwhelming in support of this concept. But I am not too sure that, based on the record that we have seen in SIS to date, you people particularly agree that a national system is desirable.

You have spent a million dollars on translation and you have spent $1,600,000 on abstracting and indexing. I don't know how [illegible] did spend on mechanized systems, if anything. I have seen nothing in your statement today that would lead me to believe that you are even moving forward in the direction of an ultimate national system.

You spent $11 million on many worthwhile projects, I am sure, but I have not seen anything in your statement that would indicate the ultimate goal within the framework of the law that you operate under. I must say, if section 901 were administered by people who see the great opportunities in incorporating the national information system, I would say that we do not need H.R. 8809. I am the author of H.R. 8809, and I would be the first one to say we do not need it in that instance.

H.R. 8809 is the result of testimony and conclusions that the language incorporated in the present bill is permissive. It does not direct you to establish a system. It merely says that you shall do certain things to improve the dissemination of science information.

Based on the record, with all due respect, I do not see your agency moving in that direction. Therefore I must respectfully disagree with you and the Bureau of the Budget that this legislation is not necessary. I am convinced that the only way we are going to get this country progressing in a meaningful direction is for the Congress to clearly spell out its intentions.

I said earlier that perhaps I was wrong in suggesting that we try to have the Office of Science Information Services do this. It is quite apparent to me from testimony before this committee that you do not quite realize the scope of the assignment. I do not think you quite realize the magnitude of the problem. The best proof of that is that we have been at this business now for 6 years and I have seen nothing in your agency that has changed to indicate that you want to move toward a national system.

With all due respect to my colleague, I think your testimony is nothing more than tokenism. I don't believe this even begins to meet the needs and the problems of the scientific community. It had been my hope that with H.R. 8809 we would give you the tools that you need to move in that direction. Obviously you do not want those tools. You feel that you have enough legislation, enough authority in section 901 now and you can proceed in the manner you have for the last 10 years.

I must respectfully say this is not enough for the needs of America going into the decade of the 1970's. That is my judgment. Perhaps my colleagues do not agree with me. Every Member in this Congress uses his own judgment. They are entitled to their own judgment, and you as a witness are entitled to your own judgment.

I am respecting your judgment, even though I disagree with you.

Dr. ADKINSON. Over 60 percent of our funds in the past 2 years have gone for systems development and improvement and less than 40 for the support of the routine abstracting and translating. This is a marked change from 1964 when we had practically nothing in systems development and improvement; practically no funds. There has been a reprograming to push the development of these large systems like chemical abstracts, biological system, engineering system, et cetera.

There has been a big change in the last 4 years with a continued stronger emphasis each year on developing these big systems and supporting those activities that help to interconnect them as they get developed. This is our thrust and it is moving. We feel we are doing a good job. I would agree with you we could do a great deal more if funds were available.

Mr. PUCINSKI. How much help have you given to chemical societies, chemical abstract services?

Dr. ADKINSON. To the American Chemical Society—from the Government—and we are the largest share of it—over $9 million in the last 4 years.

Mr. PUCINSKI. To do what?

Dr. ADKINSON. Develop this system that Dr. Seaborg was talking about this morning.

Mr. Pucinski. This system that is now being developed is being developed with substantial aid from the Federal Government?

Dr. Adkinson. Yes, sir; large sums of money—most of it from the National Science Foundation.

Mr. Pucinski. And the other systems that you are funding are also being developed with Federal funds?

Dr. Adkinson. That is correct; in physics, psychology.

Mr. Pucinski. What is your objection to taking these systems together in a single coaxial cable so there can be some inbreeding and crossbreeding of scientific knowledge?

Dr. Adkinson. No objection.

Mr. Pucinski. Who says only a chemical scientist shall have available to him the information being generated by the chemical abstracts society? We have heard extensive testimony over the years and one of the things that the scientists have asked for most frequently is a crossbreeding of scientific knowledge, in order that they could reach into other disciplines and learn if those other disciplines offer assistance to their own research. Why then do you come before the committee and say you do not believe that tying all this together is desirable?

Dr. Adkinson. I did not understand that I had said that, sir.

Mr. Pucinski. You say right here "Nor does it appear desirable at present to establish by legislation a formal national system. Constraints imposed by such a formal system might well inhibit rather than assist the productive evolution of these services."

If the Federal Government is now spending as much money as you claim we are—I have no reason to question what you are saying, we probably are—what is then wrong in going the next step and providing some facility, some communications network to tie all these together? Where is this going to inhibit or impose constraints and inhibit rather than assist the productive evolution of these services? You are attempting it now, and you are spending taxpayers' money on it now. Why then can't we tie it together?

Dr. Adkinson. First of all, we are making a strong effort to experiment with tying these together, the American Chemical Society systems with systems on university campuses. I spoke about the interaction between the British and American Chemical Society. The National Library of Medicine system is depending on the chemical societies system now and we fostered that.

There are interconnections. We are encouraging the interconnections so you will have a network of systems.

The sentences in my statement that you are referring to only refer to the legislation.

Mr. Pucinski. What is wrong with the legislation? What does this legislation do that is so obnoxious that you would recommend against it?

Dr. Adkinson. The position of the National Science Fundation is that the legislation is not necessary, that we can do everything that is necessary under the present legislation. And that is the position they have taken.

Mr. Pucinski. Well, is there anything in the present legislation that would prohibit duplication by the Federal Government?

Dr. Adkinson. No.

Mr. PUCINSKI. H.R. 8809 would prohibit such duplication, wouldn't it?

Dr. ADKINSON. That is correct.

Mr. PUCINSKI. Is it possible that the opposition to this legislation can be found in the fact that we make every effort to protect the existing systems without having the Government impose its judgment on these systems?

Dr. ADKINSON. Well, there is certainly no intention on the part of the Science Foundation to impose a system because our whole thrust has been to support the not-for-profit groups who are building systems. We are not designing a system. We are helping those who do have systems or who want to build new ones, so I do not think that we want to impose another system on them.

Mr. PUCINSKI. Obviously, Mr. Adkinson, there are other members of the committee who would like to discuss your testimony, and I don't think it would be fair to deny them that opportunity. As you heard from earlier testimony, the other members do have an intense interest in this subject and in your testimony about the legislation. If it is agreeable to you I am going to excuse you at this time but we will recall you so that the other members of the committee will have an opportunity to familiarize themselves with what you are doing and what you are not doing.

I must say, though, that even within the framework of your own statement, I am not too certain, when I look at the statement of Dr. Seaborg and the other testimony before the committee—the need is so big and the challenge is so great, that I am no longer sure that you have the capability. I don't mean you personally; I mean your agency—within its present structure—hasn't the capability to do this job. I am not too sure that maybe, the wisest thing might not be to phase out SIS and turn this project over to some agency that has the capability and would be able to take on this big job.

It won't be long now before NASA will have completed its basic mission. They are interested in this program. It is entirely possible that Congress might very well decide that NASA could be restructured to include all the sciences, not only the air space sciences.

It is quite clear to me, your testimony today indicates that your shop does not want it. I have never been one to try and impose something on anybody. You people don't want it. I am sure there are other people in this Government that will be very happy to take it on. I think that the Defense Department might be very happy to take this on. We have a good beginning there already, and at Cameron Station. There are other agencies that might be a little more enthusiastic and might be able to see the challenge in a greater perspective.

With all due respect to the National Science Foundation and to your own shop. I suggest that we excuse you at this time. I will be asking you to come back when the other members are here, because I think it is only fair to them to have an opportunity to discuss this with you.

They may agree with you. They may be in complete agreement with you. That is what makes the Congress an interesting institution.

Dr. ADKINSON. I will be glad to come back whenever we can arrange the schedule.

Mr. PUCINSKI. Thank you very much. Our next witness is Dr. Launor Carter who is here from Santa Monica, Calif.

Dr. Carter is a graduate of the University of Washington and received his Ph. D. from Princeton University. From 1955 to the present, he has been vice president and is now general manager of public systems division, System Development Corp., in Santa Monica, Calif.

He has responsibility for all of SDC's contracts work in public education, library and documentation, health, management systems, telecommunications, and other projects.

From July 1962 to 1963 he was chief scientist with the U.S. Air Force and served as senior civilian scientific adviser to the Air Force Chief of Staff. He is the author of countless publications in the field of psychology and communications.

Dr. Carter, we are very pleased to have you here. You have heard testimony of Dr. Seaborg and you have heard testimony of Dr. Adkinson and I am sure you have had a chance to review previous testimony before this committee. I know you are well aware of the enormous opportunity that confronts our Nation at this point in time. I am most anxious to hear your testimony. Your formal statement will go in the record at this point in its entirety and perhaps we could prevail upon you to either summarize it or discuss any aspect of it if you wish. On the other hand, if you wish to read the statement that is agreeable to me, too.

STATEMENT OF LAUNOR F. CARTER, VICE PRESIDENT, SYSTEM DEVELOPMENT CORP., SANTA MONICA, CALIF.

Mr. CARTER. Mr. Chairman, in view of your time, it might be better if I summarized it rather than read it although I would be happy to read it.

Mr. PUCINSKI. Off the record.

(Discussion off the record.)

Mr. CARTER. I will read my statement then, sir.

I thank you for your generous introduction. Also I want to point out I have had a fair amount of experience in the information field itself. I think you know in 1965 I was head of the study teams that prepared the reports for COSATI which resulted in major recommendations.

I have been a member of the Science Information Council of the National Science Foundation and have just recently retired as Chairman of that Council.

In addition I was a member of the National Advisory Commission on Libraries appointed by President Johnson.

I. INTRODUCTION

It is particularly pleasing to be able to testify before this committee regarding H.R. 8809. It was in 1963 that Congressman Pucinski chaired the significant hearings regarding problems of scientific and technical information transfer. Those hearings, along with other studies, helped set the stage for a number of advances in this important area.

Since 1963 the field of information science has matured with significant progress. The literature in the field of information science has expanded to such an extent that it is now impossible for any one person to be familiar with its totality. The growth of the literature in this area is illustrated by the fact that my colleague, Dr. Carlos Cuadra, editor of the Annual Review of Information Science and Technology, has in preparation the fourth volume in as many years summarizing the state of the art of information sciences.

Not only has the science and technology of information transfer progressed greatly in the last decade, but there have been significant advances in the implementation and development of several important science information systems. Perhaps one of the best known is that associated with the National Library of Medicine.

Congress only last year recognized the important work being done at the National Library of Medicine by establishing the Lister Hill Center for Biomedical Communications, which is chartered to develop a comprehensive information system in the biological and medical sciences.

Another notable advance of the last few years has been the work of the U.S. Office of Education in the establishment of the Educational Resources Information System, commonly known as ERIC.

The National Science Foundation has developed a program for the support of abstracting and indexing services utilizing the publication programs of the various professional societies. In the past decade we have seen the establishment of many important science and technical information centers.

While there have been notable advances in many separate areas, the need continues for an overall plan and agency for coordinating and integrating the many diverse and often conflicting programs which have grown up both within the Federal Government, in the professional societies, and in the private sector.

I believe, Mr. Chairman, that you and your staff are familiar with the report my staff and I prepared for COSATI and which was published in 1967 by John Wiley & Sons as a book entitled "National Document-Handling Systems for Science and Technology."

In that book we devote a number of pages to describing the various national responsibilities which the Federal Government should undertake, and we also describe the many problems which are presently confronting the scientific and technical community in the area of information transfer.

I do not propose to review those problems here except to say that I believe they are still in need of serious attention. Without an integrated and coordinated system the various conflicts and incompatibilities will increase with time and become more difficult to solve.

Thus, Mr. Chairman, it is most appropriate that you should again take the lead by sponsoring H.R. 8809 and holding hearings on the important subject of a National Science Research Data Processing and Information Retrieval System.

II. THERE IS A NEED FOR A CENTRAL AGENCY TO INTEGRATE AND COORDINATE

Within the Federal Government there is no agency which is specifically charged with responsibility for integrating and coordinating Federal policy and actions with regard to the transfer of scientific and technical information. Many agencies play an important role.

In the Executive Office of the President, the Office of Science and Technology and the Committee on Scientific and Technical Information have overall coordinating responsibility. At best they can serve a limited function since only one or two staff members of OST are concerned with this function and COSATI is simply a coordinating committee without any directive authority.

The National Science Foundation plays an extremely important role through its Office of Science Information Services. Its influence is particularly felt in the support of primary publications, abstracting and indexing services and advanced information systems in the professional societies, as well as the sponsorship of a number of important development programs in this area.

However, the National Science Foundation is not in a position to exert a strong coordinating and integrating influence among the other departments of Government holding a coequal status with it.

Similarly, the Office of Education has been influential in its support of college and university libraries and their information systems. The generous action of Congress in providing funds under the Library Services and Construction Act has emphasized the important role of the U.S. Office of Education in this area.

Also, the Department of Defense has a key position. Particularly notable are the many Department of Defense technical information centers and the Defense Documentation Center. The Department of Commerce operates the Clearinghouse for Federal Scientific and Technical Information.

One could go on to enumerate other important organizations, such as NASA, the AEC, the Public Health Service, the Smithsonian Institution, et cetera, all of whom have a role to play in scientific and technical information transfer. Yet there is no agency which assures that we have a well-thought-out, integrated and coordinated national program.

Mr. PUCINSKI. I wonder if I may interrupt you briefly while I go and attend a meeting I must attend.

We will stand in recess for 15 minutes. I am particularly anxious to have Mr. Dellenback and Mr. Bell and some of the other members hear your testimony because I believe that you are putting this whole problem into a clear perspective. So if you will forgive me, I will excuse myself for 15 minutes.

We will be in recess for 15 minutes.

(Whereupon, at [illegible] p.m. the subcommittee recessed until 3:05 p.m.)

Mr. PUCINSKI. Mr. Carter, I apologize for interrupting you. Resume where you left off.

Mr. CARTER. In our report we enumerated eight major areas where such coordination and integration are required. These requirements are concerned with:

1. Various administrative and organizational requirements.
2. Requirements as viewed from the point of view of the user.
3. Internal systems operations requirements.
4. Requirements regarding the production and representation of documents.
5. Requirements regarding dissemination and special services.
6. Requirements for system evolution.
7. Requirements for education and training.
8. Requirements for research and development.

Although I have heard criticism of the solution we proposed for handling these requirements, I have never heard it seriously argued that the requirements themselves do not exist.

I believe it of considerable urgency that Congress and the executive branch consider how these requirements can be fulfilled within the Federal establishment.

I would suspect, Mr. Chairman, that when you drafted H.R. 8809 you had in mind requirements of this nature, and I certainly endorse the general idea that we need a national science research data processing and information retrieval system. But I do have doubts about the wisdom of placing this responsibility within the National Science Foundation.

My concerns regarding NSF and its ability to administer a national system are not at all associated with the competence or management skill of the National Science Foundation or the Office of Science Information Services. Rather they have to do with a more fundamental problem facing the Government in all areas of science integration and coordination.

I refer to the fact that the National Science Foundation is organizationally coequal to many other agencies of Government; with the Atomic Energy Commission, the Department of Defense, the National Space and Aeronautics Administration, the Department of Health, Education, and Welfare, and so forth.

I find it difficult to believe that in an area which is as all-pervasive as scientific and technical information any agency which is at the same level as the other agencies concerned with this problem can really take the directive and integrative role that is required.

Rather I have been of the opinion that only at the organizational level of the Executive Office of the President can an agency have the necessary authority and overall purview.

In our book we devote a full chapter to evaluating the various alternatives that are available within the existing agencies. We in no way tried to imply that the existing organizations are not capable of performing the functions with which they are charged. Rather we are concerned regarding the fundamental philosophy of governmental organization.

Because of this we concluded that neither the National Science Foundation nor any other agency was properly situated or had the proper authority to undertake the large mission implied by H.R. 8809.

As further evidence on this point, I would call your attention to H.R. 8839 which is a bill to establish a National Commission on Libraries and Information Science. Section three of that bill says, "There is hereby established as an independent agency within the executive branch, a National Commission on Libraries and Information Science." H.R. 8839 is based on the recommendations of the National Advisory Commission on Libraries and the drafters of the bill wisely recognized that the commission should be an independent agency within the executive branch.

I believe, Mr. Chairman, any activity such as the national science research data processing and information retrieval system should likewise be a part of such an independent agency.

Indeed, I cannot help but wonder whether or not the intent and content of H.R. 8809 and 8839 should be consolidated and coordinated.

III. THERE IS A NEED FOR SEVERAL SYSTEMS FOR DIFFERENT SUBJECT MATTERS

From the contents of the previous paragraphs some might conclude that I believe there should be one large, monolithic technical information system. This would be completely false and contrary to my beliefs. Indeed, it seems to me that we must have a large number of relatively independent systems operating in the many different subject matters of science and technology.

But it also seems to me that there needs to be a reasonable amount of integration and coordination between these systems and that this can only be done through the monitorship of a central agency which has responsibility for assuring that there is a degree of compatibility and consistency in policy and operation among the many different systems.

I would like to call your attention to several different systems which have been established to clarify further the point that I believe many systems need to exist.

Recently the System Development Corporation has been undertaking a study of a national oceanographic data system for the National Marine Council. I think some people originally thought we might recommend a highly centralized national oceanographic information and data system.

In a limited sense we will indeed do so, but this system will consist of many subsystems which are only loosely tied together. Although our report is not yet complete, we will probably recommend that there be a new and strengthened fisheries information system. Likewise, we will probably recommend that there be a new and strengthened marine engineering system. We will also recommend a strengthening of the National Oceanographic Data Center. Although all of these organizations deal with oceanographic information, it is not essential that they be operated by one central agency. Rather it is important that there be an organization responsible for the overview of all these systems to see that their data formats are properly compatible, that the kinds of information they are collecting do not overlap unnecessarily, that similar general policies are established, and to look toward an overall national system made up of many components operated by different agencies.

As another example, consider the information requirement in education. In the last few years the U.S. Office of Education has established the Educational Resources Information System. There are 19 ERIC centers throughout the country. At each center documents are acquired, processed, and placed in the system under the overall guidance of the central ERIC administration. In addition to these 19 ERIC centers there are some 150 other information centers operating in the field of education. These vary from one-man information centers to more extensive and even automated centers. It is not necessary that each of these be brought under a centralized control, but it is important that the education community be aware of their existence, know the resources available at the various centers, be able to query the centers with regard to needed information, and that their processing be reasonably similar so that as knowledge regarding research, techniques and resources accumulates appropriate abstracting, indexing, and computer-based services may be more readily established.

In our COSATI study we developed the concept of the Responsible Agent. This concept is really quite straightforward and simple. It implies, for example, that the U.S. Office of Education should be the responsible agent for assuring that there is developed within this country an adequate education information system. You will note that we do not propose that the U.S. Office of Education should operate such a system. Rather we would expect USOE to be responsible for supporting ongoing systems, if such support is needed, and for assuring that there are information resources covering the entire field of education and that the policies and practices of the various information sources in education are reasonably standard and consistent so that users need familiarize themselves with only a limited number of procedures for retrieving information. USOE's involvement would extend to only those cases where Federal operation or financial support is involved.

Although H.R. 8809 does not deal specifically with the concept of responsible agents, it does tangentially touch on this subject. The language of the bill is as follows:

> The purpose of this act is to implement, not substitute, existing information retrieval facilities. Therefore, it is specifically prohibited under this act, for the national system to establish any government-owned or operated research science data processing of information retrieval facility where such a facility already exists under either private or public ownership.

I would like to suggest that this particular language is too restrictive in its specific prohibition on the establishment of any new system or any integration of systems where such facilities may already exist under public ownership. There are within the Federal Government many hundreds of information retrieval and document centers, and I believe that where a responsible agent has determined that a more effective system could be developed by the integration or consolidation of some of the already existing federally operated or supported system, it would be appropriate for such an agency to promote such an effort. Probably all steps in this direction should be reviewed by the central policy-making organization I have mentioned previously, but I believe it would be unwise to prohibit specifically the integration or coordination of already existing Federal information retrieval units.

I am also concerned regarding the name of the system being proposed; namely, a National Science Research Data Processing and Information Retrieval System. I would suggest that the word "processing" be deleted from the title since I do not find the problems of research data processing addressed in the content of H.R. 8809.

Every major research establishment or university research center or Government research laboratory must have available facilities to process research data. While the Federal Government plays a significant role in supporting many computer-based data processing centers, the function and role of such centers is separate from the information transfer function which I assume is the primary concern of H.R. 8809.

In summary, I wish to support the general intent of H.R. 8809, which I take to be the establishment of a national document-handling, information and data retrieval system. The establishment of such a national system requires careful consideration regarding the functions to be filled and the identification of appropriate agencies to undertake these tasks.

As I have indicated, I have some doubts that there now exists a proper agency to undertake this program, and I am also concerned about some of the specific language of H.R. 8809. At the same time, I would like to support the general interest and concern of your committee regarding this important area. Thank you very much. This concludes my written testimony. I would be glad to answer questions.

Mr. PUCINSKI. Thank you, Mr. Carter. You have certainly given this committee an excellent statement. I appreciate your suggestions. I think each of your suggestions is intended to improve this legislation and coming from one who has such vast experience in this field, I give special attention to your proposals.

I am particularly impressed with your suggestion that we ought to make this an agency that would be close to the President. I think that the earlier colloquy with Mr. Adkinson proves my point. Whatever may be his personal views on this subject, obviously he is reflecting the views of the Bureau of the Budget, the National Science Foundation, and various other people who have taken a position.

Your suggestion that this ought to be an agency that would have broader powers than the agencies now dealing with the subject, which have coequal powers is one we may want to look at very carefully.

I wonder if you might agree that perhaps the President's Committee on Scientific and Technical Information conceivably might be the vehicle for the development of this concept.

Mr. CARTER. No, sir. I do not believe that would be wise. The reason I believe this is that COSATI is a committee of the Federal Council on Science and Technology. The Federal Council is simply an organization made up of representatives of all the different Government agencies which have significant science and technical roles to play.

It is a consultative body, a group which considers common problems, which make recommendations to their various agencies but like most committees, does not have strong executive authority. I do not think you can do the coordination and integration that is needed in this area and many other areas of science without a stronger staff support, a more organized attack on these problems, than you get out of the Federal Council or COSATI.

Mr. PUCINSKI. On the basis of your experience, how would you recommend that we structure this? You suggested perhaps we could combine this bill with the Commission on Libraries.

Mr. CARTER. Yes, sir. I am concerned about that because some of the functions which are contemplated, the Commission on Libraries and Information Science would undertake would certainly be some of the functions which are contemplated under your bill.

Mr. PUCINSKI. I have reservations about this suggestion. If the National Commission were to confine itself only to libraries I would have no problem. The National Commission on Libraries, when it was an advisory board, was very helpful to our subcommittee a few years ago when we passed the Library Act. We relied heavily on their recommendations.

I believe at that time you were a member of the Commission. Your study resulted in the Library Act which has done a great job all over the country. But I am concerned that when the guidelines are written on information science, they will only add to the already existing confusion. Would you, having been a member of this Commission on Libraries see any strong objection in making this Commission a permanent commission as H.R. 8839 proposes? That we confine it only to libraries?

Mr. CARTER. Yes, sir; I tend to believe that the role of the library, particularly the research library, is going to change a great deal in the next 10 to 15 years. We already see growing up information resources such as the American Chemical Society is putting out, which you mentioned earlier. Those resources are largely going to be disseminated through some association with a library on the campus.

There are going to be computer tools of one nature or another, consoles, retrieval tools, which will operate, I believe, through the libraries with the Chemical Information Service.

They are going to go on line in 1971 and when are on line, then a research center will have a console where they could query the data base mantained in Columbus or other places. You have to integrate science information services, I think with the other libraries' services or information services.

So that, I believe, there will be an amalgamation of library and information services.

Mr. PUCINSKI. Do you think we would be wiser at this point to limit this commission to the work that it has already been doing, primarily in the library field and avoid or eliminate the information sciences? What I am fearful of, is that the information sciences are going to be the honey to attract the money, and the money will flow in that direction; and the humanities and the various other aspects of library activity will play a secondary role.

The Library of Congress presents an example of my point. The Library of Congress asked for $5 million to catalog scientific information and received it like that. Yet if they want to improve their section in humanities in the Library of Congress, they have to literally beg for funds.

You said we ought to have a separate structure dealing with sciences. Perhaps we ought to have a national commission on science information retrieval which would then work with the libraries, and with everyone else would that be the road to go?

You also said you thought maybe 8809, and 8839 ought to be consolidated and coordinated.

Mr. CARTER. Yes, sir.

Mr. PUCINSKI. Which would be the best way to move on this?

Mr. CARTER. As you say, I was a member of the National Advisory Commission, and while I wholly endorse the recommendations of the Commission, I did not myself feel they were as strong as they should be.

Part-time commissions in my view, are not the way to get things rolling, get things instituted. So I would much rather see a responsible agent or a responsible organization as a permanent agency within the Government than to see a part-time commission.

31-464 O—69——11

Mr. PUCINSKI. I presume the National Commission on Libraries will be a permanent agency of Government.

Mr. CARTER. I think the bill is pretty weak in that respect. I don't have it before me.

Mr. PUCINSKI. I would agree with you. I would be for strengthening the National Commission on Libraries, making it a permanent institute which would be an overseer for library facilities in this country.

But is there any merit to my fear that if we add the words "and information science" and give this National Commission on Libraries the further authority over information science that over the span of the next 10 years, or 5 years, the glamour will be focused on the sciences?

It is easier to get money. Numerous people look at the humanities with distress, believing they are not as important as the sciences. I believe free people have to have a strong interest in humanities. And this is why I fear putting the sciences in with the library services.

Is there any merit to my concern?

Mr. CARTER. Certainly there is merit to your concern because nobody wants to be in the position, no thoughtful person, of downgrading the humanities or social sciences, arts and so on.

Mr. PUCINSKI. There is a constant effort to do just that around here.

Mr. CARTER. But I wonder a little bit about to what extent that is really true. I thought that under the Library Services and Construction Act, there are very large amounts appropriated for general library services. I heard a comment from the Office of Education to the effect that something in the order of $400 million a year are spent through that Office for the general support of libraries. This is not for the support of science libraries.

Mr. PUCINSKI. Within the present structure we are not dealing with science information. The present structure limits it to library service. For instance, three libraries were built in my district with Federal aid. Had we not received it, we would not have built those libraries. They are invaluable neighborhood institutions.

The people of my district think these libraries are the greatest thing that has happened in the area. But had this bill included science or information science services, then the struggle for the dollar would have been divided and I doubt if we would have received enough money for the libraries.

Mr. CARTER. I think we are having a semantic problem. I believe when one says a Commission on Libraries and Information Science, one is talking about the new developments for handling information, the techniques of information retrieval, of storage, of microfilming, of indexing, which we refer to as the information sciences.

Mr. PUCINSKI. I am glad you brought that up. I think you are right. I think you now put this discussion on the right track.

If that is all that they are talking about in H.R. 8839, then obviously I certainly would not object to it and I do not think anyone else would object to it. If that bill seeks a better way to handle books and the dissemination of information in those books and libraries, fine, but you said that you thought we might consolidate 8809 and 8839. I would be leery of mixing science and the humanities. Because in the struggle for Federal funds, science would always get more than the humanities, and I am still old fashioned enough to think humanities are important.

Mr. CARTER. I don't want to press that point too strongly. I am sure you are right in your interpretation that the National Advisory Commisison on Libraries was using the concept of information science as the technique of modern librarianship, if you will. And if you go on and look at the other recommendations of the National Advisory Committee, you will see that one of them was the establishment of an Institute of Library and Information Science to help promote those techniques, so library information resources would be more useful.

Mr. PUCINSKI. How can we give greater credence to the proposal that you make here to move forward? Perhaps H.R. 8809 is wrong in presuming that you can amend the NDEA and that this project can be given to the SIS in the National Science Foundation. I believe that with the problems they have there as manifested particularly in today's testimony, which is very clear, they do not want it. We ought to start thinking about who does want it. More important, who is best qualified to handle it?

Mr. CARTER. In our report to COSATI and in the book I mentioned in my testimony, we analyze the pros and cons of NSF, the Smithsonian Institution, of OST, of several different agencies as being the appropriate organization to assume this responsibility. And you know there are a fair number of pages of analysis of the situation.

As I say, we did come up with the conclusion that there is currently no existing agency that is either properly situated within the Federal organizational hierarchy or has the statutory authority to fulfill the duties I think you have in mind. We therefore develop at some length the nature of such an organization which should be, we thought, at the level of the Executive Office of the President.

Mr. PUCINSKI. What do you call that agency?

Mr. CARTER. I don't really remember the exact title. It got labeled the capping agency.

Mr. PUCINSKI. But your point is an agency like that at the White House level would be in a more favorable position. What you are advocating is the same concept utilized on any number of similar problems—setting up a subcabinet post and then bringing in all the related agencies.

It was done in the poverty program. It was done in model cities, in the Marine Council. So you are suggesting setting up a new structure, an umbrella under which all these agencies could work but which would have a higher degree of authority than as a coequal partner with these agencies.

Mr. CARTER. Exactly.

Mr. PUCINSKI. That is a very fine suggestion, and I certainly will hope when you get back to California, you might amplify that for our committee.

I would be anxious to have these views from you, Mr. Carter, because I believe you may be right.

One final question, do you think that establishing an agency of this nature would be an impediment to the present development of systems within the various disciplines? The statement was made earlier that the strings imposed by such a formal system might well inhibit rather than assist the productive evolution of these services. Do you share that view?

Mr. CARTER. Well, in theory I clearly do not. In theory I think there should be some organization which looks out for the total scientific and technical information system. But on the other hand, the spelling out of the language of a bill and sometimes the administrative regulations that go with it, do not always correspond to the intent of the bill.

I personally believe that one could draw up an appropriate bill. I think if I may say so, sir, there is a certain weakness in H.R. 8809 by not being specific enough in some areas about how it would really work.

Mr. PUCINSKI. And being too specific in others?

Mr. CARTER. Yes, sir.

Mr. PUCINSKI. For instance, in light of your statement here I can appreciate your comment that the prohibition against competing systems could really thwart some very good developments. Perhaps that language could be improved.

Let me ask you, then, perhaps the best way to move on something like this is to first of all establish the principle that the time has come to start moving in the direction of establishing a national information system. Then perhaps we ought to take your suggestion and establish a commission that would be charged with the responsibility of developing such a system within a fixed time. Perhaps, Mr. Carter, what we need is another vehicle similar to that you served when you were a member of the Library Commission.

You gave us a blueprint for setting up a library bill. We followed that blueprint and today libraries are built all over the country. Maybe that is the procedure we ought to use.

Mr. CARTER. I think there is merit to that suggestion. Particularly if such a commission were charged with preparing appropriate recommended legislation which Congress could then consider as a rounded and a well-developed piece of legislation covering the total field.

Mr. PUCINSKI. You have been extremely helpful to this committee today and I really apologize to you for such a disjointed hearing. I want you to know how much I appreciate your coming. I think that you have given us some perspectives that we have not thought of before.

I think coupled with Dr. Seaborg's testimony, you gave us a few new directions, and I would ask you to do one more thing if I may.

When you get back to California, perhaps you would like to elaborate on your statement and give us your thinking on how a Presidential commission of this type ought to look and what it ought to do, as you see it.

Mr. CARTER. Very good, sir. I would be pleased.

Mr. PUCINSKI. I think we can agree with all due respect to the National Science Foundation and the director of the SIS, the time is long past due in getting started on a national system.

Perhaps your proposal to put together a team of experts who are capable and asking them to prescribe a formula for a national system, might be the better way of doing it.

Mr. CARTER. I will be happy to think about this and to offer some comments.

Mr. PUCINSKI. Mr. Carter, you are very kind for taking time out. I think you are going to see that your comments today will be reflected into some meaningful legislation around here.

Thank you very much.

(The comments requested follow:)

SYSTEM DEVELOPMENT CORP.,
Santa Monica, Calif., May 1, 1969.

Hon. ROMAN C. PUCINSKI,
House of Representatives,
Washington, D.C.

DEAR REPRESENTATIVE PUCINSKI: During my testimony before your General Subcommittee on Education regarding H.R. 8809, you invited me to submit additional comments regarding the way in which forward movement might be achieved in the scientific and technical document and information area. One of the things we discussed was the advisability of forming a national advisory commission on scientific and technical information needs to serve a function analogous to that of the National Advisory Commission on Libraries. While there are advantages to such a commission, my overall assessment is that such a commission is not needed. In the scientific and technical information area there have been a number of reports and studies proposing various ways of improving our national posture in this area. I believe the appointment of another commission to study the area would result in few new insights beyond the reports and recommendations which are already available. What is needed now is not another study group but rather the concentrated staff work required to formulate a clear course of action for administrative agencies and such specific legislation as may be required to improve performance in the document and information retrieval area.

As I mentioned in my testimony, the logical place for this to happen is in the Office of Science and Technology, but the size of the staff in OST is such that it cannot devote much manpower to the staff work that needs to be done. Repeated efforts on the part of the President's Science Advisor to increase the size of his staff have been unfruitful either because of the lack of adequate funding or because of the lack of clarity regarding continuing responsibility in this area. OSIS, in the National Science Foundation, has a barely sufficient staff to discharge its present responsibilities and, at its level, finds it difficult to be a spokesman for the entire community. I would suggest that a useful action would be for your committee to either request OST to do the necessary staff work or for your Committee itself to acquire an appropriate permanent staff.

In the discussion before your Committee a number of ideas have been advanced regarding the appropriate organizational structure for facilitating advanced document-handling and information transfer functions. There are several alternative organizational possibilities. As is always the case, there are various considerations in favor of and opposed to any scheme that is put forward. I believe that in our book "National Document-Handling Systems for Science and Technology" we have analyzed the various possibilities and made the arguments in favor of and against each of them. I am forwarding under separate cover a copy of the book. I would call your attention to Chapter 10, which is titled "Strengthening the Present System." Our overall conclusion is that the present system has some inherent weaknesses which mitigate against its ability to function optimally in this area. At the same time, it should be recognized that actions to significantly strengthen OST or COSATI or NSF could represent important advances. I will not review the arguments here, since they are laid out in detail in Chapter 10.

In Chapter 9 of our book we consider the possibility of several different organizational and operational structures. The alternative approaches discussed are:

1. A new operating agency within the Federal Government which we called the National Scientific and Technical Information Agency.
2. A government-chartered corporation as an operating agency. This organization would have some of the characteristics of COMSAT.
3. A national library administration as the operating and responsible agency.

We discussed the possible advantages and disadvantages and concluded that while there are many attractive features to these suggestions, their practical implementation precluded our recommending them.

As you know, our preferred recommendation involved the establishment of a "Capping Agency" and the implementation of the Responsible Agent concept. The details of these concepts are spelled out in Chapter 8 of our book.

Since our study in 1965, there have been several other major study efforts in this area. There is the report of the National Advisory Commission on Libraries, which deals with a part of the science and technical information problem. There is the extensive study of the National Academy of Science and its SATCOM effort. In our book we summarize 15 other alternative approaches that have been suggested. Again, let me say that I believe what we need now is not additional studies but rather a concentrated staff effort to formulate the appropriate administrative actions and/or legislation that is required to implement the desirable features suggested in these various reports.

It has been a privilege to testify before your Committee and, I am pleased that you are again taking the Congressional lead in this area.

Sincerely yours,

LAUNOR F. CARTER,
Vice President and Manager,
Public Systems Division.

Mr. PUCINSKI. Our next witness is Mr. B. K. Farris, vice president of Science Communication, Inc. and Mr. DeWitt O. Myatt, also of Science Communication, Inc.

We are very happy to have you here, gentlemen. I am sorry we kept you so long. I know how busy you are and I know what a big hole we put in your schedule by taking a whole day out of your activities. Forgive us. We apologize to you.

Mr. Myatt is the founder and chairman of the Board of Science Communication, Inc. Since 1941 his career has been primarily involved in information science and technical communication. He has published numerous articles dealing with the subject of information retrieval and is a recognized expert in the field.

Mr. Farris, since 1963, has served as vice president of Science Communication, Inc. and directs the technical data systems division which includes scientific and engineering information system analysis and design, information services, technical management consulting and related projects.

He has worked with the Aerospace Corp. in California, with the Applied Physics Laboratory of Johns Hopkins University, and with various private and Government agencies. He has received recognition from various technical engineering societies and is widely respected in his field.

We are pleased to have two such illustrious members of the scientific community with us today. You both have prepared statements, which will go in the record at this point, I believe, and you can proceed in any way you wish. Perhaps on the basis of all the testimony that has occurred here today, which you have listened to, you might want to put your two statements in at this point and then discuss them and discuss some of the additional information that was given here today.

Mr. MYATT. Thank you. I would like to suggest that Mr. Farris give a brief version of the formal statement that he has entered into the record.

I will follow with a few additional comments.

We have been expressly interested in a number of the exchanges that have occurred this morning and this afternoon and would appreciate the opportunity to comment on them and also to answer any questions you might want to address to us.

Mr. PUCINSKI. Proceed in any way you wish.

Mr. MYATT. First, I would like to say that before Mr. Farris and I became information scientists we started as physical scientists. We have been working in the information science field with the use of the chemical and chemical engineering backgrounds, and with working experiences in such fields as medicine, chemistry, rocketry, agriculture, and materials development.

The working associations we had with pilot plants, with chemical processing, and with the research laboratory have been very beneficial in our information work. We feel that some of the perspectives that we will be developing today with you came because of that original background.

I think with that, without further ado, I will ask Mr. Farris to proceed.

STATEMENT OF B. K. FARRIS, VICE PRESIDENT OF SCIENCE COMMUNICATION, INC., McLEAN, VA.

Mr. FARRIS. Thank you. I am pleased for the opportunity to appear before this committee and discuss the possibility of implementing a national system for improving the management of scientific data and information. Although such systems should not, in fact cannot, be implemented on a crash basis, implementation cannot be delayed if the United States intends to maintain its position of preeminence in science and techology.

Too frequenly, when data systems of the future are discussed, it is in terms of fantasies of the year 2000, rather than the actions to be taken in 1969, 1970, and so forth. Hopefully, I will be able not only to convey some of the potential of the future but to suggest some reasonable first steps toward that future.

My comments today will concentrate on data and data handling systems, rather than document handling systems. For the past 2 years, I have been engaged in extensive study of national scientific and technical data system concepts. A significant portion of my recent work and that of my colleagues at Science Communications, Inc., was conducted for the Committee on Scientific and Technical Information (COSATI) of the Federal Council for Science and Technology. Since this work included an assessment of approximately 90 issues concerning national data systems and development of a plan for further study and implementation of national scientific and technical data system concepts, I would like to offer some excerpts from our final report for inclusion in the record of this hearing.

SUMMARIZING EXCERPTS FROM THE SCIENCE COMMUNICATION, INC., REPORT-STUDY OF SCIENTIFIC AND TECHNICAL DATA ACTIVITIES IN THE UNITED STATES [1]

SPONSORSHIP ACKNOWLEDGEMENTS

The work reported herein was sponsored by the Task Group on National System(s), Committee on Scientific and Technical Information (COSATI) of the Federal Council for Science and Technology. Financial support was provided by

[1] *Study of Scientific and Technical Data Activities in the United States.* Final Report Contract F44620-67-C-0[illegible]. Science Communication, Inc., April 30, 1968.
Volume I—Plan for Study and Implementation of National Data System Concepts. AD 670 606.
Volume II (Parts A and B)—Preliminary Census of Scientific and Technical Data Activities. AD 670 607.
Volume II (Part C)—Preliminary Census of Scientific and Technical Data Activities. AD 670 608.

the Advanced Research Projects Agency of the Department of Defense, with contract administration by the Air Force Office of Scientific Research. Work was initiated on 1 September 1966, under Air Force Contract F44620-67-C-0022, and completed 30 April 1968.

I. PURPOSE, OBJECTIVES, AND METHODS OF THE STUDY

A. *Background*

In 1962, the Federal Council for Science and Technology established the Committee on Scientific Information under the auspices of the Office of Science and Technology, Executive Office of the President. In 1964, the name of the Committee was changed to Committee on Scientific and Technical Information (COSATI) to indicate that its scope of interest included technical as well as scientific information activities. Since its establishment, COSATI has been extensively involved in improving Federal scientific and technical information activities. In addition, COSATI, through its own leadership and initiative, is stimulating organizations in and out of the Government, in the United States and overseas, in science and technology and other fields, to seek new methods of improving their capability to communicate information efficiently and effectively both within and between communities. Perhaps the most ambitious of COSATI undertakings to date involves the work of a Task Group to study the complex area of planning for national information system(s). The charter of this task group identifies two principal goals and objectives:

> Undertake those investigations needed to (a) inventory and evaluate the resources (people, libraries, and other services, equipment, materials and funds) currently being utilized in national and other domestic scientific and technical information activities: and (b) ascertain the information needs of users such as: scientists, engineers, managers, practitioners, and the technical public, as individuals and as groups, in and out of the Government.
>
> Based upon these and other findings, prepare recommendations and plans for the development of national information system(s) to include actions for Government agencies, suggestions for actions by the private sector, and steps to move from current to advanced information systems.

The Task Group has sponsored a set of complementary studies to accumulate background information and to assess its relevance to the requirements and feasibility factors relating to national scientific and technical information systems concepts. The first study examined the current status of document handling and made recommendations concerning a national document handling system.[2] A second study dealt in depth with abstracting and indexing services in the United States.[3] Another study analyzed the structures and functions of informal information communication systems.[4] Based on the results of these studies, other findings, and the experience of its members, the Task Group is formulating recommendations and plans for consideration and implementation of national information system concepts.

B. OBJECTIVES OF THE STUDY OF DATA UNDERTAKEN BY THE TASK GROUP ON NATIONAL SYSTEM(S)

Prior to 1966, relatively few comprehensive studies had been conducted of scientific and technical *data* systems. Previous studies and surveys had been restricted to the data activities of an agency, to a specific scientific or technical field, or to selected elements of a total data system—e.g., data processing equipment. Consequently, the COSATI Task Group on National Systems has undertaken a broad-scope study that can be used to guide the formation of national policy with respect to systems for scientific and technical *data* collection, reduction, storage, retrieval, analysis, and dissemination. Specifically, the study by the Task Group is intended to:

---

[2] *Recommendations for National Document Handling Systems in Science and Technology: Appendix A—A Background Study—Volumes I and II*, System Development Corporation, Santa Monica, California, September 1965. Contract AF 19(628)-5166.

[3] *A System Study of Abstracting and Indexing in the United States*. System Development Corporation, Falls Church, Virginia, 16 December 1966, Contract NSF-C-464.

[4] *Exploration of Oral/Informal Technical Communications Behavior*, Semi-Annual Technical Report, American Institutes for Research, Silver Spring, Maryland, 15 March 1967, DAHC-04 67 C0004.

Assess the degree of attention that is being given to data on the national level;

Clarify the role that scientific and technical data—in various stages of refinement—play in the technical decision process; and

Formulate data system policies and/or actions that will benefit the interchange of technological know-how and the conduct of research.

For the purposes of the study, data are described as quantitative or qualitative representations of properties, characteristics, or attributes of objects, events, measurements, or observations. In common usage, data connote factual, as opposed to conceptual information; in addition, the term is frequently used to denote the factual information content of a document, rather than the document or artifact itself. The latter distinction permits differentiation beween this study and many previous studies which dealt with document handling systems or with abstracting, indexing, or other treatment of conceptual information content of documents. The scope of the study, roughly defined, includes activities involving the following types of scientific and technical data:

Data acquired in the course of conducting experiments or examining natural phenomena, or in the course of performing tests according to precribed procedures;

Data which describe the characteristics or performance of a natural phenomenon, a material, a device, or a component; and

Data which instruct, guide, or aid skilled or semi-skilled persons in the proper use, maintenance, or replacement of artifacts, or in techniques and procedures.

This study is intended to establish how the various types of scientific and technical data are acquired, stored, retrieved, packaged, and disseminated for specific types of uses; why these packaging methods have been adopted; and what changes in methods are foreseen in the future. Special emphasis is placed on uses made of data by various functional groups (e.g., basic research, equipment and systems development, product application, etc.) and the degree of processing or refinement of data needed for such functional groups.

A further objective of the study, which is to be conducted in several phases, is to facilitate an open discourse and provide an opportunity for expression of the views and knowledge of the many individuals and organizations that will be key participants in the development, operation, and use of future data systems.

The scope of the Task Group study can be summarized as encompassing scientific and technical data activities which are potentially amenable to determination of requirements for national data systems or for other types of coordination which would improve our national scientific and technological posture.

C. APPROACH AND PRODUCTS OF THE INITIAL PHASE OF THE STUDY

In September 1966, Science Communication, Inc. was awarded a contract to initiate this study. Specifically, Science Communication, Inc. undertook to conduct a preliminary survey of scientific and technical data activities, data-related problems, and data system needs within government, the professions, and industry. This initial phase of the COSATI Task Group Study was undertaken to produce a preliminary census of current data activities and a plan for further study and consideration of various concepts of national scientific and technical data systems.

The following Summary of Conclusions and Recommendations (Section II) highlights some of the more important conclusions reached in this initial phase of the study. It must be emphasized that these conclusions are the result of a very limited effort in terms of the ratio of the size of the study effort to the magnitude of the problem area examined. However, these conclusions, together with the other findings and recommendations in the Science Communication, Inc. Report, provide, for the first time, visibility and articulation of the data segment of scientific and technical information activity. The conclusions and recommendations are considered significant for two reasons. First, they were formulated from the findings of an extensive census-survey of scientific and technical data activities. Second, they summarize the assessments of approximately 300 experts who were asked to comment on approximately 90 issues and recommended solutions which Science Communication, Inc. identified as most critically relevant to national scientific and technical data system concepts.

Volume I of the Science Communication, Inc. Report not only discusses issues and provides recommendations for their resolution; it also outlines a systematic plan for executing the recommendations in the context of a National Scientific and Technical Data Program. Section III describes this plan.

Volume II of the Science Communication, Inc. Report consists of three parts. *Part A* presents scenarios of data activities in ten selected fields of science and technology. Each scenario covers the characteristics of data, data flows, formal data efforts, and representative data related problems or issues identifiable with the field. The fields covered are: aerospace science and technology, electronics and electrical engineering, materials science and engineering, chemistry and chemical engineering, agriculture and food technology, biomedical sciences, pharmacology, social and behavioral sciences, environmental and geosciences, and oceanography. A supplementary scenario describes data activities as conducted within the research, developmental, and applications phases of scientific and technological activity.

Part B summarizes results from analyses of selected areas of scientific and technical data activity. Areas analyzed include data activities of medical research institutions, professional societies and trade associations, commercial data processing service centers, and U.S. Army research, development, test and evaluation activities. *Part B* also includes a review of data handling equipment capabilities potentially applicable to national scientific and technical data systems.

Part C consists of an in-depth census of 226 formal data efforts which are representative of the efforts currently operating in the United States which most likely would be considered in conjunction with planning and development of national data systems. The following types of data efforts are included in the census: Data service centers, Data-document depositories, Data program development and coordination, Non-designated (Agency) data handling and service operations, and Small evolving data handling and service operations.

The Science Communication, Inc. Report equips the COSATI Task Group on National Systems and other interested organizations with a preliminary definition of the challenge awaiting those who will assume the leadership in creating improved scientific and technical data systems. In addition, it provides a focal point for reviews and discussions to further define required actions and enlist the participation of the many organizations and individuals who must contribute to the development of improved scientific and technical data management and handling systems.

II. SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

A. Scientific and technical data-perspectives and policy implications

Conclusion: The utility of our national scientific and technical data resource can be substantially increased by improved management.

Although the Federal Government and non-government organizations in the U.S. jointly expand in excess of 20 billion dollars annually to support research and development efforts, few policies exist to guide the management of the resultant scientific and technical data. In fact, current policies and programs have resulted in an imbalance between the efforts expended to generate new data and the efforts expended to maintain, evaluate and make maximum use of available data.

Recommendation: The Executive Office of the President should issue a policy statement establishing the objectives of a national program to improve the management of scientific and technical data activities within government, the professions, and industry.

The statement should not only identify goals but designate responsibilities and identify means to achieve the program objectives. Specifically, the program should achieve redistribution of Federal expenditures so that an appropriate percentage of each agency's research and development budget is allocated to data activities. The program should involve upgrading of existing data systems and services, and development of the capabilities required for implementation of improved systems for future data management and handling. In addition, the program should provide funds to support exploratory study and planning of data management and data handling systems in those areas of science and technology which can most benefit from such study and planning.

The total program should be structured and administered in a manner which will assure appropriate participation by all sectors of the scientific and technological community.

Conclusion: No effective means currently exists for coordinating and integrating the data management and data handling activities of the governmental, professional, and industrial sectors of science and technology.

Despite the extensive efforts of COSATI and the respective agencies of the Federal Government to coordinate intra-government scientific and technical information activities, no broad-gauge means has been established to coordinate these efforts with those of non-government organizations. The National Science Foundation is currently funding and working with professional societies to establish discipline-based information systems, and many other government agencies cooperate with a limited number of non-government organizations. For example, the Department of Defense co-sponsors meetings and working groups with data-oriented sub-groups of the American Ordnance Association and the National Security Industrial Association. However, existing arrangements are not adequate to support the implementation of the program required to achieve optimal use of the national scientific and technical data resource.

Recommendation: A National Advisory Council for Scientific and Technical Data should be established.

The Council membership should represent the various segments of scientific and technical data activity, both governmental and non-governmental. The Council should function principally as a review and consultative body and should be structured to permit the operation of Panels concerned with the following types of data activities: (1) Discipline-research (scientific) data activities; (2) Developmental-mission data activities; (3) Applications-product data activities; (4) General-purpose data activities; and (5) Data system technologies and development activities. Through operation of its Panels, meetings such as a White House Conference and special studies, the Council would provide a forum dealing with data management and data handling system requirements. Based on inputs from this continuing forum and Council review of current data management practices and data system performance, the Council would evolve recommendations to guide the National Scientific and Technical Data Program. The Council should maintain a small, permanent staff which would function as the secretariat for the Advisory Panels and would monitor planning and other special studies initiated by the Council.

Conclusion: Scientific and technical data and data activities are exceedingly complex; national data programs and system development efforts must be capable of effectively recognizing and accommodating this complexity.

The extent of this complexity can be gained by considering the attributes of scientific data activities associated with discipline research as compared with those technical data activities associated with mission development or product application activities. Each of these types of data activities use data (even the same data) in different ways, prefer specific packaging methods, and are driven by different motivational factors in the generation, handling, and application of data.

Recommendation: National data programs and related policies must be implemented with due consideration of the diverse types of data activities which are conducted as an integral and vital part of science and technology.

Present knowledge indicates that the National Scientific and Technical Data Program should consist of at least two subprograms—one formatted to develop improved data management and handling systems for scientific data activities, and one formatted to the requirements of technical data activities. This would permit the total program the flexibility required for effective interaction between government, industry, and the professions. More specifically, it would permit the Federal Government to tailor its support of data system development efforts in accordance with the extent of the public interest.

In addition, the National Data Program must be structured to complement and build on existing data efforts, both governmental and non-governmental. Especially, it should provide a means for including a voice for the interests of the pre-existing data service programs in the mission-oriented Federal agencies and in commercial service firms such as publishers.

Conclusion: The full utility of scientific and technical data is not currently realized under existing data management and data handling policies.

Analogous to the preservation of academic freedom, the individual scientist has rightfully striven to preserve independence from external influences on the conduct of his scientific work. As a consequence, the scientific community has avoided centralized coordination of its activities, including conservation of the knowledge structures which constitute the bases of the various disciplines. It is assumed that the informal structures, such as the invisible college and the more formal mechanisms associated with publication o fthe scientific journal and monographs, provide adequate vehicles for communicating data and for maintenance of the unity which is so vital to a strong science. This assumption fails to give due weight to the changing character of the role which our society expects science to perform and the changes which result as scientists attempt to react to these new expectations. It also fails to note the inadequacies of the scientific paper, professional journal, and abstract publication as a set of tools for the communication and maintenance of the increasing pool of factual information or data being generated by scientists.

Although due to other causes, the data management and conservation practices currently followed in developmental or applications activities in science and technology are equally ineffective. For example, in spite of the large amounts expended to develop costly items of equipment for applications, such as defense and space exploration, data describing these equipments are not maintained in well-structured, full-indexed files readily accessible to other potential users.

Recommendation: Each scientific or technical community, including mission-oriented agencies, should reappraise its current procedures for managing and handling scientific and technical data, especially in regard to their adequacy for conservation of the data as a costly and potentially reusable resource.

Each community should establish a focal point and procedures to identify the characteristics of its data resources, to articulate data management objectives, and to formulate plans and programs to implement data handling systems development or other actions to achieve the goals of the community. In effect, each community should create a body (office, committees, etc.) to serve as a spokesman and coordinator for the cooperative data activities of the community. Such data activity coordinators might be housed in professional societies, trade associations, educational institutions, or government agencies; however, participation in the activities of the coordinating body should be open to all members of the community. In fact, the ability to assure a large involvement of the community in its activities should be a prerequisite for recognition of the coordinating body as the designated agent to participate in National Scientific and Technical Data Program development. In addition, such groups should explore the feasibility and potential utility of data indexes or inventories, data-source referral services, computer-composed handbooks, computer-maintained data banks, and other means of maintaining and increasing the utility of the data base serving a given community of users. The coordinating body should serve principally to act as an initiator for the development of such service; however, if other means are not feasible, the coordinating body could undertake provision of such services.

Conclusion: There is inadequate knowledge concerning the nature (quantity, quality, location, ownership, usefulness, etc.) of existing scientific and technical data to permit optimum design of national data management programs or data handling systems.

It is amazing that, despite the large expenditures for generation of data and level of sophistication generally acknowledged to exist in administration of scientific and technological activities, a comprehensive inventory of data does not currently exist for any of the major communities in science and technology. As a consequence, many important decisions, concerning either scientific and technological programs or data handling, are made with little detailed information concerning the available data resource. In many cases, Federal contracts or grants are awarded for generation of new data when the awarding agency is unable to supply the contractor or grantee with information concerning the nature, quality, availability, etc. of previous measurement results.

Recommendation: A National Index of Scientific and Technical Data should be developed. Such an index is essential if data management is to be planned on a systematic basis. Also, such an index would be immediately useful to scientists and technologists who currently expend as much as 30% of their working hours searching for data required to perform their job.

The index envisioned is not one single, comprehensive index; rather, it would consist of sub-indexes covering the data resources useful within individual communities. The initial index should cover existing scientific or technical data files, data reference tools such as handbooks, and computer processible data. Subsequently, it could be extended and refined to index data at the document level.

The form of the index should be adapted to the requirements of the using communities. In many cases, the index will be most useful if compiled and maintained in a computer searchable form. The National Index could be pursued as a central element of a National Data Program with the index compilation activities in each scientific or technical community being coordinated by a selected organization such as a professional society or trade association. Commercial firms could disseminate the Index in either hardcopy or computer processible form.

Conclusion: Federal policy relative to scientific and technical data management must recognize and facilitate maximum use of the existing scientific and technical data resource.

Science has fostered wide dissemination and accessibility to scientific data with restrictions limited largely to those conventions required to acknowledge the generator. To a lesser extent, copyright has been employed to enable the publisher to maintain an economically viable channel for dissemination of data. In contrast, mission-oriented agencies of the Federal Government and commercial firms frequently restrict the distribution or accessibility of the data which they generate. In some instances, it is because the agency or firm does not wish to disclose its position; in other cases, the agency or firm has no desire to restrict the data, but has no incentive to expend the funds and/or effort required to make the data available to other users.

Recommendation: The Federal Government should establish a policy to encourage the accessibility of scientific and technical data to as many potential users as possible.

Such a policy would not conflict with full recognition of the property rights of individuals or organizations. Rather, it would be promulgated with a specific delineation of private data (data which an individual or organization does not desire to disclose or release), proprietary data (data which the owner or possessor will release under prescribed conditions such as payment of a fee), and public data (data for which ownership and possession is in the public domain). Government support should be given to efforts for removal of the barriers which result in data being restricted when, in fact, the owner or holder has no objections to use of the data by others.

Initially, the Federal Government should take actions to see that data generated under its sponsorship is managed so as to assure maximum use. For example, all Federal research and development programs should direct a minimum level of effort to this objective. This should be supplemented by a central clearinghouse which would support the special data husbandry operations required to move data from a restricted or limited use context (e.g., an agency project file) to one where the data has higher visibility and greater use potential (e.g., a government-issued index to data of potential interest to a specific user group either government or non-government).

In addition, where commercially generated data have high utility for a large or significant segment of a scientific or technological community, the Federal Government should be prepared to underwrite the cost of organizing and disseminating the data. However, this should be undertaken only when costs or other factors preclude such actions by commercial service firms.

Conclusion: As data handling becomes increasingly automated, the need for standardization of data handling methods will become increasingly important to the National Scientific and Technical Data Program.

To a lesser extent, there will also be factors leading to increased need for some standardization of the form and quality of data. However, any steps towards standardization of data form and quality must be taken with caution and with a full appreciation of the implications for the conduct of scientific and technical work. As the major supporter of scientific and technical work, the Federal Government has a vital interest, as well as the means, to assure that standardization requirements are delineated and implemented.

Recommendation: The Federal Government should take action to assure development and application of standardized methods of handling basic scientific data, especially those automated methods broadly applicable to data systems in more than one field of research.

Scientists in specific areas of research must make the final determination of whether standardization of measurements and data is feasible or desirable. Whereas, Government-initiated standardization of data handling methods supporting research on a broad basis appears desirable, standardization of data handling methods supporting development or applications activities does not appear warranted except within specific Government-development programs. Industry, through cooperative arrangements, should be encouraged to upgrade and standardize its developmental and applications data activities. In situations where it can be shown that standardization will contribute to a better integrated and stronger national scientific and technological competence, the Federal Government should, if required, subsidize standardization efforts. At a minimum, the Government should provide increased technical assistance and financial support to standardization activities.

Conclusion: The diverse connotations assigned by different communities, organizations, and individuals to scientific and technical data, data artifacts, and data management and handling efforts constitute severe barriers to systematic planning and evaluation.

For example, in engineering and other application-oriented activities, *data* is frequently used to connote all documentation required for accomplishment of the scientific and technical objectives of the project, program, or organization. Whereas, in research or discipline-oriented activities, *data* is used to connote factual information as contrasted to conceptual information. Further, a preliminary review of the currently accepted definitions in the various Government agencies are not consistent. One result of this non-standardization is inefficiency and increased costs incurred by contractors and other non-government organizations who deal with more than one government agency.

Recommendation: The Committee on Scientific and Technical Information (COSATI) should promulgate a set of definitions which delineate an internally consistent set of terms covering scientific and technical data activities.

These definitions, if carefully formulated, will provide a guide to encourage consistent usage of scientific or technical data terms throughout the Federal Government. The existence of an acceptable set of terms will facilitate the establishment of more precise and effective policies and procedures dealing with data activities. Specifically, it will facilitate acquisition of data from non-government sources and will make it easier to communicate concerning data between government offices.

Conclusion: Just as science is international, scientific and technical data activity is often international in scope.

In many areas of science and technology, such as atmospheric science, it is very important to obtain data on a world-wide basis. Where these needs exist, many scientific and technological communities in the United States, through the International Unions and similar organizations, have become participants in international data activities. Currently, much international data activity involves multi-nation efforts to collect data on a world-wide basis. In many cases, these data will constitute a part of the data base which future national data systems must handle. Consequently, it is critical that U.S. participation in such activities be planned and conducted on the most informed basis possible. A current problem is that the attention which responsible offices have been able to give to this activity has not kept pace with the increasing volume and importance of international data activities.

Another aspect of this question is the immense size of the total data management effort; the U.S. cannot hope to independently perform this function for all areas of science and technology.

Recommendation: Offices in the Federal Government designated as responsible for representing U.S. interests in the area of international data activities should be strengthened not only to permit them to better represent U.S. interest, but also to enable them to establish better communications and working relationships with on-going activities in the U.S.

The requirement for effective coordination of U.S. involvement in international data activities and program development is expected to continue to increase as data management becomes more formalized and national data systems are developed. It will become increasingly important to guard against unilateral actions by individual organizations or communities. Also, a means must be established to determine which areas of scientific and technical data management the U.S. will undertake jointly with other countries and which would best be pursued totally or largely by the U.S.

B. Current issues and problems—nature and possible resolutions

Conclusion: The inadequacy of classifical methods for structing and communicating scientific and technical data in current working contexts has created unnecessary apprehension.

The more evident symptoms of this apprehension include fears, such as those voiced in the Weinberg Report, that science could lose its unity and effectiveness by fragmenting into a mass of repetitious findings, or worse, into conflicting specialties that are not recognized as mutually inconsistent. Subsequent study indicates that the existing apprehension represents the expected preamble to a significant change in data management and handling methods.

Recommendation: The currently evolving expressions of need for large-scale scientific and technical data handling systems should be viewed as a response to opportunity, not an act of desperation to avoid inundation by the flood of data.

Science and technology has not only generated massive quantities of data; it has also developed computers and other tools which offer unprecedented opportunities for improved management and handling of this data resource. In fact, these tools, if properly applied, offer the potential for quantum increases in the uses of data, thereby not only increasing the return to supporters of science and technology but also reducing the total cost involved. The nation should no longer tolerate only partial use of data; data is not consumed by use, but rather gain information value with reuse.

Conclusion: Current research and development administration, especially within Federally-sponsored programs, frequently gives preferential consideration to research or development to generate scientific and technical data over activities directed to assembly, evaluation, and application of existing data.

It has been stated on several occasions that the individual scientist is frequently encouraged by diverse factors, some sociological and some related to the current nature of research funding and administration, to undertake new measurements before fully digesting previous measurements. In many instances, individual scientists or technologists, as well as research and development projects, have found it easier to repeat measurements than to locate the results of previous measurements. Such regeneration of data can be very expensive, especially if it should require flight testing of a supersonic aircraft such as the RB–70 or launching of an instrumented satellite.

Recommendation: Each Federal research and development program should be required to allocate a minimum percentage of its budget to husbandry and conservation of the scientific or technical data generated by the program.

For example, basic research programs might allocate 10%, applied research programs 15%, and developmental programs 5%. These funds need not be identified as line items in the agencies' budgets, but an annual report of compliance should be made to a centralized review body such as the Bureau of the Budget or the Office of Science and Technology. The intent of this recommendation is to assure that a reasonable effort is expended to conserve data generated by Federal expenditures and to assure that it is readily accessible for application in either other Federal programs or in the other sectors of our society.

Conclusion: Although essentially the same problems are observed in data handling activities in the different fields of science and technology, no mechanism now exists for the coordination of efforts toward solution of these problems.

Perhaps, the reason for so little comparison of experiences is the belief widely held by the directors of data-document depositories, data-evaluation centers, etc. that the problems faced by each data handling effort are unique. Although this study has confirmed the uniqueness of some aspects of data handling efforts, it has also found that most efforts encounter similar difficulties in the areas of application of new technologies, financing of costly development efforts, and recruitment and retention of capable personnel. Also, present operation philosophies do not indicate an awareness of the potential interaction between data efforts serving a common community of science or technology. The current evaluation of the effectiveness of many of these efforts is that it is very low because they do not permit effective interaction between the data resource and the potential user.

Recommendation: The Federal Government should establish an information center to serve as a depository and dissemination agency for information dealing with design, development, operation and management of scientific and technical data systems.

The center should serve to support participants in the National Scientific and Technical Data Program, especially the National Advisory Council for Science and Technology. The services of this center should be extended to non-government as well as government offices. Such a center could be established by consolidating and augmenting some of the current information service activities of the NBS Research Information Center and Advisory Service on Information Processing, the NSF Office of Science Information Service, and the Bureau of the Budget Management Study File.

In addition, professional societies, such as the American Society for Information Sciences, should establish panels or subgroups of data system professionals and should undertake development of publications and meetings to communicate developments concerning scientific and technical data management systems. In addition, the roles and functions of these existing efforts should be re-examined as part of the National Scientific and Technical Data System planning. Careful consideration should be given to ways in which the operations of the efforts serving a given community of users could be coordinated to contribute more to effective data management.

Conclusion: Current requirements are largely undefined.

Additionally, effective methods are not available for predicting future data requirements. This factor, as much as any other single factor, has restricted the development of large-scale data handling systems.

Recommendation: Existing data service centers such as the National Oceanographic Data Center and National Space Sciences Data Center, and new prototype data resource centers, should be used as test beds to study data service needs.

Factors to be examined should include the effect of usage levels and user satisfaction resulting from the availability of different configurations of data services. For example, remote console access to a centralized data bank should be compared with desk-top microfilm services. Other factors examined should include degree of data evaluation, format of data presentation, user charges, etc.

Conclusion: Current scientific and technical handling practices do not fully employ available technologies.

Despite extensive use of computers for performance of mathematical computations, science and technology have only recently begun to exploit the computer as a tool for structuring, storing, and maintaining large files or banks of scientific and technical data. A more mundane example of the lagging use of technology is evident in the current practices for composing and disseminating data documents or artifacts. For example, despite the technological capability to maintain handbooks essentially current, most handbooks are five years or more out of date. If significant advances are to be made in the application of new technologies, knowledge must be gained concerning the effectiveness of these new tools for performance of specific data management and handling functions within real-world work environments.

Application of currently available data handling technologies offers potential for substantial increases in the utility of the existing scientific and technical data resource. This increased utility can be achieved by two means, first, by performance of current activities in a more effective manner; and second, by using new technologies to conduct activities previously impossible. An example of the first means would include computer maintenance and searching of indexes to data. The second application, which offers the greater potential, is to use large automated data files to perform pattern recognition or other types of higher level analyses. Another new use potentially exploitable is computer-aided design which brings the data and the computer into the daily work pattern of the scientist or technologist.

Recommendation: The Federal Government, professional societies, trade associations, commercial publishers, and other collectors and disseminators of scientific or technical data should explore means of applying modern technology for more effective assembly and dissemination of scientific and technical data.

Areas to be examined should include use of computers to maintain the data base and compose handbooks. Also, microfilm and computer processable media should be more extensively used to disseminate data. In appropriate cases, data should be disseminated in more directly useful forms such as in combination with computer programs for designs, diagnosis, or other applications of data.

The Federal Government should sponsor demonstration projects in which innovative data handling tools and media would be tested. Some of these demonstration projects should be in government programmatic contexts and some in non-government contexts. These demostration projects should be conducted as controlled experiments with results carefully documented for educational and training purposes. Where possible, existing projects intimately associated with on-going research and development should be used as demonstration projects. A typical candidate project might be the National Institutes of Health Chemical/

Biological Information Handling Program. This program was only recently initiated and is intended to develop an on-line data system to serve the researchers involved in the NIH Toxicology Research Program.

Conclusion: The lag time between data generation and dissemination using traditional publications is frequently from two to five years.

This lag time is caused by several forces and conditions which prevail primarily in the scientific community. First, the practicing scientific investigator is motivated to publish data only upon generation or verification of a significant theory or hypothesis; and data generated at the outset of a theoretical investigation may therefore not be published for several years. Secondly, the time lapse between preparation of a paper and actual publication may be as much as one year, because of the slow review process and the backlog of papers that exist in scientific fields. Thirdly, the additional effort required to publish data which do not relate directly to interim investigative conclusions, deters and sometimes eliminates its publication.

Recommendation: Programs should be developed to more directly couple experimentation, tests, etc. with data systems.

As on-line use of computers in scientific investigations becomes a widespread reality, automated data banks should be developed, particularly in the physical sciences, environmental, and geosciences. Pilot programs should be implemented to determine the feasibility of such data banks and to examine the associated problems, especially structuring and access aspects of such systems.

Conclusion: Although the total investment applied to generation of data concerning products and processes far exceeds that applied to generation of basic scientific data, inadequate effort is expended by the Federal Government to organize this data for secondary uses.

As an example, files and search procedures do not exist to permit a potential user to locate data describing previously developed equipment meeting a given set of performance characteristics. Such data normally cannot be located unless the searcher has informal knowledge concerning the probable location of the data.

Recommendation: Current efforts, such as the Department of Defense Engineering File, should be substantially accelerated, and other equipment development agencies without such systems should initiate study of their feasibility.

A logical start toward such systems would be an inventory operation to develop an index to the existing files. If this were done in a number of agencies, it would make a major contribution toward the National Index of Technical Data.

C. Systems development—Requirements and implementation concepts

Conclusion: It cannot be expected that existing groups will cooperate in efforts to develop national systems where the purpose is intangible or Federal domination might restrict the legitimate freedoms of scientific groups, commercial firms, etc.

Many scientists and technologists object, as a matter of principle, to the involvement of the Federal Government in planning or coordination of scientific and technical data management programs or data handling systems. It must also be noted, however, that an equal or greater number recognize that neither the individual scientist and technologist nor the professional organizations have the necessary resources or have exhibited a capability to assume responsibility for creating data management and data handling systems responsive to current needs.

Recommendation: A National Scientific and Technical Data Program must be planned and administered in a manner which accommodates the interests and capabilities of diverse groups and organizations.

The structures of data systems cannot be dictated by fiat from a top-level policy position. Rather, such structures must evolve from working-level responses to real needs. In fact, national systems are already developing in this fashion. The current need is for coordination and financial support of these evolving systems. Each scientific and technological community must be encouraged to contribute to formulation of goals and implementation plans for national systems. This can be facilitated by the establishment of an office or other type of organization to serve as a focal point for national level data system planning.

This organization should be located and staffed in a manner which permits participation not only from government but also professional societies, trade

31-464 O—69——12

associations, industrial organizations, and educational institutions. Centralization of responsibility for national system development should be limited largely to programming and broad planning functions. Detailed planning implementation and operation should be on a decentralized basis.

Conclusion: The inability to define a single system structure responsive to all data management and data handling requirements does not constitute a valid justification for delaying consideration of new or improved data systems.

Data management systems employing modern technologies such as the computer are still only in the concept definition phase. Current knowledge as to how best to use these tools will not support a crash program to create a large-scale, highly automated and totally integrated system. First, more must be learned as to which functions are most important and how each function can best be performed.

Recommendation: The present should be recognized as a timely point for initiation of national systems planning and development effort.

It is anticipated that at least six years will be required to develop national data systems serving specific communities in science and technology. This period can be profitably used to explore alternate system configurations, and relative effectiveness in serving specific data management requirements. This effort should produce a base of knowledge which would substantiate later decisions relative to the extent to which such specialized systems could be integrated into a more unified system.

Conclusion: Data management is in a state of transition which is being driven largely by the introduction of computer and other improved data handling methods.

For the foreseeable future, data management must continue to be a decentralized process directed by the scientists, technologists, and administrators responsible for specific scientific and technical endeavors. However, as data system management methods and systems are developed and implemented, a capability will be created for management of larger and more complex sets of data.

Recommendation: In the near future, efforts at the national level should be directed toward the development and test of systems or tools to facilitate better data management.

Initially such tools or systems should be designed to facilitate currently definable data management functions, such as identification of the location of relevant data. As soon as data management functions are defined, data management requirements should be analyzed and articulated for workers at all levels from the bench scientists to the administrator of national scope scientific and technical efforts. This should be done jointly by systems analysts and the workers involved in each level of activity.

Conclusion: The most valid requirements for development of national scale data handling systems exist for systems operating within scientific and technical communities rather than between communities.

This conclusion is derived from a consideration of the volume and frequency of intra-community communication of data versus inter-community communications. And to a greater extent, it derives from the feasibility of being able to effectively identify intra-community data management and handling requirements as compared to the feasibility of identifying such requirements on a multi-community scale.

Recommendation: National data system development efforts should be focused on individual communities.

These communities will probably be defined on several bases. In one case it might be on the basis of the common discipline; in another, it might be on the basis of a common mission objective; whereas a third might be based on an interest in a type of process such as metal fabrication.

Conclusion: Data handling systems are tools to facilitate data management.

Therefore, implementation of effective data handling systems is dependent upon a prior definition of data management objectives. Unfortunately, individuals currently attempting to develop data handling systems are frequently forced to proceed without adequate definitions of data management objectives. As a consequence, the data handling activity frequently fails to interact effectively with the scientific or technical program objectives. More specifically, many data evaluation and service centers do not engage the individual scientists or engineer within his normal daily work routine. In contrast, the computing center requires an explicit statement of the user's objectives before it can undertake to serve him. Consequently, the computing center has become a vital element in the normal work routine of the scientist and engineer.

A survey (Volume II of this report) of formal data efforts currently serving scientific and technological communities reveals that the data efforts serving any given community operate totally independently. In other words, they do not formally view themselves as facilitating accomplishment of a common set of data management objectives.

Recommendation: The total data management requirements of a community to be served should be examined prior to implementation of data handling systems as part of the National Scientific and Technical Data Program.

This examination should not only include the management requirements which generate a need for archival data handling, but also those requirements which generate needs for data transmission and data processing associated with generation or use of data. This approach will result in maximum service to the user because it not only will enable the user to have a voice in the system design, but will encourage the integrated application of different data handling efforts.

Conclusion: National scientific and technical data system development efforts must consider not only the scientific or technical field to be served by the system, but also the specific type or phase of activity to be served.

For example, the public interest (i.e., non-commercial interest) is high in discipline-research related data activities because such activities generate and maintain data widely useful in our current society. Whereas, non-public or commercial interest is greatest in product-applications data activities. Economic or profit-oriented incentives are easily discernible in the case of product-applications data activities; whereas, they are practically non-existent in discipline-research data activities. Another relevant factor is the stage of development of a data system. It is likely that many data systems could be self-supporting, once established. But the time and cost required to establish the system constitute the threshold barrier.

Recommendation: Federal support of national scientific and technical data programs and systems should be pro-rated according to the type of data activity served and the stage of the data program or system.

In effect, what is suggested is a cost-sharing plan whereby the Federal Government's share is high for systems or programs to serve discipline-research or non-commercial data activities and low for programs or systems to serve product-applications data activities. In either case, the share of cost borne by the Federal Government would decrease progressively as the data system advanced from program planning, to system development, and finally, to system operation. For example, the Federal Government might bear 100% of the cost of planning for a data system to serve discipline-research in chemistry, 75% of the development costs, and 25% or less of the operating cost. In contrast, the Federal Government might bear 90% of the cost of planning for a data system to serve the food processing industry, 50% of the development costs, and none of the operating costs.

Conclusion: To be effective, data service operations must be complementary to the normal work routines of the scientist or technologist.

Many of the currently operating data evaluation centers and other data service efforts are ineffectual because they are too far removed from the daily service needs of the worker. This occurs because the operations of these services do not begin until the generator of the data has recorded, analyzed, printed and disseminated the data. Often four or more years pass between the date when the data are recorded and when a data evaluation center offers them to a secondary user.

Recommendation: A part of the National Scientific and Technical Data Program should be the development of integrated data resource and service centers.

Data resource centers which incorporate into one facility several of the data handling systems and services which the scientist or technologist now must use separately should be tested. The data resource center could provide the user ready access to data acquisition facilities, computing equipment, automated archives of relevant data, archives of computer routines, reactive display consoles, automatic report generators, and long-distance communication terminals. If established within a project or other context where workers were engaged in a joint effort, the center could test techniques for communication from worker to worker as well as from worker to a data resource. Such resource centers could also be used to test the feasibility of on-line data reduction during experiments or tests, and the concepts of working data files and archival data files concurrently accessible to a worker at his individual console. Preliminary studies indicate that such centers could be developed relatively economically.

Conclusion: Data systems complement other information systems; however, it is short-sighted to view data systems as simple extensions of document handling systems.

This short-sighted view fails to give due consideration to the extensive interactions between the scientist or technologist and his data prior to publication. In recent years this interaction has increasingly involved use of the computer in analysis and evaluation of the data. This view also fails to give due weight to the large volumes of data which are exchanged through channels other than publication, e.g., the data (specifications, engineering drawings, test reports, etc.) flow which occurs within a program to design and develop a satellite launch vehicle.

During the past decade, an imbalance has developed between the emphasis which the Federal Government and other organizations have given to study and development of document handling systems as compared to the emphasis given to factual information or data handling systems. Practically all of the more 20 plans for national scientific and technical information systems put forth during the past decade have dealt exclusively with the problem of handling documents. Few of these plans seriously considered the extent to which documents perform optimally as the vehicle for the two major functions of information systems—communicating and archiving knowledge.

Recommendation: Data management and handling systems in their ultimate form should be viewed as providing a capability for a totally new level of interaction between the scientist or technologist and the accumulated data resource.

This ultimate goal cannot be quickly realized, however much of the required effort is already being expended. What is involved is not a radical change in level of effort; rather, it is coordination and better direction of current efforts, supplemented on a selective basis. Existing data programs could be integrated to form the major volume of operations in a national data system. As an example of a simple initial step, document handling systems could initiate indexing of the data content of documents processed.

D. Systems capabilities—Assessments and remedial actions

Conclusion: Current research and development directed specifically to study of critical factors important to development of large-scale scientific data handling systems is totally inadequate.

A wide disparity currently exists between the technical capabilities of data processing and transmission devices and knowledge as to how best to apply these capabilities in scientific and technical data handling systems. Projects MAC and INTREX at the Massachusetts Institute of Technology, the laboratory automation project at the California Institute of Technology, and the Information Resource Center element of ILLIAC-III at the University of Illinois are representative of the types of studies which are needed. These three projects illustrate the varying levels at which the national systems concept should be studied.

Recommendation: The Federal Government should budget at least one-tenth of one percent of its total annual expenditure on research and development for research on techniques and procedures for managing and handling scientific and technical data.

This research should provide general support to data management and data handling activities and should not be directed to development of methods or tools for specialized applications. In order to assure efficient use of these funds, the administration of this research program should be centered in one agency, such as the Institute for Computer Technology at the National Bureau of Standards.

Conclusion: Current personnel and institutional capabilities are not adequate to support a crash program to develop a national scope scientific and technical data handling system.

Survey of professional societies, trade associations, computer service centers, etc and discussions with leading data specialists have revealed a low incidence of serious consideration of, or work toward, establishment of large-scale scientific and technical data handling systems. Exceptions to this general observation were noted only in operational- or mission-oriented areas of activity such as weather forecasting, air pollution control, etc.

Outside of limited programs in Government agencies such as the Department of Defense, formal educational and training programs for scientific and technical data specialists, scientists, and managers are, for all practical purposes, nonexistent. In addition, sociological factors and career management practices currently discourage the more capable scientists and engineers from engaging in scientific and technical data handling efforts.

Recommendation: Information and data managers should be developed from two sources—one is the current population of working scientists, engineers, data processing specialists, etc.; the second is the current and future population of students in colleges and universities.

As an interim measure, the Federal Government and other employers of scientists and engineers should search for individuals interested in scientific and technical data systems and should support the special training required for those individuals to become proficient in analysis, design and operation of modern data systems. Adequate training programs are not currently available; and since the amount of training needed now and in the near future is substantial, employers should foster such training in any institutional setting where it can be conducted successfully. In addition, employers must provide incentive for their employees to undertake such training by establishing job positions and career development opportunities. In contrast to the interim solution, the long-term solution hinges on the colleges' and universities' developing the capability of introducing all students to modern data management systems, regardless of whether the student later becomes a data system specialist or a scientist or engineer who will be a user of such systems.

Conclusion: Although data switching networks and computers are frequently mentioned in juxtaposition to one another, automated data service networks, for all practical purposes, do not currently exist within science and technology.

Among the several reasons for this are: (1) An inability to define user needs which provide economically justifiable requirements for such data service networks; (2) The current high costs of data transmission and remote access terminals; and (3) The difficulty of structuring and maintaining centralized data banks of sufficient breadth to serve diverse user groups.

Recommendation: Appropriate organizations should test the effectiveness of centrally supported, decentralized data resource centers as an alternative systems concept to data switching networks.

For example, the National Institutes of Health might support and provide centralized data collection and selected programming services for a series of data resource centers located at leading medical research centers, or the Department of Transportation might support data resource centers at laboratories involved in highway safety research. Each local data resource center would be configured so as to use data files and manipulation programs furnished by the central service unit in the sponsoring agency. The users of the data resource center would augment the basic data file with locally generated data or data assembled because of high utility in local work. Periodically, the central service unit would obtain read-outs of locally generated data to ascertain if it should be packaged for distribution to other local resource centers. The initial tests of the local data resource center concept should be conducted as controlled experiments with cost and effectiveness parameters carefully documented and analyzed so as to provide guidance for planning of national data systems.

A major objective of these tests should be development of data file structuring and access methods which are considered the key barriers to large-scale data handling systems of the future.

Conclusion: There is an almost complete absence of criteria for the evaluation of the economic performance of current data handling efforts.

Most past efforts to apply cost-benefit criteria to measure the effectiveness of data efforts have been inconclusive, due to difficulties in quantifying the benefits from the operation of such efforts.

Recommendation: Cost-effectiveness should not be the principal criterion to determine whether or not efforts should be initiated to explore the feasibility of improved data handling systems.

Until effective methods of data management and handling are demonstrated, effectiveness, rather than low-cost, should be the major aim of development objectives.

III. IMPLEMENTATION OF RECOMMENDATIONS—A TIME-PHASED PLAN

A series of recommendations concerning further study of scientific and technical data systems(s) concepts were presented in the previous section. Most of these recommendations could be implemented independently; however, as noted previously, a major deficiency of current efforts toward data systems development is a lack of a means for coordination or a focal point for integrative actions. Too frequently, when data systems of the future are discussed it is in terms of fantasies of the year 2000 rather than the actions to be taken in 1969, 1970, etc. This section embodies our major recommendations in an integrated, time-phased plan. This plan identifies a network of actions which constitute a desirable sequencing of major steps and indicates some of the interdependencies among the recommendations for study and implementation of national data system(s) concepts.

A. Basic considerations

As indicated in the introduction to this report, the Task Group has previously established three basic guidelines for effort directed to development of national scientific and technical information systems. These guidelines were:

There should be no disruption of existing information channels;

Account must be taken of widely differing capabilities of existing systems and the realities of funding long-established practices, rapid changes in information technology, and the differing needs of various segments of the user communities; and

The Government cannot direct the private activities that form a major element of the national information capability—that it can only encourage them to join forces in a national system.

Also, the Office of Science and Technology had previously enumerated four desirable characteristics of national information systems. First, the systems would minimize the duplication of human effort both in the generation of data from research and development and in the handling of information resulting from this effort. Second, national information systems would require the establishment of certain standards for quality and form. Third, systems would *not* normally be operated by Federal departments and agencies, although exceptions would be required in some areas of science and technology. Fourth, the responsibility for national system(s) would be fixed in one Federal department to focus attention and effort on a specific set of objectives and activities.

Some of the basic questions examined in formulation of the recommended plan included:

What are the principles which should guide national scientific and technical data system development efforts?

How can the present situation be best illuminated and analyzed to relate present operations and capabilities to the overall objective of a more effective use of our national scientific and technical data resources?

How can on-going efforts be promptly and effectively synthesized into a more unified and systematic total effort?

What new or additional programs or systems will be required to either identify requirements or develop new means of serving existing needs?

What should be the functional purposes of new programs and systems?

What should be the relationship between the components, both new and old, of the total scientific and technical data program?

What controls are required to assure that the national scientific and technical data program and related systems can be developed and operated effectively and efficiently?

The implementation plan proposed is based upon a belief that evolution of an effective scientific and technical data system must progress through the following stages:

(1) Development of an increased awareness and understanding of current scientific and technical data resources, data management and data handling capabilities, and data use factors by the many individuals and organizations who must participate in the future planning, development, operation, and use of scientific and technical data systems.

(2) Application of systematic planning and evaluation methodologies to analyses of the data management and data handling system requirements for individual communities and between communities within science and technology.

(3) Coordinated application of improved data handling methods which

satisfy the higher priority functional service requirements, especially those who are not currently being served,

make optimal use of available personnel skills, equipment capabilities, and existing data resources, and

are acceptably economical.

(4) Monitoring, evaluation, and refinement of data management programs and data handling systems to maintain a data system adequate to support national objectives for science and technology.

Efforts, to date, by the Task Group on National Systems have been directed almost exclusively to Stage 1 of the above sequence. The implementation plan presented in this section extends this effort and outlines actions required to move through the remaining stages of national data systems development. The plan is not highly prescriptive as to the configuration and functional structure of national data handling systems. Rather, primary emphasis is given to identification of actions which will evolve goals, competencies, and motivations which can be integrated into a comprehensive, yet decentralized program to achieve optimum utility from our national scientific and technical data resource. The recommended program should not, in fact cannot, be implemented on a crash basis; neither can its implementation be delayed if the U.S. intends to maintain its position of preeminence in science and technology. The plan is offered as a preliminary blueprint for establishment of a National Scientific and Technical Data Program. If the recommended plan is initiated in FY 1969, national scientific and technical data systems could be a functional reality as early as FY 1975.

B. General plan

From the onset of this study, the search for effective means to deveolp a national data management capability has captured the attention, and remained the focal point of planning objectives. Study findings indicate that a fresh approach to organization, new working relationships, a working appreciation for the apparent and subtle differences between the data management needs of one community and another, and closer dialogue between the individuals and organizations involved are required for improved national data management. The plan recommended is intended to evolve a transcendence from the scale of individual or single-organization level data management to a broader, cooperative national program. It would be futile to attempt to escalate current efforts to a national data management program before the goals and objectives of such a program were firmly established and understood. An orderly and systematic step-by-step transition is necessary so that current programs are not disrupted and so that the proper stimulus can be established to evoke a responsive attitude among required participants. The plan introduces the recommended program in such a way that its development will be user-oriented, that the program will be responsive to change, and that timely modifications can be made during the transition from current data management practices to those established by the National Scientific and Technical Data Program.

Study indicated that an effective data program must not only include both government and non-government participants but should provide for interaction of these two major classes of participants at all functional levels within the planned program. The functional levels covered by the plan are:

Centralized programming functions,

Planning and coordinating functions, and

Development and operating functions.

The centralizing programming function consists of establishment of policies, definition of priorities, husbandry of legislative and budgetary needs, and overall review and evaluation of program effectiveness. This function would be coordinated by the Office of Science and Technology with consultation from the National Advisory Council for Scientific and Technical Data.

The coordinating and planning function consists of a systematic effort to involve a larger segment, both government and non-government, of the scientific and technological community in a cooperative planning effort directed to upgrading of existing data services and systems and to formulation of actions leading to improved future systems. The National Advisory Council for Scientific and Technical Data and its staff would coordinate the total planning effort with responsibility for coordination of detailed level planning assigned to two program offices—one for scientific data activities and one for technical data activities. The National Advisory Council would maintain responsibility for integrating the planning efforts of the two program offices, other organizations such as the mission-oriented government agencies, and its own study results into a unified national program plan.

The development and operation function consists of implementation of programs and plans. Initially, this function involves local study and examination required to evolve national program needs. In subsequent phases of the program, this function involves the actual development and operation of data management and data handling systems. These functions would be conducted by designated agents within the various scientific and technological communities. These agents might be professional societies, trade associations, educational institutions or government agencies.

The proposed implementation plan (which is presented in detail in the report) contains four sequential and evolutionary phases, each of which is a prerequisite to succeeding phases and the ultimate objective. The following sections describe the plan and the sequence of steps involved in its execution. Description of the plan concentrates on the centralized programming and the planning and coordination functions because the plan, itself, is intended to evolve a further definition of the development and operation functions. Also, the descriptions of the plan emphasize new programs and organizational responsibilities. However, it should be noted that continuation and improvement of current data handling operations is a vital part of the recommended National Scientific and Technical Data Program. The new programs recommended are not intended to supplant existing operations but to extend coordinated data management and data handling operations to additional areas of science and technology and to provide a means for coordination and improvement of existing programs and services. Panels of the National Advisory Council for Scientific and Technical Data provide a channel to assure that existing programs such as those of mission-oriented government agencies and agencies currently involved in collection of general purpose scientific data, have an effective voice in the development of national program plans. It is equally as important to note that the Panels also provide opportunity for inputs from commercial publishers and other non-government interests.

C. Phasing of the plan

The implementation plan consists of four phases, only three of which have been detailed. The final phase, which is systems operation, obviously cannot be prescribed at this time.

Phase I—National Scientific and Technical Data Program Definitions. This phase, extending for one year, can be viewed as consisting of two sub-phases. The first sub-phase essentially consists of establishment of the organizational structure required to implement the plan. The second sub-phase is devoted to a more explicit definition of the program plan.

The first sub-phase is initiated by review of the recommendations in this report by the Task Group, COSATI, and other advisory bodies to OST and the FCST. Assuming general approval of the recommendations, OST would initiate efforts to formally establish the National Scientific and Technical Data Program. This would involve coordination with affected Federal Agencies, the National Academy of Science-National Academy of Engineering, and exploration of the requirements for Executive and/or Congressional actions required to establish the Program. The two Federal agencies most affected, the Department of Commerce and the National Science Foundation, each are currently operating under specific legislation relative to facilitating the utilization of scientific and technical information by the non-government segments of science and technology. Pertinent legislation includes Public Laws 507 and 776, both passed by the 81st Congress, and Title IX of the National Defense Education Act of 1958. However, new legislation may be required either to establish specific authority for cost-sharing between these departments and non-government organizations or to establish a stronger justification for program funding.

Major organizational structuring steps to be taken during this sub-phase include establishment of a Scientific Data Program Office in the National Science Foundation, and a Technical Data Program Office in the Department of Commerce, creation of a Data Systems Technical Information Center to support the Program, and the organization of the National Advisory Council for Scientific and Technical Data. Figure III–1 displays these organizational elements of the Plan and their relationship to other elements of the National Scientific and Technical Data Program.

Another important preparatory action will be the establishment of minimum budgets for data management activities within each of the Federal Agencies performing scientific or technical research and development.

The initial sub-phase would culminate with a White House Conference designed to inform the U.S. scientific and technological community concerning the Program and to enlist cooperation in its development.

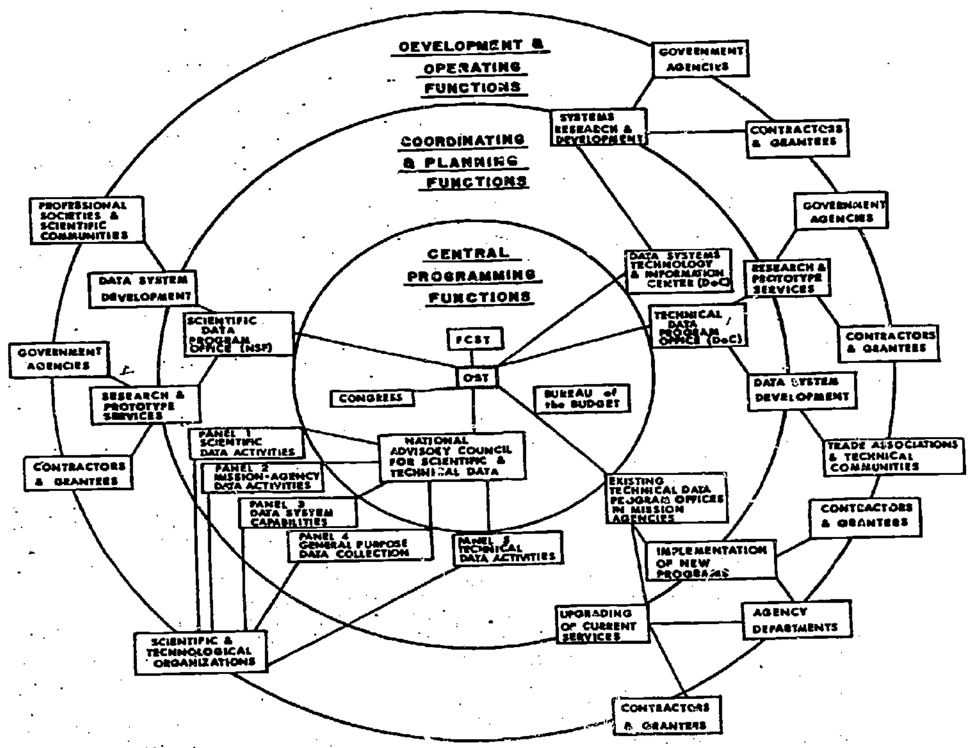


FIGURE III-1. PRINCIPAL ORGANIZATIONAL and PROGRAMMATIC ELEMENTS of the NATIONAL SCIENTIFIC AND TECHNICAL DATA PROGRAM

The second sub-phase involves development of the National Scientific and Technical Data Program Plan. During this period, each of the major organizational elements of the Program would formulate and contribute inputs to the Plan. Both the Scientific Data Program Office and the Technical Data Program Office would further define their program objectives and establish procedures for selecting and establishing priorities among scientific and technical data activities to be included in their programs. Simultaneously, other Federal Agencies would identify the data management and handling projects within their respective agencies which would be coordinated with the National Program. These projects would be identified at the earliest possible date so that their interface with the National Program could be defined.

During this sub-phase, the National Council for Scientific and Technical Data would assemble a staff and establish contact with representatives of the various scientific and technological communities. Specialist panels would be selected and the panels would formulate inputs to the National Scientific and Technical Data Program Plan.

Phase I would be terminated by the joint issuance of the National Scientific and Technical Data Program Plan by the Office of Science and Technology and the National Advisory Council for Scientific and Technical Data.

Phase II—Formulation of the National Data System Development Plan. This phase of two years duration is vital to the proposed plan. It is during this period that requirements for data management and data handling systems will be critically reviewed both at the local and national level. Simultaneously, developmental and prototype tests will be conducted to ascertain the adequacy of equipments and methods to meet data management and handling requirements.

During this period, the Scientific Data Program Office and the Technical Data Program Office will be pursuing two activities. First, they will each select a limited number of scientific or technological communities to participate in Federally supported data system planning and development programs. Funds will be provided to a selected organization within the community for evaluation of data management requirements of the community and formulation of a data system development plan responsive to these requirements. The selected organization within each community will be required to obtain the cooperation and participation of other institutions in the community and will be required to follow general planning guidelines established by the Data Program Office. The latter requirement is intended to facilitate review of the plans and to permit study of similarities and differences of requirements from community to community. It is anticipated that an inventorying or indexing of the data resource of the community quite likely will be a part of the procedure employed to ascertain data management requirements. A second activity of each Program Office will be support of prototype efforts to develop methods or to initiate services which offer unusual potential for improving the management, dissemination, or use of data within specific scientific communities. These prototype tests would be selected not only to alleviate specific problems but also to identify those methods and services which should be considered for implementation on a broader scale. For example, the Technical Data Program Office might explore the utility to commercial food processing firms of a data resource referral service which provided access to data files created by the activities of the Department of Agriculture, DOD Quatermaster operations, etc. The Scientific Data Program Office might explore the feasibility of creating an index to the data content of the journals serving a given community of researchers. All of these prototype services would be carefully monitored to ascertain their potential application to national systems.

Whereas the Scientific Data Program Office and the Technical Data Program Office would direct their support largely to specific communities, a concurent program centered within the Department of Commerce would support tests of new methods and services broadly applicable to the data management requirements of several scientific or technological communities. This program would emphasize the adaptation of computer and other technologies to data handling functions.

During this phase, non-government organizations would begin to play an increasing role in formulation of the National Data Program. Professional societies, trade associations and other appropriate organizations would apply to the Scientific Data Program Office or Technical Data Program Office for planning grants for their communities. Once selected as the designated organization and awarded a planning grant, the professional society, trade association, etc. would coordinate the evaluation and planning effort, making sure to provide for participation of all interested groups in the community. The designated agency would culminate its participaiton in this phase of the program by submisson of a data system development plan to the sponsoring Data Program Office. This develoment plan would be formulated specifically to meet the requirements of the community and might be highly complex or simple, and might require extensive or little change in current data mangement and handling practices in the community.

During this phase, the National Advisory Council for Scientific and Technical Data, its staff and panels would be studying inter-community data management and data handling requirements. In addition, these bodies would be formulating plans for integrating appropriate data management and data handling efforts into a national program. These efforts would terminate in the joint issuance with the Office of Science and Technology of a National Data Systems Development Plan. This plan would integrate findings from prototype tests of methods and services as well as the system development plans generated by individual scientific and technological communities. It would also integrate findings from operations and analyses conducted by the mission-oriented agencies of the Federal Government. Since these data handling operations are intimately associated with on-going research and development efforts and would have a longer operating history than any of those initiated and tested under sponsorship of this Program, their contribution to formulation of the National Systems Development Plan should be substantial.

Phase III—Development of National Systems. This phase of three years duration will test the feasibility of national data system development. During this period, several systems will be under development concurrently and will undoubtedly differ substantially as to structure and functional purposes. Each of the Data Program Offices will be contributing to support of development of full-scale data handling systems to serve specific communities of scientific or technological activity. A significant part of the activity during this phase of the Program will be devoted to development and testing of methods and facilities for serving the data handling needs of specific communities. These facilities may be centralized or decentralized depending on the needs of the community served. However, considerable attention will be given to questions of standardization to assure an optimization of compatibility between all systems being developed as part of the National Scientific and Technical Data Program. The National Advisory Council will study standardization requirements and make recommendations to be promulgated through the Data Program Offices.

Whereas the development effort within specific scientific or technological communities will be largely evolutionary, the development efforts within Federal Agencies will be increasingly integrative especially in the area of general purpose data collection. Through its appropriate Panels, the National Advisory Council will continue to study and develop plans for consolidation of the data activities of Federal Agencies wherever it can be shown that such consolidation would result in more effective national use of the data resource.

The development phase will be terminated by a review of development and integration efforts. This review by OST and the National Advisory Council will precede the shift of systems from developmental to operational status.

Phase IV—Operation of National Systems. This phase of the Program will increasingly involve non-government organizations for it is hoped that many such organizations will voluntarily participate in the Program without requiring government support of development operations. This should become increasingly feasible as effective methods are developed and the benefits accruing from data system development are demonstrated. It should be noted, however, that it will probably be a considerable period before the Federal Government can terminate its support of data system development efforts. In fact, it can be anticipated that even after the first scientific and technological communities reach an operational status with their systems, other communities will not yet have initiated determination of data management requirements.

D. Special implementation considerations

1. Fiscal Factors: In the previous sections of this report, current technical data activity has been characterized, key problems and opportunities identified, informed judgments concerning national systems aspects marshalled, and specific policies and actions recommended. A national data program that embodies these recommendations has been articulated and a phased plan for its implementation has been structured. If this plan is placed in effect promptly and supported at the level recommended, it can be expected to yield operational data-system activity, nationally significant in its volume and character, by 1975.

Within the Federal R&D program activity,[5] the means exist to create virtually overnight a major shaping force for future national data systems. It can be implemented by adoption of our recommendation that each agency allocate a designated minimum percentage of its budget to husbandry of the data generated by the program. Based on the suggested "tithing" criteria of 10% for basic research programs, 15% for applied research, and 5% for developmental programs, an activity level in the Federal agencies of approximately $1.35 billion per year would thereby be identifiable as related to the National Scientific and Technical Data Program approximately three years after the Program was initiated.

It should be appreciated that this effort level is a relatively modest fraction of the estimates others have made of data activities in Federal programs. For illustration, activities associated with general-purpose data collection are estimated as over $400 million annually: DOD data-activity costs are variously estimated as between $2 and $3 billion annually. The program and reporting

---

[5] *Federal Funds for Research, Development, and Other Scientific Activities, Fiscal Years 1966, 1967 and 1968*, Volume XVI: National Science Foundation, NSF 67–19.

accountability suggested in this recommendation therefore should impose minimal burdens on programs containing any reasonable present level of data-husbanding activity.

An estimated $71.8 million of "new" money, or about 0.4% of the R&D budget, will be required initially to fund the national-level planning, development, and support offices of the Program. Fundings should be expected to increase appreciably over the initial 6-year period covered by the recommended implementation plan. It is expected that a $100 million budget level would be reached by the sixth year and would then recede to the initial budget level which would then be maintained for a number of years. A breakdown of the budgetary allocations considered appropriate for the second year of the plan follows:

	Million
National Advisory Council	$2.5
Scientific Data Program Office:	
(50 percent) data system development program (matching funds)	16.0
(30 percent) special data services	9.6
(10 percent) supporting research	3.2
(10 percent) administration	3.2
(100 percent) total	32.0
Technical Data Program Office:	
(40 percent) data system development program	8.24
(40 percent) special data clearinghouse service	8.24
(10 percent) supporting research	2.06
(10 percent) administration	2.06
(100 percent) total	20.60
Data Systems Technology Program Office	16.70
Total	71.80

These activity levels are believed sufficient to establish a program activity that has some reasonable chance of producing meaningful development actions at the national level. We think it particularly important that the Program, from the beginning, begin to function as a facilitator of advancement in data-management activity in major data-producing and data-using institutions. It will be noted that the "new-money" level proposed is intended to facilitate such developments nationally, and also that it totals only 5% of the Federal data activities to be identified and accounted for by the National Scientific and Technical Data Program.

As a matter of somewhat incidental interest, initial funding for the Scientific Data Program was established as 0.5% of the basic and applied research budget of the Federal Government. The Technical Data Program fund was established as 0.2% of the development budget, and the Data Systems Technology Program as 0.1% of the total Federal R&D budget.

Over the 6-year development cycle projected, the functional efforts of the National Program will fluctuate appreciably in scale and character. Figure III–2 reflects a current estimate of the magnitude and pattern of these changes through to the point characterized by continuously operating systems.

As inferred previously, the initial year or Phase I of the Plan will require only a small amount of funding. Such funds can probably be obtained from existing agency budgets for FY 1969. The second year of the Plan, FY 1970, would represent the initial year for specific funding for the Program. From this initial level, the amount of funds expended in the Program would increase much more rapidly than the funds budgeted specifically for implementation of the Plan. Some of these funds would be contributed by non-government participants in the form of matching contributions to program costs. A much larger increase would result from identification and coordination of other Federal Agency data management and handling activities with the new elements of the National Data Program to be established in accordance with this Plan. The latter aggregation of existing Federal data activities will account for much of the increase in the level of implementing and operating effort shown for Phase IV in Figure III–2.

PHASE DESIGNATION	PHASE I	PHASE II	PHASE III	PHASE IV
PROGRAM ELEMENT	PLANNING		IMPLEMENTATION	
	NATIONAL DATA PROGRAM DEFINITION	NATIONAL DATA SYSTEM(s) CONCEPT DEFINITION	NATIONAL DATA SYSTEM DEVELOPMENT	NATIONAL DATA SYSTEM OPERATION
TIME SEQUENCE	1 YEAR	2 YEARS	3 YEARS	CONTINUOUS
RELATIVE LEVEL of EFFORT by FUNCTION				
CENTRALIZED PROGRAMMING*	1	>1	1	<1
PLANNING & COORDINATION	2	20	60	20
IMPLEMENTING & OPERATING	0	10	100	>500

*Arbitrarily designated as 1

FIGURE III-2

RELATIVE EFFORT LEVELS IN THE FOUR PHASES OF THE RECOMMENDED NATIONAL DATA PROGRAM

2. Technical factors: The discussions and recommendations of this plan employ the simple term "data" for what is clearly evident as extremely dynamic and diverse congeries of fact-matter within the national and international patterns of scientific and technological activity. This diversity must be dealt with realistcally as the National Scientific and Technical Data Program is implemented. Broadly, it constitutes an underlying reality that cautions against approaches that can founder by being too inflexible.

Some of the technical and economic factors that significantly affect implementation concepts are:

Physical growth of a specific data body calls for progressive change in data-management methods. Technologically desirable "housekeeping" of th body may call for special assistance to the data-handling institutions implementing the transition from one stage to the next.

Intellectual growth of a subject field requires a continual housekeeping effort on terminology, a responsibility traditional to the professional society. In addition, a field will sometimes go through a revolutionary reform in its conceptual structures, as the field of chemistry did when the phlogiston theory was overthrown, or when key methodologies such as instrumental chemical analysis began to replace "wet" methods. The work required to reform data languages and structures, and to generate new data bodies can be massive under such circumstances, and at times will justify implementing aid. Technology-transfer program activity is a sphere of current importance that may generate need for translational dictionaries and similar tools highly relevant to the data program.

Growth or diversification of the population using a data body, or a shift in its demand patterns, is another factor than can generate new implementation requirements for data service. For example, high-technology practices have created new demands and also provide potential new support for more rigorously validated data resources and more responsive services than have been traditionally demanded.

3. Sociological Factors: Sociological factors affecting implementation are probably more controlling than the technical and economic factors. Probably the most powerfull one, fear that new data programs will compete with or weaken existing systems, is too familiar to need elaboration here. There are, however, some we can identify as specific and probably important within the scientific and technological community existing today:

The community does not, in general differentiate the data activity and the potentials for improved data activities and systems, from information activity as a whole. Data-oriented discussions, however, have readily awakened awareness and frequently strong enthusiasm. We have the sense of a strong latent recognition of the potentialities in breaking new ground with data programs. The essentially fallow ground now existing requires at least a modest educational cultivation. However, a thoughtfully framed program dropped into the present near-vacuum may thereby gain adherents much more rapidly than if it had to find its place among a diffuse array of pre-existing, inevitably competitive activities.

Major data programs will produce more conscious recognition within the community of the potentialities for technological use of scientific data. They should have the effect of promoting science-based technological approaches, and of stimulating work within the community on better-codified terminology linkage between scientific and technological languages. In implementing the data program, important benefits should result by drawing the community into the language-codification activities required to create adequate intellectual control of the data-handling systems that will be developed.

The typical scientist and technologist has not been accustomed to view technical tools such as his data resources as also being a national resource. In part, this is the result of the phenomenological nature of most scientific and technological data, whose nationally significant attributes principally associate with their management rather than their substance.

4. *Priority and Incentive Factors:* The supply of development support funds provided for the Scientific Data Program and the Technical Data Program can be expected to prove much smaller than the demands made on them for data program development cost sharing. This situation should promote sound and vigilantly administered support commitments. It should also constitute an important educational exposure for Program specialists whose advice would normally be sought when major system priorities are under discussion.

A source of genuine expertise must be developed during the early years of the Program to prepare for the crucial decisions when operational system priorities must be weighed. The complexity of these considerations has become strikingly apparent in this exploratory study: as more is learned, we expect further complexity to become evident.

We also expect that sound rationales can be developed for identifying the significant value elements of a proposed data system development program. We believe the following factors are significant when evaluating the benefits expected to accrue from data system development efforts and expenditures:

Economic.—Generation cost; commercial value; national security contribution; gross national product contribution.

Ownership.—Private; proprietary; public.

Source.—Generated, acquired.

Usage.—Uniquely applied; routinely applied; number of users; degree of interdisciplinary usage.

Processing.—Obsolescence rate; degree of knowledge structuring; volume; existing systems orientation; compatibility with ADP format.

Amenity to Systems Management.

The Science Communication, Inc. Report rates each major field of science and technology in terms of the above factors.

Refinement of methods for establishing priorities and optimizing return on data system development expenditures constitutes a critical requirement if the National Scientific and Technical Data Program is to be implemented efficiency. At least initially, however, the selection of areas for program development can probably be made on the basis of less systematic and more intuitive bases. For example, the competence of the individuals or organizations applying for Federal support could easily become the over-riding consideration, for currently high competence in data system development is exceeding scarce. In order to attract the best available data system development competencies, it may be desirable to publicize the Program under a designation such as Project Dataphore. This title would emphasize the increased functional utility for data which is the main objective for the proposed Program and National System Development Plan.

That special activity which we call science began as a collection and classification of facts or data. Scientists classify data into patterns, associate data, and thus establish the relationships between them. It is widely recognized that scientific progress is served by and is dependent upon maintaining, expanding, and refining the structure of related sets of scientific data. Conversely, it is less often admitted that current methods for performing this data management function are less than optimal and fail to utilize fully available tools and know-how.

One of the deterrents to realization of improved data systems for science is the myth of a body of perfectly organized knowledge. According to this myth, the result of every new measurement in science is a contribution which almost automatically moves into its appropriate place in the knowledge structure. Here it can be found by anyone wanting to use, disprove, or refine it; that is, the flow of information is perfect. This pleasant myth provides a comfortable rationalization for the scientist or research program manager who knows that Nobel Prizes or other valued recognitions are earned by conducting measurements, not for husbanding data. As a result, we currently have an imbalance between the amount of resources being expended for generation of new scientific data and the amount of resources being expended to assure that the potential utility of data generated is fully realized. For example, our study for COSATI found that, although Federal agencies were encouraging everyone who could get a boat in the water to make oceanographic measurements, many of these agencies would not pay the costs incurred in processing these data so that they could be submitted to the National Oceanographic Data Center. Fortunately, subsequent action has been initiated to remedy this specific problem, but many others continue to exist.

Any action to establish a national science research data processing system should be viewed as part of a broader goal—that is, improved management of scientific data, including achievement of an optimal distribution of effort between data generation and data husbandry. In furtherance of this objective, I recommend that the Congress establish a compliance reporting requirement for each Federal agency conducting a program of scientific research. At the end of each fiscal year, each agency would be required to submit to the Office of Science and Technology, the National Science Foundation, or other appropriate agency, a report identifying the data management activities it had conducted or funded during the year. It would be required that the total effort expended on data activities equal a predefined percentage (for example 10 percent) of the research of the research budget of the reporting agency. The initiation of this reporting requirement would focus attention on data management activities and would make badly needed funds available without special incremental funding.

There are several justifications for a concerted, federally initiated, program to upgrade data management practices. Among these is the substantial investment by the Federal Government in data acquisition activities. It has been estimated that scientists and engineers spend anywhere from 20 percent to 40 percent of their working time acquiring data. A conservative estimate, therefore, of the amount of Federal money being spent for just this one facet of the entire data handling process—that of data gathering—is approximately $3 billion annually. It should be noted, however, that such costs do not necessarily reflect the current value of the data. For example, the Department of Defense estimates that it expends about $2 billion annually for items of scientific and technical data. The current value of its investment in 50 million engineering drawings, 225,000 technical manuals and other items of data is difficult to express, for it represents the vital reservoir of engineering knowledge upon which the continued effectiveness of our defense system depends.

Underlying the initiation of a national science data processing system or any other program to improve data management is the assumption that the Federal Government has responsibility to insure effective management and utilization of the Nation's rapidly growing resource of scientific data. I suggest this responsibility involves more than making significant scientific documents available to potential user; merely providing document sources does not assure that data are effectively communicated or conserved for future use. This assertion concerning Federal responsibility subsumes the view that scientific and technical information is a vital national resource; a resource to be utilized in the most effective manner by all professions, industries, and agencies; and one that must be maintained in the best possible working order if its potential and optimal benefits are to be exploited.

Based on extensive study of scientific and technical data activities, I have concluded that classical methods for structuring and communicating scientific and technical data are marginally effective in meeting today's needs. Classical methods rely heavily upon the concept of formal publication; however, I estimate that less than 5 percent of the results of scientific and technical measurements are ever formally published. This estimate appears shockingly low until one realize that approximately 25 billion measurements are made each day in the United States. Over $30 billion has been invested in instruments to make these measurements, and roughly $12 billion is expended each year on personnel to operate these instruments and related systems.

Obviously, many of these measurements do not generate scientific or technical data which need to be conserved. However, a large portion of the more than $20 billion expended annually in the United States for scientific research and development does generate data of continuing utility. In some areas, such as space and oceanography, the availability of new measurement technologies in conjunction with large Federal expenditures of research and development funds has unleashed an avalanche of such new data. For example, the physical facilities of the NASA Office of Tracking and Data Acquisition have a capital value of more than three-quarters of a billion dollars. Today, NASA's tracking and data network is receiving approximately 300 million data bits each day. The Goddard Space Flight Center reports that 30,000 bookkeeping entries are required to keep up with the 2,300 computer tapes which it processes each week. Obviously, only a fraction of these data are ever formally published.

Even when published, specific facts or data are not easily located and retrieved with available tools and aids. It is important to recognize that the major scientific and technical information systems operating today (for example, the Defense Documentation Center, Chemical Abstracts, and the National Library of Medicine MEDLARS) do not index the data content of the documents handled. In fact, no methods presently exist for effective and efficient indexing of the data content of documents. I, therefore, suggest that implementation of the proposed National Science Research Data Processing and Information Retrieval System include development and application of methods to index the data contents of documents.

I could further detail what I consider the inadequacies of existing methods for structuring and handling scientific data, but I do not consider it constructive. Rather, I would like to state a premise which, I believe, most people will accept and then develop some ideas from this premise: If we consider the long-range future, a change in the methods for handling scientific data is inevitable.

I believe that a radical change in the way in which scientific data is handled is already underway. Further, continued change or transition in data management and data handling systems is inevitable and can be expected to grow in significance.

Assuming this premise to be true, what should the National Science Research Data Processing and Information Retrieval System or similar federally initiated programs attempt to achieve?

Meeting the challenge and opportunity to construct new and effective means of treating data is one of the most crucial problems facing science and technology today. The challenge is based on the realization that the opportunity exists to build superior systems by utilizing new tools, techniques, and knowledge and, in so doing, greatly extend the utility of scientific and technical data. It is this challenge, more than the fear of being inundated by the flood of data that should prompt the search for new means to handle data more effectively.

The PSAC Panel on Handling of Toxicology Information recognized future potentials when it recently concluded that the existence of a computerized toxicological information system would perhaps allow the creation of those new broad scientific conceptualizations which will speed the progress of toxicology and pharmacology by quantum jumps. Such positive goals should guide all national information system development efforts.

National data systems will not constitute a new activity so much as an effort to get better organized and do a more effective job of data management in both the public and private sectors. For this effort to be successful, objectives must be articulated, priorities established, responsibilities assumed, and resources allocated.

The development of an effective national data system should not conform to one monolithic blueprint. Rather, the national system will evolve to satisfy specific requirements of "real" communities in science and technology. Some data management and handling programs or systems will probably be subject oriented, some process oriented, some mission oriented, and some by a combination of these when they exist to serve a "real" community of scientists or technologists.

National systems for management and handling of scientific and technical data are now evolving from the efforts already in existence within many scientific communities and agency missions. The role of the Government should be to focus on these present efforts, to coordinate them, and to provide data management policies on a broad national scale.

The possibility of a highly centralized operation of national data systems is neither feasible nor desirable. What is needed is not a

31-464—69——13

unilateral system created by a Government fiat, but the creation of order within the current process of national data systems development. Incentive must be provided for an orderly development, most specifically in the form of Federal funds made available to elements of the evolving systems to enable them to develop their potential effectively. Specifically, it is suggested that the National Science Foundation be authorized to award grants and enter into cost-sharing agreements with professional societies or other institutions qualified to plan and implement data systems to serve specific fields of science.

A logical initial step in the development of national data systems appears to be the inventorying of existing data resources and creation of indexes to facilitate access to this resource. Such an undertaking, if pursued on a crash basis, would be very costly; however, the task could be subdivided and pursued by individual scientific and technological communities. The development of an inventory appears to be a prerequisite step before data management and data handling requirements can be identified. Also, the development of indexes to data could serve as important service tools prior to the implementation of more ambitious data systems. For example, a data referral service could be based on the index of data existing within a community of science or technology.

Such services would constitute a vital supplement to the National Referral Center.

I would like to emphasize the importance of the preceding recommendation. I do not think it is widely recognized that despite the many billions of dollars that are expended for the generation of scientific and technical data that, to date, we do not know how much data exists. We do not know where it is. We do not know what shape it is in. We do not know how to lay our hands on it. Effectively, it is not available.

I recommend that the Congress amend H.R. 8809 to provide specifically for the establishment of a national index of scientific data. The existence of a program to create such an index would provide a focal point for action by interested agencies and private groups.

It also appears that a need exists for a service similar to the Science Information Exchange which would inform data centers and other organizations interested in a given class of data as to which research and development projects plan to generate such data. Such services might substantially reduce the lag time between generation and subsequent use of the data by another scientific or technological organization.

Responsibilities for operation of activities, such as the above, logically fall to designated organizations within each scientific or technological community so that they will be carried on in close association with the work of that community. Such decentralization would appear much more effective than a single national service center.

Advanced technological methods and equipment are essential to the concept of national data handling systems for the future. Therefore, the Federal Government must provide national data system policies flexible enough to allow for effective introduction of technological change and provide financial support to assure timely application of appropriate equipment capabilities.

We are fortunate that the U.S. expenditure of over $100 billion in research and development over the past decade has generated not only large masses of data; it has also generated equipment capable of handling the data generated. We now need to learn how best to apply this equipment. For example, it does not appear unreasonable with available computer technology to expect that we could maintain handbooks reasonably current. This might not appear like a high goal until you realize that many scientific and technical handbooks are more than 5 years out of date.

Quite likely, new data handling equipment will be introduced into information systems in an evolutionary fashion with the computer first used as an aid for structuring, storing, and formatting data for distribution in conventional forms. Knowledge gained from such experience will then be applied to implementation of more highly automated systems including query processing capabilities. Similarly, computer techniques which are already widely used in design and other data manipulation operations at the work station of the scientist or technologist will continue to be refined and expanded in application. It therefore does not appear unreasonable to anticipate a future merger of data handling systems to serve all of the scientist's or technologist's data handling needs—both archival and day-to-day manipulation. At least this possibility provides a future frame of reference which can guide data handling system development efforts.

Despite the great potential offered, radical changes in data handling systems probably will not occur quickly simply because system designers do not know precisely the data service needs of scientists and technologists. In addition, even when service requirements are well de[illegible] the system designed does not yet know how to effectively match data handling equipments and methods to data service requirements. I therefore caution against expecting spectacular early returns from national data programs. Rather, it must be realized that time is required to better define service needs and to test alternate service formats. Fortunately, many excellent programs are underway which can serve as test beds for new system concepts.

Earlier, I enumerated some requirements for effective implementation of national data system concepts. Now, I return to the most crucial requirement—allocation of required resources.

If this Congress cannot authorize at least $50 million for the first year's operation of the national science science research data processing and information retrieval system and cannot expect to be able to continue and expand this funding in future years. it will be exceedingly difficult for the system to approach its potential.

In recent years, I have witnessed the initiation of promising programs such as the national standard reference data system, the toxicology information program, the State technical services program. These and other badly needed information and data programs have been denied the funding essential for a fair test of their effectiveness. In my opinion, it would be better to continue a slow evolution of new systems than to create a big splash which would quickly dissipate; perhaps, leaving a misimpression of the validity of national scientific data programs.

Lewis Mumford, in his book, Technics and Civilization, states that "behind all the great material inventions of the last century and a half was not merely a long internal development of technics: there was also a change of mind. Before the new industrial processes could take hold on a great scale, a reorientation of wishes, habits, ideas, and goals was necessary."

The development of data management and handling systems for the future will also require the dual forces of intellectual reorientation and technological advancement.

Basic to data handling systems of the future will be computer technology. Utilization of its full potential challenges data management to reorient its viewpoint and technical capacity from that of document handling—manipulating and delivering documents which contain information—to one of scientific and technical data handling—manipulating and delivering the data or information itself.

STATEMENT OF DeWITT O. MYATT, PRESIDENT OF SCIENCE COMMUNICATION, INC., McLEAN, VA.

Mr. MYATT. I believe it would be appropriate here to enter a brief summary statement I have prepared of the major points we wish to leave with you.

HIGHLIGHT OBSERVATIONS CONCERNING MANAGEMENT OF TECHNICAL DATA AS A NATIONAL RESOURCE

What exists now

Data are generated primarily for their utility, as an integral part of specific efforts to:

Advance scientific theory (e.g., by research scholars, to train PhD's, to understand explosion phenomena).

Develop new technological arts or products (e.g., an industrial chemical process, a weapon system, an artificial heart).

Manage a technological activity (e.g., petroleum refining, registration of pesticides).

The national data resource thereby exhibits a pluralistic character. Data quality criteria are strongly influenced by the scientific and technological traditions—the "state of the art"— of the community in which the data are generated and used. These criteria evolve as the technical nature of the communities evolves.

In technologies that have become increasingly science-based, existing data resources are being used directly for more of the work associated with technological development and management. Much of this data-oriented science-technology activity is computer-oriented.

Present data activity is supported principally by mission justifications. The data base required for each activity must largely be created *de novo*, or compiled from files or documentary sources. There is limited consideration of the usefulness of a mission-related data package for missions in other activities.

From a national-level perspective, the husbandry of scientific and technical information is largely in an aboriginal condition. The bulk of the present national data resource was originally generated to meet technical needs of specific organizations. Most of these organizations have no charter, operating tradition, nor financial support for identifying and conserving information from the viewpoint of its national value. This situation exists in most of the Federal agencies, as well as in industrial, academic and other private activities. At least 5 years of patient development will be needed before programs assuring the usage of a national resource can become substantially operational.

What appears needed

A national-level policy recognizing the need for husbanding all relevant facets of the scientific and technical data resource

A program that effectively deals with the pluralistic character of scientific and technological data activities

Identification of the operational roles that should be assumed by private and governmental institutions

Federal underwriting where necessary to develop and support operational responsibility and capability

Enough immediate further study or operational response relevant to data activities to sustain viability of this issue as a piece of unfinished business that is nationally important.

Recommendations for immediate congressional action

Enact a national mandate for conservation of the types of technical information considered important as a national resource

Require an annual compliance report, on an agency-by-agency basis, of the information-husbandry activities now conducted pursuant to the normal management of each Federal agency's scientific research and technical development program

Provide for the establishment and continued operation of a National Index of Scientific and Technical Data

Provide for a detailed feasibility study of a National Science Research Data Processing and Information Retrieval System. The study should be addressed to the development and design of an operating program. Due weight should be given in the study to the testimony offered before appropriate Congressional hearings, and with consideration of the several existing major studies and programs addressed to national and international science-technology information needs and goals.

Mr. PUCINSKI. Thank you very much, gentlemen. You heard earlier the discussion on the suggestion made by Mr. Carter that perhaps H.R. 8809, because it would have an agency of coequal stature with the agencies it would be dealing with, would to some extent adversely alter its effectiveness. Would you comment on that on the basis of your experience?

Mr. MYA . I think there is great pertinence to his point. Each Federal agency has its own mission, its own charter. Even though one might be given in addition an information housekeeping charter, it will be put in a position of calling for working assistance from the other agencies in fulfilling the charter. This does not sound like the best administrative construction that is possible.

We conducted a study for COSATI on the current state of affairs with regard to data systems. In that study we also struggled with the questions of how to gain the objective we described as the husbandry of the national data resource. We arrived at a plan that in some respects was similar to the so-called capping agency construction the System Development Corporation recommended in its COSATI study of national document handling systems.

We found our greatest challenge associated with the diverse ownership of data and the wide distribution of data activity. If they were only of operational concern within the Federal Establishment it would be a relatively straightforward management decision to assign the total power and authority and responsibility to a single agency within the Federal Establishment. But the establishments of science and the scientists, and the enormous volume and value of technological information generated by our industries are outside of the Federal Establishment. A topping management construction that was properly concerned not just for the Federal data resource, but for the national resource, posed a very interesting question of management, ultimate control, and direction.

The best we were able to come up with, and we convinced ourselves that this would be workable, was to utilize a guiding authority that would have representation from the private sectors. This appeared possible through one of the quasi-Government organizations of high technical standing, such as the National Academy of Sciences-Engineering. By providing a strong voice and a continuing interest in participation from that source, we thought a working arrangement could be established that would do the job.

We assumed that to get the thing stuck together, Federal funding and Federal initiative probably was essential. We are hopeful, as working information scientists, that once this were done there would prove to be some very interesting and promising opportunities for shared investments between the private and public sectors in some of these systems which were intended to become national in their character. The right sort of seed-corn support fed through the right type of an organization seems needed to start it. So I would say that at the very top, our ideas did not differ a great deal from Mr. Carter's.

Mr. PUCINSKI. Do you think that setting up such a system now would impede or impose constraints on the evolution of a stronger system?

Mr. MYATT. The situation is in a very tender condition at present, I think. So far as the working skills are concerned, we are still in a developmental condition, even in understanding all of the things that are out there.

I feel personally that the stipulations—and here I find also I independently share Mr. Carter's concern—that you have in your bill could have the tendency to cramp the developmental effort.

I was impressed by the position that Dr. Charles Hitch took when he was a member of the Rand Corp., in an address he gave at the President's Conference on Technical and Distributional Research. This conference was held in the midfifties and it was very popular at that time to criticize overlapping research programs in the defense and missile field.

Dr. Hitch had the courage to stand up and present the argument that it is prudent, where there is a really critical problem, to back up your attack on the problem by having two or three people working different ways to solve that problem. Generally this is the way I feel about those elements in your proposed bill.

Mr. PUCINSKI. Do you think that the state of the art is sufficiently advanced at this point to enable us to start on a system that would begin tying together some of these existing activities?

Mr. MYATT. That is happening where there are different little systems that identify—peeking over the back fence at what the other fellow is doing—something that they would like to have. On a grassroots level this process is taking place at the present time. The process is going much more slowly than it needs to go. The efforts to link these smaller systems that are operational now require a sort of a bargaining on the part of two people before you have the motivation for the mutual effort required to coordinate, and perhaps standardize.

When the scientist has the justification of his mission to support that work, there is no threshold of difficulty of any serious magnitude that is involved. This is an atomistic process that is occurring. Commitments of this type that are in existence is very persuasive evidence to me that we have good tools present now. I think it is timely to dare to be ambitious in trying to do something for a national purpose.

Mr. PUCINSKI. If we had a national presidential commission that wanted to commission your company to help set up a national system, could you do it?

Mr. MYATT. Yes.

Mr. PUCINSKI. Do you have the capability?

Mr. MYATT. We have the capability to develop a design that I believe would prove sound. We are a small organization and most of our experience has been in studies and designs. And I think our track record has been pretty good.

Mr. PUCINSKI. What about the techniques that would have to be developed for programing the hardware and also for getting from the hardware the kinds of things you need?

Mr. MYATT. The largest technical problem—and it is still a very tough problem in many technical fields—is the indexing problem. How do you put the handles on the information when you put it into the system? Because the computer is a powerful beast, but it is very rigid in many respects still.

What we call it is the necessity to codify knowledge in a particular specialized area. The field of chemistry is a magnificent accomplishment in codification of knowledge about the structure of a molecule.

In places like that you will see very exciting work being done and very large gage potentials.

Mr. PUCINSKI. In other words, what you are saying is that we could move forward now.

Mr. MYATT. Yes, sir; indeed.

Mr. PUCINSKI. Whether we do it within the framework of H.R. 8809 or whether we do it during a presidential commission or other vehicle, you gentlemen feel that we can move forward?

Mr. MYATT. Yes, sir. I frankly think we should be looking at it from the standpoint of a national conservation of a national asset, because I consider the technical information resource as a national resource. From a national perspective we are still essentially in an aboriginal condition. But we have the capacity to get civilized pretty fast.

Mr. PUCINSKI. Can we afford not to move forward, Mr. Farris?

Mr. FARRIS. I think we are moving forward already and it is a matter of at what rate we desire to move forward.

I think we should move forward more quickly than we are now. I do not think this because we are in any great danger of running into a catastrophe if we do not move more quickly. It is the opportunities which we are missing which trouble me. We have not yet envisioned information systems with the capabilities that we are going to have in 5 or 10 years. We have not realized what a Nobel Prize level scientist could do if he had information available to him in an optimal form.

To date practically all scientific research is carried out on what I call the lowest level of interaction between the scientist and data. We have not demonstrated that we can identify patterns of data from different sets, data from various disciplines.

Nothing bad is going to happen to us if we do not do something. It is the opportunities we are giving up if we do not do something that justifies action.

Mr. PUCINSKI. Are there any questions, Mr. Radcliffe?

Mr. RADCLIFFE. Actually, I think Mr. Farris answered the only question I had; he said that we have been moving forward. I was a bit curious when Mr. Myatt spoke of a design for this. Does that mean development of the software?

Mr. MYATT. The identification of national purpose is, I think, one thing that would be extremely helpful.

You have to remember that most technical information is generated because of a particular mission purpose. Before the man who is the project engineer is through, he feels he does not have as much support as he needs to do his assigned job.

Unless there is a directive he can be responsive to or that he must be responsive to, his perspectives on the value of the data he has generated remain provincial.

It is a social engineering problem essentially, to get to the individual working scientist and engineer who is the originator of the information and who essentially retains it in a privately held condition except through the one major process that is working today, which is essentially the document publication process.

A pitifully small fraction of the data generated by scientists actually gets into documents and publications. That is the information system that most people have been talking about. Technical data is such an enormous challenge we do not know fully how to deal with it at the present time. We have very exciting potentials for work on ways of identifying data at the point of generation—not after they have been filtered into publications—that do have national significance and national value.

There are some tough questions of public value involved here. There are also some very interesting questions about how there might be trades between publicly supported systems of publicly available information, and people who have generated and possess privately held information and who need some of the information from the public systems.

I think you can see there is very interesting horse-trading potential that can be developed into a better sociology of usage of scientific and technical information.

Mr. PUCINSKI. It is because of this very thing you are discussing that I was so deeply disturbed today with the statement by the Science Information Services. All of these witnesses have told us about the great progress that is being made. We have some very big companies working on various disciplines.

When I hear the spokesman for the Science Information Service say, "Well, we do not need it, and if you set it up it is going to impede the present activity," it seems to me the witness is in error. If I heard you correctly, the science community is saying, "We have the capability and we have the facility, we ought to start moving in the direction of making all of this more readily available to those who need it."

Am I correct in that statement?

Mr. MYATT. The working techniques of information science promise much at the present time. Obviously there are many problems to be resolved.

Mr. PUCINSKI. Dr. Seaborg listed some six or seven problems that need further discussion and work. You are right.

Mr. MYATT. There are some fascinating problems to work on.

Mr. FARRIS. I would like to comment on that point because in our study we did come to some conclusions about the roles of some agencies, and perhaps some organizations that do not exist now, in any future national scale scientific and technical data system. We identified in essence, three functions to be performed.

One, the broad programing function. This is a commitment on a policy level of what you want to devote to this effort and we feel there does not exist a body to make these types of decisions and commitments today.

We further said there should be a planning level that would carry out the planning of these commitments, and we also said there should be an operating level. At the planning level we identified the requirement for two programs offices, one of which would logically fit within the National Science Foundation and it would cover planning for the area of scientific data activity. Another, perhaps in the Department of Commerce or similar agency would cover technical data activities.

These are two totally different worlds of activity, totally different motivational patterns, totally different structures. Even the public interest is considerably different in these two areas.

Mr. MYATT. The sciences versus engineering. Scientist complemented by engineer.

Mr. FARRIS. As stated, there must be a level at which these programs and plans are carried out, implemented. This should be a decentralized basis, involving both the Federal Government and private enterprise.

I do think there is a role for the National Science Foundation here and I want to clarify that point.

Mr. PUCINSKI. Mr. Radcliffe.

Mr. RADCLIFFE. Only one perhaps very obvious question.

Do you feel, with your experience in this field, that the National Science Foundation has been insensitive to the problems, has been unresponsive to needs in this area? What has been the problem? Or is there one?

Mr. FARRIS. I would say that we are obviously on the outside and we do not know who drags their feet. The National Science Foundation has done a lot of very good work. In many respects they are in the forefront of the activity that is going on, specifically with the American Chemical Society. But somewhere there is a funding valve that is too restrictive that needs to be opened, whether it is within the Bureau of Budget or exactly where it is, I do not know.

I am identifying a need for a resource commitment. Whether the fact that the funding valve is not open sufficiently is due to the failure of the organizations who have the responsibility to request the money or whether the scientists have not come in and put their prestige and political force behind the requests, I do not know.

Mr. PUCINSKI. There is a resolution pending or being circulated for a complete investigation of the Bureau of the Budget. I intend to support it because I want to learn more about this secret government, this fourth branch of government that has complete veto power over every agency of government, over the Congress, over the congressional committees. I want to see who these people are, what makes that agency tick, where are they recruited from, what are their motives. Above all what are their qualifications.

Some of the things that are going on in the Bureau of the Budget are absolutely scandalous and that is not a partisan issue because I am sure Mr. Nixon has inherited most of the people that are there.

They never come before the voters. I am sure there are people in the National Science Foundation—including Dr. Adkinson, and others of us who are all victims of the straitjacket known as the Bureau of the Budget.

I am supporting any action we can get to investigate that agency.

Gentlemen, we are very grateful to you for your testimony. I said earlier when we started these hearings that this is no sport for the meek. We are dealing with a very, very important subject but one in which I believe we can find a great deal of help. This country is going to a trillion dollar economy in the next year or two. Estimates that I have seen project that by the year 2000 which is only 30 years from now, we are going to have a trillion dollar economy, a labor force of some 220 million people, a population of 325 million. And so it seems to me that for anyone to suggest that we can wait any longer to bring some sort of order into the huge proliferation of scientific data is listening to the wrong drummer.

I am one Member of Congress who is not going to let the Bureau of the Budget derail or veto a program that has been supported by some of the most respectable scientists in this country.

Let these faceless people of the Budget Bureau come forth. Let them sit in that chair and tell us how in good conscience they can continue to oppose the program we are trying to put forward for this country.

The hearing will stand adjourned until tomorrow morning at 10 o'clock.

Before we adjourn, I would like to put in the record a statement by Dr. E. R. Piore, vice president and chief scientist of the International Business Machine Corporation in connecton with H.R. 8809.

(The statement mentioned above follows:)

STATEMENT BY DR. E. R. PIORE, VICE PRESIDENT AND CHIEF SCIENTIST, IBM CORP.

Dear Mr. Chairman: I am pleased to have this opportunity to provide your subcommittee with a progress report on the matters discussed at your hearings in 1963. The national need for more effective information retrieval systems continues to exist, and IBM's interest in this area remains high.

You may recall that in our 1963 statements, Mr. T. J. Watson, Jr. and I emphasized that progress would be made in a step-by-step fashion. That is the way it has been. In the six years since then, there has been steady progress in our ability to cope with the technical and administrative problems of large scale systems.

In our case, much of that progress has been based on development of information systems for internal use within IBM. As a large employer of scientists and engineers, we have been especially alert to find ways of processing information so as to improve their productivity and assist in the management of technical activities.

The procedures tested and used internally for our own use have been widely adopted externally, and IBM is proud of that.

In making this progress report, therefore, I propose to discuss first of all our internal IBM experience with information systems. Second, I shall review the status of experimental programs that we have underway. Third, I will comment on some of the national programs that are evolving.

Finally, I would like to discuss with you some of the educational implications of all this activity. To get the maximum benefit from such information systems, we must have scientists and engineers educated in the effective use of the new techniques, and we must have information specialists capable of handling the systems and responding to the users' needs.

It seems to me particularly appropriate that these educational considerations should come before the General Education Subcommittee.

Let me begin, then, by reviewing IBM internal experience with information systems.

IBM's internal information activities

IBM's internal use of information retrieval technology has grown considerably since 1964, when System/360 was announced. Systems which existed then have become larger and more sophisticated, and a number of new ones have been developed.

One of the new information retrieval applications is our Management Information System for System/360, a general-purpose communications-oriented data retrieval and reporting system, which is operating in our Corporate Headquarters and in more than twelve of our plants and laboratories. We use it to store and retrieve a wide variety of information, including engineering project data, patent investigations, personnel, sales and purchasing information, document distribution, etc. The system provides rapid response to inquiries over communications terminals and is relatively easy to use.

Another new application which we use extensively is the Administrative Terminal System for System/360. This system provides terminal-based data capture and text editing services. We use it to keep certain of our rapidly changing files updated daily, and to convert text into machine readable form as a byproduct of its original publication.

Our company-wide communications system, the Internal Tele-Processing System (ITPS), links our plants, laboratories and sales offices around the world. The system presently is connected to more than three hundred terminals in the United States and Canada over dedicated, leased communications lines and to locations in Europe and Japan via transoceanic cables. This system has proven valuable in applications beyond those for which it was originally developed.

Our field engineers, for example, use ITPS in an information retrieval system known as RETAIN (Remote Technical Assistance and Information Network). Abstracts are sent from RETAIN central to field engineers in our branch offices over the ITPS network. These summaries report on product innovations and improvements, manufacturing changes, programming changes, installation planning data, and service and maintenance recommendations. In this way, our field engineers can learn of technical developments in System/360 and other IBM products hours after their release. Each day, branch offices send back requests for full texts of those abstracts of importance to them.

The IBM Technical Information Retrieval Center (ITIRC), organized in 1964, is sponsored by the IBM divisions and operated by the Corporate Staff in New York as a central service for the IBM community. A satellite operation is maintained at San Jose, California, and a subcenter, the ITIRC European Centre, is operating at La Gaude, France, to provide quicker and more efficient service.

Information retrieval and dissemination services provided within IBM include:

Data base.—These encompass IBM R&D Projects, Manufacturing Research, and Sales Applications Projects, IBM Standards, Management Briefings, Managers' Manual, Corporate Instructions, IBM Technical Reports, selected U.S. Defense Documentation Reports, abstracts of articles from over 130 non-IBM Journals, IBM Inventions, selected University Reports; all within the spectrum of IBM technological interests.

Retrospective searches.—A complete search of a file of data in response to a specific question by matching words and logic with the abstracts or total text stored in the computer. The nature of the request dictates which of the textual data files are to be searched. Over 150,000 abstracts are available for searches with an average of 40–50 searches performed daily.

Current information selection.—A current awareness system to match weekly new additions to the stored literature. Scientists, engineers, managerial, staff, and line personnel are alerted monthly to current information by matching their individual professional profiles, which are stored in the computer, against the abstracts or text being added to the file. Approximately 2,000 abstracts are added monthly and compared against 3,500 profiles at Armonk, New York, and 500 profiles at La Gaude, France.

Microforms.—All documents cleared for copyright reproduction are filmed and stored in the Center to supply microfilm, microfiche, or hard copy upon request.

Master microform sets are distributed to requesting IBM libraries for local use. Over 32,000 documents are on microfilm and 30,000 are on microfiche.

Programing packages.—Several information retrieval programs are available to IBM libraries and specialized functional groups for local use. An excellent example is the use of such an information retrieval system by the IBM Suggestion Plan center in Endicott, New York, to compare newly-submitted suggestions against 370,000 previously-submitted suggestions to determine novelty and avoid unnecessary follow-up review.

The use of the ITIRC system by our IBM people has shown a gratifying growth. In 1965, there were about 10,000 uses made of the system, and in 1968 the number was over 29,000. In 1965, IBM personnel requested 2,700 restrospective searches of the material on file, and in 1968 there were 8,200 such requests. In 1965, a total of 1,250 IBM people received about 300,000 routine notices of new publications, and in 1968 a total of 3,400 people received more than 1,700,000 such notices.

As you realize, computers play an important role in helping us manage this kind of growth in information services. Despite a growth from 1965 to 1968 of 200 per cent to 500 per cent, depending upon the service considered, our operating costs have risen only 60 per cent above their 1965 levels because of the effective use of computer-based methodologies.

We have developed an experimental video distribution system to enable persons at various locations at our Corporate Headquarters to receive information from our Information Center on closed circuit television terminals.

This experimental video system allows such data as printed documents, unit record microfilm, video recordings, motion pictures, as well as computer-generated information to be recalled from the Information Center's files and be displayed on the closed circuit television terminals.

The Information Center, when fully developed, will provide Corporate Management and the Corporate Staff with convenient access to a single medium for receiving information from a large variety of sources, without leaving their offices.

Information specialists in the Center provide the human interface between requests for information and information sources. These specialists, trained in computer techniques and terminal operations, have a thorough knowledge of the content of data files and are familar with the information stored in other media.

IBM experimental programs

In the past few years, we have made significant progress in several areas, and I would like to convey to you a picture of the present technical situation in the following problem areas.

1. Data Base Creation
2. Information Retrieval Programming
3. User Assistance
4. Hardware Technology

In each area, I should like to indicate relevant IBM experience and future indications derived from research and development efforts.

Data base creation.—In dealing with collections the size of the existing scientific and technical literature, we are speaking of millions of items each containing thousands of words. At the present time only a minute fraction of this material is in computer-usable form. There are a number of alternatives for making this material more accessible, but each appears to involve a considerable investment.

While it would reduce transmission costs substantially to have the complete text of all the items in digital form, the cost of one to four cents a word for keyboarding makes this alternative rather expensive. Certain collections might be considered valuable enough to warrant this effort, however.

At the present time, the best solution might be to store the main material in image form and to provide condensed search information as indexes in machine-readable form. In this area we have made much progress in recent years. The major concern is that there exist many items which have not been deeply indexed by professional documentalists and our supply of well-trained indexers is extremely tight under present loads. One way of ameliorating this situation is to provide computer assistance to the indexers. At IBM, we have both research and development programs on this topic. In particular, we are constructing various components of an integrated library system for a reasonably sized library complex.

The cataloger (indexer) in this library will be seated at a display console and will be able to interact directly with the computer in the selection of index terms. One of our customers has had experience with some of the features of this computer-assisted mode and is extremely pleased with the assistance it provides.

In addition, we are performing reseach on this area in order to evaluate further techniques to assist the indexer and improve the quality of his indexing of material that has already been published.

The situation is changing dramatically, however, in the case of new material. For purposes of editing and revision, many types of documents are being captured in machine-readable form at their original keyboarding. We are using both magnetic tape Selectric typewriters and terminals attached directly to computers.

If our experience is borne out, future literature will pose fewer problems than that of the past. Character recognition by machine provides some hope. While studies are only beginning on computer recognition of the wide variety of fonts and formats in books, much progress has been made. We are particularly proud of our contribution in the form of a character reader for the Social Security Administration. This reader recognizes up to two hundred different type fonts with very high accuracy. Much work will have to be done to provide the capability for reading unformatted text, but the basic capability is in hand.

This trend, coupled with the economic desirability of photocomposition, could result in every significant new document being available in machine-readable form in the near future. As an example, within IBM, we have had for several years automatic computer-based procedures that maintain, manipulate, and publish customer documentation for our most widely used computer programs.

In summary, data base creation remains an extremely pressing problem, but we have seen major progress in recent years.

Information retrieval programming.—There are two aspects to programming for a large Teleprocessing information retrieval network. The first deals with the specific application of searching for documents and the second with the basic system programs for controlling the computer-terminal complex.

In the first area, we have continued to achieve good progress. We have become convinced of the validity of searching for documents using the unindexed full text or abstract. To this end, we have maintained and supported a computer program that has been provided to our customers. At least two of our customers have added components to the programs and are now using it with terminals to perform on-line searches in an operational environment. The program is sufficiently general to deal with the majority of moderate-sized data bases that are accessible to machine search.

With regard to programming the computer-terminal complex, much additional capability has been achieved, but the field is still in a state of technical ferment. Within the last few years, we have been faced with the problem of on-line searching and maintenance of multibillion character data bases. There are many approaches to this problem and for many of them there exists little or no operational experience at any level of size. Sorting out the technical aspects of these alternatives and extrapolating their consequences to the multithousand terminal, multimillion item systems under discussion is still a major technical challenge.

User assistance.—Any successful system must be accessible not only to the professional computer programmer, it must also allow searching by the technical investigator. In this area, there are again two methods of approach.

The first approach (probably most attractive to the layman) is the use of natural English for posing the questions. IBM and others have continued research and development in this area, but progress has been extremely difficult. The complete range of subtleties available in natural languages are for the present far beyond the capability of our machines and programs. However, for very restricted environments, IBM and others have created and are testing small experimental prototype systems.

There is also work proceeding on the coaching of the construction of a question at a computer terminal. This may, in fact, be the more satisfactory alternative because it combines two attractive features. It avoids the difficulties of interpreting natural languages, thus allowing a greater precision in the formulation of the question. It also provides means for the computer to tell the user about the contents of the data and hereby cue him to using the best words to construct a query. Experimental systems operating in this mode are also becoming available.

Hardware technology.—In the hardware area, more and more functions are becoming feasible.

IBM has achieved the trillion bit storage capability discussed in my earlier testimony but the present device is designed for an application somewhat different from information retrieval and provides about on access to the data base every two to three seconds. This experience is expected to guide us toward devices that can operate 10 to 100 times faster.

With regard to faster access devices, the problem is the relationship between storage capacity, cost and sheer physical size. We are in the process of installing systems that store only billions of bits, but they require complex physical layouts to maintain fast access speeds. Progress is encouraging, however, and improvement factors of two and four in capacity at modest increases in cost continue to appear.

National Programs

The marriage of communication and computer technology holds out hope that access to data banks and information centers can be made convenient and economical for everyone. Before traveling to the library or information center to find a document, we will be able to search the catalog or index from a terminal at or near our work location to determine what, if anything, this center has on the subject we are interested in.

There are emerging, therefore, in business, industry, universities, and government, some networks that are designed to provide access from remote points to a centrally stored data bank. The most recent announcement of such a network concerns an installation for the *New York Times*.

The feasibility of regional and national networks is now being studied. The impetus comes from cost advantages of centrally acquiring, processing, and storing index data together with the cost benefits of central equipment to support the operation of a network.

Data banks of bibliographic information may be mission-oriented (as in the case of NASA, AEC, the National Library of Medicine, the American Petroleum Instute) or they may be discipline-oriented (as in the case of Chemical Abstracts or the American Institute of Physics). The processors of the information will probably wholesale these data to operators of national or regional networks who will retail it via communication links and terminals to the ultimate consumer.

A researcher working for a pharmaceutical company might then be able from his office to search the index files of the Food and Drug Administration, the National Library of Medicine, Chemical Abstracts or a data bank established on a central or regional basis by some organization such as the Pharmaceutical Manufacturers Association.

Professional societies such as the ones united in the Engineers Joint Council have long performed the information wholesale function. Industry associations such as the Paper and Pulp, Textile, Steel, Petroleum associatios have for years collected, abstracted, and indexed relevant literature and sold the published indexes and abstracts to members. Several professional societies and industry organizations contemplate the establishment of terminal-oriented networks, thus serving not only as wholesalers but as retailers of information.

One of the most advanced information networks is the Biomedical Network of the State University of New York. Headquartered in Syracuse, this network is a pilot project for the SUNY library network that will eventually tie 60 campus locations together. The Syracuse computer stores medical literature references obtained in machine-readable form from the National Library of Medicine, a union catalog of the collections of the SUNY medical libraries, and the catalog of books of the National Library. Access to the data base by means of typewrited-like terminals via telephone lines has been extended beyond the State University. Terminals are also installed at the Harvard Medical Library, the Columbia University Medical Library, the University of Rochester, and Albany Medical College.

Similar medical networks are being planned in other areas of the United States.

Thus far, I have limited my discussion to networks designed to facilitate access, i.e., to tell the user what items that may be relevant to his needs exist in the collection. Another equally important service that networks will be expected to render is to provide physical access to the information itself: the text, the photographs, tables of data, graphs, etc.

In the library field, inter-library loan arrangements have existed for a long time. In many instances obtaining a book from the State Library or another library in the system after days and sometimes weeks may be adequate. Microfilm-Video technology will make it possible to transmit image information over the same network as the computer-generated bibliographic data to a user terminal. Serious legal obstacles lie in the path of this development—the copyright problem.

So much for the progress report.

I would like to conclude with a few remarks on the educational needs implied by these evolving systems.

The equipment and techniques already developed are far ahead of our ability to use them. This, as I have mentioned, places a special premium on our efforts to train our scientists and engineers to use the new information systems. And by that, I mean training them in these matters during their formal education cycle. Technical people tend to follow the information-gathering habits that are formed during their regular schooling. They tend to carry them on throughout their professional careers.

If the advantages of new techniques are not made available to the present generation of students, the nation must accept a relatively slow acceptance of new information concepts on the part of its scientists and engineers.

The second aspect of the educational problem concerns not scientists and engineers, but the information specialists who operate these systems for their benefit.

Libraries of all types are turning to the techniques of data processing to help solve their problems and serve their clients—but for many librarians this means a large jump into a new technology.

At the very least, this means library directors and operational staff heads should have an elementary understanding of what a computer is and how it functions. Second, they should be aware of how it has been, and is being, used within the total library environment. Third, it is essential to know what the machine can and cannot do, in terms of library applications. Finally, these people should be in a position to evaluate the existing systems in terms of their own operations and needs.

Realizing the importance of this introduction to computers, IBM has instituted a training program designed specifically for librarians. Each year, a one-week course for two to three dozen academic library directors is given at one of IBM's customer education centers. In addition, three regional seminars of equal duration are conducted throughout the country for not only library directors but their staff heads as well. Finally, local courses of one to five days are conducted by local IBM branch offices for library personnel within their territory. Lectures on various aspects of library automation are being put on videotape, and a series of manuals is being published on library operations. Hopefully, all this activity will help bring the librarian closer to the computer and provide the knowledge and understanding he needs.

It will be clear to you that this is to an extent a matter of enlightened self-interest on our part, and I mention these needs and these programs not in order to claim credit but to make a larger point.

We are moving quite rapidly into an era of large-scale information systems. For millions of people, this will mean dramatically new and improved methods of conducting our daily routine. If the nation is to realize the full benefits of these developments, it becomes important that people are educated to run and to use these systems effectively.

In our experience, this is not something that can be left entirely to happenstance.

Mr. PUCINSKI. Thank you very much.

(Whereupon, at 4:30 p.m. the hearing recessed until Wednesday, April 30, 1969, at 10 a.m.)

SCIENCE AND TECHNICAL INFORMATION RETRIEVAL BILL

WEDNESDAY, APRIL 30, 1969

House of Representatives,
General Subcommittee on Education of the
Committee on Education and Labor,
Washington, D.C.

The subcommittee met at 10 a.m., pursuant to recess, in room 2261, Rayburn House Office Building, Hon. Roman C. Pucinski, presiding.

Present: Representatives Pucinski, Bell, Ruth, and Dellenback.

Staff members present: Allan Kiron, technical adviser; John F. Jennings majority counsel; Alexandra Kisla, clerk; and Charles W. Radcliffe, minority counsel for edu

Mr. Pucinski. The committee er.

We will proceed. The other of ommittee are on their way here and they will be assem. e of the problems we have this morning is that the majority leader is testifying before the Subcommittee on Poverty and many of our members are down there. But in order to expedite this situation here I thought we would proceed at this time rather than wait because I am sure that Dr. Rothman and Mr. November are anxious to get back to New York.

If we may have Dr. Rothman and Mr. November take the stand we will move along and the other members will join us shortly.

Gentlemen, we are very pleased to have you here this morning. Dr. Rothman, as I understand it you are director of information services for the New York Times. You graduated from Queens College and received your masters degree at New York University and your Ph. D. in comparative literature at Columbia University in 1956.

Certainly you bring to this committee a wealth of knowledge on this subject.

Mr. November, we understand you are the director of library services and information division of the New York Times. You received a degree in economics at Harvard in 1958 and you were a Henry Fellow in economics at Kings College in Cambridge, England in 1959.

We are privileged to have you gentlemen join us this morning and tell us something about the capabilities of information retrieval. We have been watching with great excitement the system that you are developing at the New York Times and I think it is something that was long in coming.

The New York Times is recognized around the world as one of the great storehouses of information. I am very pleased to learn that you gentlemen can set up a more orderly system of retrieving that information. I am sure it is going to play a tremendously important role in this country.

I am hopeful that eventually you are going to develop through Intelstat and similar devices, into a world-wide network. I am not quite sure that the American people are aware of the full significance of what you are doing and the impact that it can have on so many aspects of our social and economic and educational and scientific endeavors.

I view your project with great excitement and am anxious to hear your testimony.

I would recommend that you gentlemen proceed in any manner that you wish. You have a prepared statement which will go in the record if you wish at this time and you be the judge of how you want to proceed. As I say, the other members of the committee will join us here in the morning.

(The statement referred to and a news release follow:)

STATEMENT OF DR. JOHN ROTHMAN, MANAGER OF INFORMATION SERVICES, NEW YORK TIMES

For the last three years The New York Times has been working on the development of an information retrieval system which, when put into operation, will make available vast resources of information now hidden in the clipping library and other facilities of The Times with incredible speed, thoroughness and comprehensiveness.

By using modern data-processing techniques and equipment, the system will process material efficiently and economically, store it securely and in proper order, and make it available via computer to inquirers.

The system will comprise abstracts of The Times and other materials stored in a computer, full text of these materials stored in microform in an automated device linked to the computer, and appropriate computer-linked input/output facilities.

Initially the system will serve the news and editorial departments of The Times and eventually a wide range of customers requiring comprehensive, authoritative information.

HOW THE SYSTEM WILL WORK

The heart of The Times Information Bank will be a third-generation, real-time computer (IBM System 360/50) and software combination which will be designed especially for immediate computer-to-user response (time-shared) with a large number of remote terminals. A large direct-access mass storage facility will be included to insure rapid handling of the large data base.

Remote terminals will be tailored for the customer to any one of three models:

Keyboard input with video output.

Keyboard input with high-speed printer output.

Keyboard input with slow-speed printer output.

Linked with the computer will be an automatic device for the storage of microfiche containing images of the actual clippings. This device will be capable of storing and rapidly retrieving the equivalent of 3.5×10^6 pages of newsprint. Other peripheral equipment will include a microform camera at Microfilming Corporation of America, Inc., a wholly-owned subsidiary of The New York Times, for miniaturization of full text; input terminals—probably cathode ray tube and keyboard—and a computer-telephone interface for audio computer-to-user answer service.

It will be possible for the user, through the audio system, to query the computer directly and receive an answer. It will also be possible to use the audio system for placing calls automatically and answering inquiries that have been previously placed.

The computer will actually converse with the inquirer; the computer will talk, the inquirer will use his dialing device. Modular system design will be a paramount consideration to allow for expansion of central facilities as customer demand increases.

HOW THE SYSTEM WILL BE PUT INTO OPERATION

The information retrieval system will be made operational in four overlapping stages or phases:

Phase 1

The computer, software and full text device will be installed at the 43d Street location of The Times. Only a portion of the design memory size will be installed initially with additions as the needs are forecast. Data input, system checkout, and debugging will be completed and followed by limited use of the system by selected individuals to test fully the operational design features of the system.

Phase 2

Remote terminals will be installed in the New York office of The Times and editors, reporters and other personnel will be shown how to operate the retrieval equipment to receive both abstract and full text items stored in the system.

Phase 3

Remote terminals will be installed at other locations of The Times. Personnel at these locations will be taught the proper use of the equipment for rapid recovery of stored data. There will be no capability at these distant terminals for electronic viewing of full text items; full text will be sent to the location from New York or stored at the distant location in microform.

Phase 4

Ultimately, remote terminals will be installed at customer location. Customers will be trained in the operation of the system and will have full inquiry privileges. Output to customers, however, will be limited to abstracts, citations and a subset of the full text items in storage. Non-Times articles, information from early editions, and killed items will not be transmitted to customer terminals.

For customers who anticipate no need for installation of heavy-use terminals, telephone service with direct hook-up to the computer will be available. A no-charge service will supply computer citations of Times references to the inquirer by means of voice recordings.

During peak load periods, the computer may temporarily store an inquiry, then initiate a call to the inquirer, and automatically supply the citations. If the inquirer desires abstracts in addition to the citations, he will signal the system, a computer assistant will enter the conversation, and a fee will be charged for either telephonic recitation or mailing of the information.

WHAT WILL GO INTO THE SYSTEM

As of D-Day in early 1971, detailed abstracts of all material published in The New York Times and in a wide variety of other publications will be processed into the computer. An initial data base of earlier materials is readily available from the tapes of The New York Times Index which has been in a successful computerized operation since January 1968 (this operation has served as a pilot project for the enlarged system).

Gradually earlier selected data will be incorporated into the system at a planned, orderly rate. These earlier data will be obtained from The Times Morgue clipping files which will then be retired and eventually complete phase-out of the Morgue will be achieved.

Information from earlier annual Indexes will eventually be edited for automatic system input, possibly by OCR equipment. Data which predate the actual time when the system commences operation will be drawn exclusively from The New York Times, whereas current data will come from many news sources.

The Times anticipates that future expansion of system input will include storage and retrieval of photographs and other graphic materials; bibliographic citations of relevant books and other reference materials available in The Times Reference Library; and interface with other large reference libraries and information centers using an automated system.

POTENTIAL MARKETS AND USES

The Times envisions that real-time access to its gigantic store of background information, whose depth and scope equals that of The Times' own news-gathering, will prove to be of immeasurable value to major reference and research libraries, general business services, radio and television stations and networks, public relations and advertising agencies, and individuals such as scholars, journalsts, and researchers in every field of endeavor.

To assist in future planning, The Times has retained the services of Arthur D. Little, Inc. of Cambridge, Massachusetts, one of the world's most respected research organizations. It will be this company's responsibility to determine the size and scope of the potential market, evaluate the kind of response the system and the service it performs may expect from potential customers, and scientifically forecast what changes are likely to occur in the demand for the kind of service the system will be capable of producing.

[News release, Mar. 26, 1969]

NEW YORK, N.Y., March 26, 1969.—The New York Times today announced the development of The Times Information Bank, a real-time, interactive retrieval system which will make available vast resources of material to major research and reference libraries, government agencies, journalists, scholars, and other media, including radio and television networks, with speed, thoroughness and comprehensiveness.

In a news conference at the company's headquarters, Ivan Veit, a vice president of The Times, said International Business Machines Corporation and its Federal Systems Division have been retained to assist in the design and implementation of the system. Additionally, Arthur D. Little, Inc., the well-known research organization, will assist with market development.

He said, "We envision that the instantaneous accessibility of a gigantic store of background information on virtually every subject of human research and inquiry will prove to be of immeasurable value not only to major reference and research libraries, general business services and other media, but also to individuals engaged in all forms of research.

"The system will serve the news and editorial departments of The Times and shortly after becoming operational will be extended to include a wide range of customers who require rapid, comprehensive and authoritative information."

Mr. Veit noted that the first input into the retrieval system will be abstract data from The New York Times Index beginning January 1, 1968, which are already on magnetic tape. Gradually earlier selected data will be incorporated into the system at a planned, orderly rate.

He said that data which predate the actual time when the system commences full operation in early 1971 will be drawn exclusively from The New York Times, whereas current data fed into the system will come from many other sources.

"The New York Times," said the company's executive, "intends to enhance its reputation, through its information retrieval system, as one of the world's most reliable and authoritative sources of information. We feel the potential market for the services which the system will be capable of producing extends into many areas.

"For example, the services could be put to invaluable use by government agencies engaged in social research, scholars preparing such major documents as doctoral dissertations, general business services conducting research in specific areas for various clients, journalists marshalling material for books and articles. The list could be extended to include the news and public affairs departments of radio and television networks, advertising and public relations agencies, and the research arms of the many philanthropic foundations."

Future expansion of system input, he stated, will include storage and retrieval of photographs and other graphic materials, bibliographic citations of relevant books and other reference materials available in The Times Reference Library, and interface with other reference libraries and information centers using an automated system.

The system is being developed under the direction of Dr. John Rothman, director of information services at The Times.

STATEMENT OF DR. JOHN ROTHMAN AND ROBERT S. NOVEMBER, NEW YORK TIMES LIBRARY SERVICE DIVISION

Mr. NOVEMBER. Thank you very much, Mr. Chairman.

We thought we would tell you the background of our decision to undertake this ambitious new system. Dr. Rothman could describe in greater detail exactly what we are doing and how we are doing it.

We appreciate your kind words about the New York Times. We think of ourselves as a newspaper and sometimes, immodestly, as a great newspaper, where a tremendous amount of resources are devoted to gathering and presenting to our readers a variety of news.

We have almost 1,000 reporters and editors engaged in this endeavor. Back in 1851, when the New York Times was founded, the index to the Times was begun simultaneously; so we have a tradition of over a century of useful retrieval of the information in the newspaper, making it available both to ourselves and to other research users.

As everyone knows, in the last decade the technology of information has been changing very markedly and we at the New York Times felt that the time had come for us to adapt this to an information system for two major reasons.

First, and foremost, so that we could maintain our position for our readers of presenting the news comprehensively and completely, so that our reporters and our staff members themselves would have access to information in the best possible manner.

The second reason, which is also important, is that we see ourselves as not only a newspaper but as a tremendous reservoir of information, and we have been searching for ways to make that information useful, not only in the form of the newspaper you pick up in the morning or the New York Times News Service which we maintain, but in a way that would be particularly adapted to information needs.

Several years ago, therefore, a committee composed of members, the news department of the Times and the business departments, was formed under Dr. Rothman's direction to create and initiate such a system.

I think the best way to proceed is for Dr. Rothman to explain exactly what we are undertaking now.

Dr. ROTHMAN. I think probably the best way to start is by describing briefly what we had before we went into this project. The Times had four principal information facilities. The clipping library or morgue, the New York Times Index, the reference library, and a photo library.

These were completely separate, not only administratively, but they each followed their own procedures and they each had their own vocabulary. For a member of the staff to get the best of information from all four meant instituting four separate searches, going to four separate facilities on four separate floors and getting the information out in each case using the separate system.

This was a very wasteful and inefficient process. The first thing that I recommended to Times management about 4 years ago was that we try some coordination of the four facilities and then try to apply the latest available technology to making a single system out of the four.

This is in effect what this project contemplates. We are going to start with just the clipping morgue and the index but we are planning to add to this project before too long the facilities of the photo library and the reference library.

The clipping morgue is a vast repository of wealth that even we are hardly able to gage and which because of the nature of the newspaper clippings—the clipping is fragile and it deteriorates just by sitting for a while—cannot be made accessible except to a very limited number of people.

I spend more time than I like just politely denying access to the clipping morgue to all sorts of people who claim to have some kind of privilege or need to use it.

We estimate—and this is a very rough estimate—that our clipping morgue right now contains somewhere in excess of 20 million clippings. They would roughly divide—and this is very rough, we did a hasty sampling and, of course, it changes almost from day to day—as follows: our current subject files probably contain about 3½ million clippings; our current biographical file, which consists of about 1¼ million names, contains about 4½ million clippings; and the ex-current or inactive subject and biographical files together contain somewhere around 12 million, give or take a million.

Some of the information goes back for decades. We do not know exactly how much. And some of it is very, very recent indeed. We try to process today's clipping into the files within 24 hours.

The morgue is essentially a single access system. If you are looking for material on information retrieval and a House of Representatives subcommittee you can either go to the appropriate files on information retrieval or you can go to the appropriate files on the committees of the House or you can go to personal name files, if you happen to know the names of the people involved.

In each file you may find some material that is relevant to all three along with I don't know how much material that is not relevant to any but the one. You cannot take the three separate access points, or descriptors, or clues, and put them together and get out only that material which is relevant to all three.

This is not possible in a manual system. It is possible in a computerized system. And this is possibly the largest single advantage that our information bank will give. It will make it possible for people to think of Cornell University and student demonstrations and Mr. Perkins and riots in the last week only and retrieve only that information without getting what we call noise or irrelevant material.

The New York Times Index, as Mr. November mentioned, goes back to 1851. It was an entirely separate operation. It works by having each relevant item of information in the paper abstracted and then the abstracts arranged in chronological order under subject headings which are arranged alphabetically.

The index comes out twice a month in booklets like this and then we publish a cumulative volume once a year. As I mentioned before, the index operation is entirely separate from the morgue operation, yet we handle by and large the same material or at least the bulk of the material that the morgue handles here as well.

What the future system envisages is that we take all the material that is presently processed into our morgue, which means virtually everything that is published in the Times, plus relevant background material from some four dozens or more other publications; to abstract these in great detail, to index them in great depth and to have the abstracting and indexing done by trained information specialists who will be processing this material directly into a large computer from on-line terminals.

The original clippings will be reformatted, pasted up on pages about 8½ inches by 11 inches, and microphotographed. The photo chips will be placed on microfiche, and the microfiche stored in a mechanical device which will be interfaced with the computer in such a way that any one clipping on any one fiche will be addressable directly by the computer using some equivalent of the date, page and column citation that will follow each abstract.

An inquirer will sit at a terminal, presumably a keyboard and video tube terminal, and will phrase a question in terms of descriptors, bylines, dates, the kinds of articles in which he is interested (say, editorials, letters to the editor, news analysis) and so on.

When his question has been phrased and accepted the system will search an on-line file of the abstracts, and will product on his screen in chronological order all the abstracts that are relevant to his request.

He will scan the abstracts, getting from them whatever information he desires, and then if he wishes to see any one or more of the original clippings, he will be able, by pushing an extra function key, to see an image of the clipping displayed on the screen.

That, in brief, is a description of the system as we envisage it going into operation sometime early in 1971.

There are certain exceptions that I must make. We will not be able for some time to transmit images of the clippings themselves outside of the Times headquarters building in New York because the technology of facsimile transmission is still inadequate. We expect users in remote places will either have their own microfiche file or will write or phone us for full text, or if they want something much less sophisticated, they will be able to use the New York Times microfilm.

We expect to go back almost instantly. The New York Times Index has been in a successful computer operation since January 1968. We will be able to feed the tapes of the index back to January 1968 into the system, so that we go into operation in early 1971, we will have instantly available to us more than three years of background information (although it is limited to the material processed into the index).

We will at that point, of course, have remaining for us the New York Times clipping morgue. We are planning, as rapidly as we can, consistent with control and careful selectivity, to go through all the material that will then be reposing in our morgue and we will be gradually processing it into this system.

I would not be able to even guess right now how long this process is going to take bcause it means going through 20 million clippings in effect and picking out those that are most worthwhile and then gradually feeding them into the system. However, we will do this as expeditiously as we can.

We are also planning, as soon as the system is in operation, to index our photograph file in machine-readable form and feed references to that into the system. We are planning as a later step to put our reference library catalog into machine-readable form and process that into the system, so that we hope that by perhaps some time in 1975, a user will be able to inquire of the Times and obtain abstracts and copies of its material and references to other sources, bibliographic material, maps, charts, diagrams, cartoons, and other graphic material that we have.

We believe that this is going to be a staggering source of information and that most of the information in it will be available to the users in what we call real time. You query the system, you push your final question mark key, and the question is accepted and processed and within fractions of a second you start getting a responsive and relevant answer.

The technology is here. If I may make a general statement: my own feeling is that machinery is here long before we know how to use it best. We are using existing devices and in some cases the latest, refined models of existing devices.

The heart of our system is going to be an IBM 360–50–I model with probably another computer of the same kind as back-up. The descriptors and location of items will be stored on IBM 2314 disk drives. The abstracts themselves will be stored on the IBM 2321 data cell. I have only fairly recently become familiar with the capabilities of the data cell. We will be able to store in one data cell approximately 20 years worth of abstracts.

The microfiche storage and retrieval device that we are planning to use has not yet been finally selected, although we probably will have the selection made within the next week or so.

The devices that we have looked at are in operation [illegible] are perfectly capable of handling what the system wants.

For terminals we have a variety of choices. One of the terminals that we are most seriously considering is one that will be able to project on the same screen both the abstract information coming from the computer, and the video information coming from the microfiche retrieval device. That terminal, however, also has not yet been finally selected.

I think the only other thing that I might want to say now is that I am ready to try to answer any questions that you might have.

Mr. Pucinski. Dr. Rothman, there is no question that what you are attempting is one of the most revolutionary breakthroughs in the dissemination of information in this country. In my judgment the New York Times library, file, morgue, or whatever you want to call it, is undoubtedly the greatest warehouse of information on the humanities in this world.

You are lucky that you have a 100-year background and can draw upon 20 million clippings. You have chronicled every significant development in these 100 years, and I am very excited that the New York Times has made this decision. Surely it is a costly decision.

I am wondering if this system will ultimately be available to private subscribers, to non-New York Times people, to libraries, to Members of Congress, to whoever wants to subscribe to it, and will this be on a subscription basis or fee basis?

Dr. Rothman. The answer is certainly, definitely,

I do not think that the Times could have considered undertaking a project of this magnitude requiring an investment of this kind if there were not the possibility of marketing access to this information.

The Times is a business and we do expect to have some revenue out of this system. We know that the demand for access exists as you kindly indicated in your remarks just now. We are definitely already in touch with a number of potential users and many of them have contacted us, even before we actually made the announcement.

I have certainly, in professional association with other libraries and Government agencies—Library of Congress and so on—talked about this project which has been under study for almost 4 years now.

We have had some delegations in from university libraries and government agencies including the Library of Congress. It will be possible for a subscriber to buy or rent a terminal and subscribe to access to this system on probably a range-of-fees basis. We have engaged Arthur D. Little, Inc., a very well-known and respected market research organization, to do a study of the potential market for us and one of the things that we hope to be able to determine on the basis of this study is what the range and scope of the demand is and what range and scope of services we should offer.

We have some idea of that already. We do expect that at least major central public libraries will have terminals available and that patrons of the library will be able to use it, possibly by paying a small fee to the library and the library then would subscribe to the access service on a monthly or annual basis.

Certainly we expect that most of the news media, most of the large news media, will wish to subscribe to access to this service on a fairly regular and large-scale basis.

Mr. PUCINSKI. Let me take a hypothetical situation.

A young student doing research at the University of Chicago on Sino-Soviet relations—when this system is completed I presume this young student will, by going to the library at the University of Chicago, be able to energize the questions that he has and feed them into the system.

Now, as to the feedback. Will that be a printout or how will the finished product come back to the student and what will he have in the finished product?

Dr. ROTHMAN. It depends on the kind of terminal. If it is a video terminal he will see a display of fairly detailed abstracts, summaries of news items, each one followed by its proper citation, and the abstracts will be in chronological order.

If there is a printer terminal—and I would imagine that large installations like a university library would have both—if there is a printer terminal and the student or the researcher has asked for a substantial amount of information, it will be printed out for him on a high-speed printer and he will be able to take with him computer printouts of the abstracts in their chronological order, giving proper citations.

If he wishes to have the clippings themselves, then he would have to go, as I mentioned before, to a separate store of the full text. This might be microfiche, and we are planning to offer to libraries the microfiche that we are developing for this system.

The library would have to have a reader or a reader-printer, which I understand are available at relatively low cost. He would get out the right microfiche, put it under the scanner, and obtain either an image of the clipping he can read on the screen or an electrostatic copy that he can take with him.

Where the question requires a larger volume of information he would probably—they would probably call us and we would produce either large sets of the abstracts and/or large sets of the clippings in a batch, off line, and ship them to him at whatever rates will prevail for this service.

We expect to publish on demand all sorts of special subject accumulations. For example, if there should be an interest developing in some particular subject, importation of meat from Argentina for instance, and someone wants a retrospective grouping of material that the Times has published on this subject, we would be able to produce that presumably on a 24-hour turn-around basis.

Mr. PUCINSKI. I have several other questions but I will yield to Mr. Dellenback now and we will come back to my question.

Mr. NOVEMBER. Could I add one item to this.

As we see the technology now, it will be possible for users, primarily libraries or institutions, to use the communications stations that they have. For example, if there is a TWX machine in the library we will have a service whereby that library can subscribe and a patron can sit down at that TWX machine, ask the system for information on the House of Representatives and the output will then be abstracts printed out on that machine in the library. It is possible with the technology to have in some places video terminals which are much quicker, and in other places slower-speed printers which will serve the needs of a variety of potential subscribers.

Mr. DELLENBACK. That is part of the answer to one of the questions I was going to ask. I was going to ask about the degree of compatibility of your system. You say it is just uniquely something, that you must have your own source material on, and your own printers to make it work effectively.

You must have your own system all the way through. There is a sufficient degree of compatibility apparently—this is really a question—so that your system can feed into other types of systems and it does not require the same investment across the line, am I correct?

Dr. ROTHMAN. We expect to be able to do this to a degree. We have chosen hardware, the IBM System 360, which is the one that is most widely used for information retrieval purposes at a number of other installations.

The NASA facility uses System 360. Medlars (the National Library of Medicine) is moving over to System 360. I believe the National Agricultural Library is using it and of course the Library of Congress, Project MARC is going to be on System 360. We will provide for hardware compatibility.

Software compatibility is a different story. At this stage of the game it is very difficult to achieve and we are of course developing our own programs. (It would be very difficult to find existing computer programs that would be able to handle this system as well as any other of similar magnitude.)

However, the whole industry is striving toward greater compatibility and toward easy conversion programs. So that we expect in the future to provide the convertibility and of course we have that very much in mind.

We are checking—in the course of developing the system, we have been checking and are continuing to check—on what is being done at other large installations of which I have only mentioned three or four.

I have spent a great deal of time over the last years doing this. I am continually in touch with other large information users and large information systems. We hope that everyone will be sufficiently aware or will be made aware of the necessity to provide software compatibility.

Mr. DELLENBACK. Without seeking any special business information which you consider confidential and is not what I am seeking to reach for, can you give us some idea about costs involved, either cost of installation or cost of utilization anticipated?

Mr. NOVEMBER. We have already said in response to this question, that is a several million-dollar investment. I think if that is agreeable with you we would like to leave it at that.

Mr. DELLENBACK. So far as the utilization, you talk about working on a subscription basis and then perhaps a major library could have an individual user fee within that basic subscription. Can you give us any idea of what you anticipate these costs might be?

Mr. NOVEMBER. This is a preliminary estimate on our part. As Dr. Rothman mentioned we have a consultant, Arthur D. Little Co., to help us formulate this to the need of our users. Our current estimate of the subscription charge would vary from $100 a month to $2,000 a month, depending on the kinds of service the user wants. Obviously that figure will have to be clarified before 1971. Getting back to the previous question I would like to emphasize again that we think of this as a tremendous information base that we hope that frankly almost every library will use.

For that reason, we are working to make it as easy as possible for them to do so. In other words, the output terminals should be those which would be available not only with our system but with other systems. So, one of our objectives is to have this hardware compatibility on the output end.

I think Dr. Rothman did not emphasize enough, also, that the system is being designed so it will be easily usable by normal information seekers, whether reporters or graduate students or undergraduates or Congressional assistants.

It is a regular English language system. Instead of speaking to a librarian and saying, "I want information," you sit at the typewriter and use the English language to get the information out.

Every attempt is being made to make this as widely usable as possible.

Dr. ROTHMAN. I would like to add one thing to this.

We are designing this system for two primary purposes. One is to serve our own staff better and the other is to make the information facilities as accessible as possible, to anyone who has need for this service.

Our own staff is likely to be extremely demanding. A reporter who is working against a deadline is not going to be able to go through very elaborate coding and he certainly is far from being an electronics engineer, so we are designing this system in such a way that he will be able to use it as easily as—and perhaps more easily than—he is presently using the morgue system, such as it is.

My own feeling is that if it is right for this person working under those circumstances, then this system will be relatively easy to use for almost anyone who might have need for this kind of information.

Mr. DELLENBACK. May I ask a further followup question on the matter of cost? Recognizing that within the range, the $100 to $2,000 a month range, based on types of use and how much time and so on, are you able to give us any unit down to the student who wants to use it for 5 minutes or 1 hour, how much is it apt to cost him to make use of the full resources?

Mr. NOVEMBER. I think we have not addressed ourselves to that question primarily because we expect most students to do this through their libraries, whether university library or public libraries.

Mr. DELLENBACK. I assume your cost of saving $100 to $2,000 a month is in fact based on some units of use. For $100 one would get x minutes or x hours of utilization or for $2,000 you would get 20 x or so on.

Mr. NOVEMBER. We don't see that as individual use of the machine. We see that as the libraries' use.

Mr. DELLENBACK. I am just trying to get some idea, if we talk way beyond your system and talk about a nationwide retrieval system—I do not have any concept at the moment of what realm of cost we are talking in. If you stay with your concept of $100 as a monthly fee or $2,000, or any interim fee you want to use, what would come for that figure? How much would one be entitled to get in the way of measurement of use for $100 a month?

Mr. NOVEMBER. Well, I was going to say, let us start at the other end.

Mr. DELLENBACK. $2,000.

Dr. ROTHMAN. If you will be good enough not to hold us to the precise figures.

Mr. DELLENBACK. We will consider this not at all binding legally and just to give us some road in. What do your calculations at this time indicate?

Dr. ROTHMAN. We are assuming for example a major publisher or television network that is going to want access to this instantaneously on say a 20-hour-a-day, seven-day-a-week basis would pay the maximum figure, on a monthly basis, and for that would be entitled to, I would imagine, somewhere between 10 and 20 questions and answers a day.

This is pure guesswork.

If they exceed that then there might be some surcharge, depending on the excess.

It may also turn out that for the large-volume users we charge a flat fee for as many turns as they might want at the device.

Mr. DELLENBACK. Pushing the stick then that you have given, let us assume that this user who might ask 10 questions a day would pay $2,000 a month for the service. This might be on, what, a 5-day week.

Dr. ROTHMAN. No, 7.

Mr. DELLENBACK. So, we have 300 questions which, in effect, might yield a price of $2,000?

Dr. ROTHMAN. Something like that.

Mr. DELLENBACK. We are oversimplifying this but I am trying to get a grasp on some unit of measurement.

Dr. ROTHMAN. When you are talking about the other end, the student or individual library patron, I would like to perhaps just draw an analogy. Many libraries now have electrostatic printers, big Xerox machines, available.

They either buy these machines or rent them from Xerox paying the standard going rate. Then, depending on volume, they charge individual patrons a quarter or 50 cents for use of the machine.

It seems to me that what we will probably do for public and university libraries is much the same sort of thing. The library will pay, depending on its anticipated use, and in turn it will charge its patrons. And the library being a public institution will probably charge just enough to defray its costs and we may have to have some agreement whereby on an annual basis we revise the charge depending on volume.

This is much the way that the scientific services, as far as I understand, now charge the industrial users. The one that I am most familiar with is Chemical Abstract Service. They charge for their computerized or publications service on the basis of the number of users at a given installation.

So, if you have a relatively small company, with just three scientists using it, they pay considerably less than would Du Pont in Wilmington. I imagine that we will follow much that kind of pattern.

Mr. DELLENBACK. Again with all the caveats that you want and I am willing to give you all the ways out that you want, if we can stay with your figures, if it means 10 to 20 questions a day and $2,000, this would mean somewhere between $3 and $7 a question.

Somewhere in this area is what I am thinking about, if my mathematics work out correctly, off the top of my head, which tells me something about the average research student in a library; he might find that he does not use it the way a scientist or the way somebody really researching a project in depth would be able to say, "This question is important, that is a minimal cost," but a student who is writing a thesis on ancient Greek pottery might think hard and fast before he started to feed 10 or 20 questions into a machine at that unit of cost.

Dr. ROTHMAN. Let me make a distinction. To some extent it depends on what kind of response they want. If they are sitting at a cathode ray tube terminal and are getting the answers displayed back, this is more expensive than if they write to us and say, "Print it out for us at 2:30 in the morning when your device is not used any other way and send it to me parcel post. I have plenty of time."

So, I don't know at this point whether we have to base our charges on the number of items requested, the mode in which they are supplied, the number of lines printed out or displayed.

Chances are that all these elements will enter into it and this is precisely the reason why we have retained Arthur D. Little as a consultant, to help us frame the prope[illegible]r these charges.

Mr. NOVEMBER. I would like to [illegible] th[illegible] to some extent the variety of the output is a variety of degrees to which you are making the computer do the work that you would otherwise have to spend a great deal of time and effort to do.

We do anticipate, for example, that we would not have to charge at all if you were to call up as a graduate student and say, "Tell me what stories you have run on archeology in Greece in the last year."

Our computer could give him those citations and if the person had the time he could then go and look up each of those stories. We would envision many small libraries would have an intermediate step of TWX machine to call the New York Times, type the question, and at relatively slow speed get back some of the answers.

Our charge for that would be less than having access to instantaneous use of information on the cathode ray tube.

Mr. DELLENBACK. There is a series of questions that would be interesting to follow but one more that is broad in scope—is there anything you can tell us as to the major problems you face—oversimplify your answers as much as you like—in trying to set up a system of knowledge retrieval when you want to gather together basic raw materials, somehow digest it in digestable form and then make it available to somebody else.

What are the major areas of problems that you face? Costs? Getting the right hardware, developing the software, what?

Dr. ROTHMAN. One of the major problems is behind us and that was getting management approval for this project.

Mr. DELLENBACK. There are no senior officers present with you?

Dr. ROTHMAN. I am joking.

I touched on the answer to this before. I think that hardware is not a major problem. The hardware is here. Also the ability to program is here. The programing language is available to us. I think it is sufficiently capable that we can do almost anything that we have to.

I would say the biggest problem is to define precisely what we want out of the system and how to structure our basic vocabulary to get at it. And then to translate that into systems specifications that the systems analysts can work with. I would think that that is the biggest problem.

I have done considerable reading and work in this field, also outside of my work for the Times. I have been chairman of a subcommittee that has drafted a standard of indexing which was recently published as the "U.S. Standards Institute Basic Criteria for Indexes."

There is the problem of semantics, of taking a piece of information, a document, text, and describing it in such a way that whoever wants it at whatever time and in whatever context can get that document out of the file, and no other. That is the biggest problem.

I think that—incidentally, I am optimistic enough to say this—I think that for our system we have licked it.

Mr. NOVEMBER. I was going to agree with Dr. Rothman. I think the major problem has been an intellectual system design problem. The opportunity of somehow using the hardware and getting all this information back in the way you want it is very dazzling.

The real problem has been to create an approach—a framework—which will make that practical.

I think it is only fair to correct any erroneous impression. I think the management of the Times has been overanxious in the other direction.

They h[illegible] been sa[illegible] to us, "What are you waiting for? Why don't you [illegible] system that we can use internally and externally?"

The problem is: Does the information group have a system that we are confident will serve the users? To create that framework is very difficult. Cost is a problem. And it is only because we are confident that we have a system that will be efficient, both as a resource for the rest of the world and for our own use that we are therefore able to justify the expenditure which this entails.

Mr. PUCINSKI. Your testimony is invaluable to this committee for many reasons. One, because I frankly believe the biggest problem is methodology. I don't think we are doing enough in this country.

Our various agencies are spending all kinds of money on research but they are really spending very little money on addressing themselves to the question of what we want out of an information retrieval system.

What language do we use? How do we cross index? What methodology is best? The Weizman Institute of Science in Israel is doing some exciting research in this field. There are a few others that are researching the problem but I must say I am very disappointed that those who control the purse strings in Government have really not had the imagination to fund reserves in this field to any great extent to help people and organizations such as the New York Times.

The Science Information Service director was before the committee yesterday and referred to all the things they are doing. But I believe they are really not doing very much in this direction.

The other thing I was impressed with is the initiative of private enterprise. You have taken on this very costly project and you are not worried that maybe tomorrow it is going to be obsolete. You are taking a chance today.

This is certainly in sharp contrast to the testimony yesterday, when the Director of the Science Information Service indicated his office could not support a National Information System because new technology may make it obsolete. This is the same attitude that was expressed 100 years ago by the Director of the U.S. Patent Office when he suggested we shut down the Patent Office because there was nothing more to invent.

As I say, thank God for private enterprise. Obviously, if we were to leave this project to existing Government agencies to do, it would never get done. I take it your system is an evolutionary system, one that will adapt itself to changing technology, and the various advances that obviously will be made in hardware as we move along. Is that a safe assumption?

Mr. NOVEMBER. Yes, sir.

Mr. PUCINSKI. And it is safe to assume after the huge amount of money that you are going to put into this sytsem, you are not going to swap it for another system in 5 years. Rather, you are going to build on the system you have.

One question comes up. Had you waited, had you not committed yourself, as you did, to a program which you hope to have in operation by 1971 and fully operational with the full 20 million clippings by 1975, had you waited as so many people have advised this committee to wait, do you have any idea what would be the increase in cost with every month that you delayed development of this operation or every year that you delayed it?

Dr. ROTHMAN. No, I would not be able to say, because there are several kinds of costs. One is the price of hardware and software, in developing the system. There is also the cost which we feared more actually—and by "we" I not only mean us in the team that was working on the project, but I am quite sure our management as well—is the cost of not doing something that would be worthwhile, and that would supply a need and bring in an apropriate amount of revenue.

And the concomitant fear that one of our competitors will move into the vacuum instead.

Mr. PUCINSKI. Of course, you have one built-in guarantee, one indestructible safeguard, and that is that you have 100 years of knowledge and information stored in your New York Times library. As far as I know, no one else is capable of catching up with you on that score.

Ultimately the Library of Congress may be computerized, as well as other sources of information. Having had a little experience in this field, it would be my judgment that it would be almost impossible for anyone to catch up with your built-in advantage of having your own warehouse of knowledge in the humanities. As far as I know, no one else can equal it.

Dr. ROTHMAN. That is true, but we have found that most of the searches for information will probably go back somewhere between 5 and 10 years and that the searches for information going further back may be relatively rare. This is a relative thing. So that possibly some other information vendor who does not have quite the file that the Times has, but who has a respectable file, nevertheless, who is out before us, would be able to preempt a good portion of the market.

We face this in microcosm with the index. The index goes back to 1851 and it covers the New York Times. Yet there are any number of published current information services around that give us a run for our money.

Mr. NOVEMBER. We did not aproach the question as to what would be the cost of waiting. We were a little bit the other way around. If now we have a system and technology that can do this for us—and again I would like to emphasize the benefit we feel for our own staff of being able to get information quickly and comprehensively—we should not wait.

The second item would be what is economically feasible at this time to do.

Mr. PUCINSKI. Dr. Rothman, you said the system at the New York Times was developed by a committee which you headed. How long had this committee functioned?

Dr. ROTHMAN. The committee was formed in June 1966. In back of it is about a year and one-half of active work that I put in pretty much by myself. The committee still functions. The committee consists of Mr. November and myself, the former chief librarian of the Times, who is now general services manager, the Times systems manager, and two relatively recent employees of the Times who have joined the Times as part of the information service staff.

The other member of the committee is a representative of the news department, the assistant metropolitan editor, who kind of represents our customer interest.

Mr. PUCINSKI. The reason I ask that question is that the legislation before us, H.R. 8809, calls for the establishment of a national information retrieval system. It describes in general what it should be like.

Perhaps it would be a good idea to rewrite this legislation and establish a Presidential commission that would be charged with the development of this system. I am not sure, but perhaps that might be a more realistic way of proceeding on a national scale with the work you have already undertaken.

In effect, you really have a prototype of what we are talking about in science information. You have illustrated what can be done in this field. I am grateful to you for bringing us up to date on the fact that the technology is here, that the hardware is here, that the methodology is here. While the New York Times will concern itself essentially with largely disseminating information on the humanities, the bill we are discussing calls for setting up a system to retrieve information in scientific and technical research.

I am very grateful to you for this testimony.

Mr. Ruth, do you have any questions?

Mr. Ruth. No questions.

Mr. Pucinski. I want to make one observation, that the New York Times of 1969 is a far cry from that of 1920. I once came across an editorial in my research on the New York Times in 1920 in which it was suggested that Dr. Goddard be fired. In effect, the editorial called him an imbecile. It stated that anyone who would suggest a rocket can be launched out of the force of gravity and then propel itself into outer space and around the moon must be completely out of his mind, and any further expenditures on that kind of project is just a waste of taxpayers' money.

That was a very fine editorial in the New York Times in 1920. I am very happy to know in 1969 there is considerably different thinking at the New York Times.

Dr. Rothman. May I respond to that? I have been asked by someone—and I don't know whether he was trying to be funny or whether he was being incredibly naive—whether in this system we are going to go back and correct incorrect material.

The answer is no.

Mr. Dellenback. I am not sure that was a gracious way to close, Mr. Chairman. May I ask a couple more questions?

You indicate it has taken you some 4 years, in effect, of your time so far, Dr. Rothman, and the committee something less than that, but you have been on this for 4 years working toward this particular issue.

If I understand your testimony correctly, you indicated that the prime body of knowledge you are going to be working with is Times knowledge, for a period of time after which you will reach out beyond, but you begin with your own, and this is a relative word, relatively limited source of raw material, a very substantial source but relatively limited.

Do you have any concept of what it might take you in time to get ready even on the basis of your research that you made to date on this system, if we were to charge you with the responsibility of developing an information retrieval system that would embrace all branches of scientific research, covering every possible field of scientific research, not just within the United States of America, but on an international basis?

Would you be ready to start on that immediately or would it take you a little time to get ready for it?

Dr. Rothman. I think it would take more than a little bit of time. Let me respond to that in several ways. How long it takes to get a system ready depends to some extent on what is there when you start.

In our case there were, as I say, four separate facilities that had been in operation for some time and that were, all of them, entirely manual. There was no machinery used of any kind.

I have been working for the Times for almost 23 years. So I started out with a very substantial basis of knowledge of what the Times had in those systems and how it was being processed. I had a fairly good idea of how it was being used.

Now, to draw the parallel to this system that you are questioning me about. Someone would have to make a study of what is now being done. how it is being done, how it is being used, and how should it ultimately be used.

How long that takes depends to some extent on how knowledgeable this person is of the field or fields and how much of the data already is available for him to see.

Mr. DELLENBACK. Since there is an immense wealth of scientific papers that is of record already across the scope of the Nation and the world, we can imagine that there would be a tremendous problem, if you would reach backward at all to try to put this in form.

Would you tend, if you were approaching that sort of problem, realizing its complexity and breadth, to try to create in the original instance a program to cover the entirety of it or would you tend to approach it from the point of putting together pieces at a time and then trying to weld the pieces together?

Dr. ROTHMAN. I am going to answer that out of the depth of my ignorance of the natural and physical sciences, which is only fair because many of the physical scientists that already have computer systems going tried to tell us how to go ahead and process our material.

I would imagine that the best way to go would be piecemeal and gradually. This is in some sense already being done. To my very limited knowledge there is already some interchange taking place between the biological sciences and the medical sciences involving the National Library of Medicine and Biological Abstract Service. This is very good.

There is some interchange between the Chemical Abstract Service and the National Library of Medicine, the Food and Drug Administration, and the National Agricultural Library in regard to agricultural chemicals. It would seem to me that kind of interdisciplinary interchange, perhaps on a limited and initially on the most obvious basis, would be the way to start. Then gradually try to use that as a nucleus and then gradually try to draw the other disciplines into this, which they will actually naturally do.

I mean, for example, Psychological Abstracts is having some sort of communication with the medical services; the National Aeronautics and Space Administration with the Engineers Joint Council, and the Department of Defense with the Engineers Joint Council.

There is a good deal of cooperation already going on and it seems to me, if you don't mind my making a suggestion to this committee, that the way to start immediately would be to encourage cooperation.

This is what we were talking about before: compatibility. To some extent this means compatibility of people and administrators and systems, just as well as compatibility of hardware and software. I would urge you to use the prestige and influence of the Congress to encourage these scholarly and professional organizations to cooperate and perhaps that way build a National System or at least that way begin to build National Information System.

Mr. DELLENBACK. While I oversimplify, you would stress cooperation, you would stress moving ahead firmly, but you would make haste slowly.

Dr. ROTHMAN. That does not necessarily follow. I think that the cooperation—you realize, incidentally, now I am expressing personal opinion—the cooperation between two related fields and two related institutions or services, that need not be made slowly. I think that should be done as quickly as possible.

Mr. DELLENBACK. I said, press ahead firmly, but when you talk about the total system, you would make your haste somewhat slowly in trying to get a total system. Is that correct?

Dr. ROTHMAN. Yes, sir; I would advise that. The complexities are such and the fields are so vast and the problems are tremendous, I think the best way to solve them is to approach them piecemeal rather than totally.

Mr. DELLENBACK. Thank you very much.

Mr. PUCINSKI. Just so there is no misunderstanding, in the event my colleague is trying to lay the foundation for delaying action on the legislation for us——

Mr. DELLENBACK. Not a bit, Mr. Chairman.

Mr. PUCINSKI. He asked the right questions. And I just want to make sure that we are all talking about the same thing. The New York Times has made a very important decision. It made a decision that at this point in time it needs a better way of disseminating the vast amount of information that it now has and has accumulated over the last 100 years. Any further delay in the development of this system would merely further complicate its development.

After sputnik it became very apparent to the Members of Congress and to the scholars and researchers of this country, that there was a very serious gap in the dissemination of scientific data.

The Office of Sciences Information Services was established to close this gap.

For 11 years it has been going through a lot of money, but I have not been able to find any evidence that it has moved forward in successfully managing the dissemination of information. Eight years ago we introduced this legislation, which would commit this Nation to the establishment of a national information retrieval system in the sciences.

This legislation clearly recognizes that it is best to move within the scientific disciplines. The American Chemical Society is setting up its own retrieval system in chemistry. The various engineering societies are setting up their own systems; various other segments of the sciences are setting up their own systems.

Because we know that there has to be a certain amount of crossbreeding of information among the disciplines, we have proposed that all of these ultimately—not tomorrow, not day after tomorrow—but ultimately be tied together on a coaxial cable, a network which will make this information available to scholars and researchers. My judgment is that in due time the New York Times system may very well become one of the strong components of a national system, on a contractual basis.

H.R. 8809 provides that the National Information System can enter into a contract with a system like the New York Times to feed its information into the system.

Would you care to express an opinion as to whether or not this country can wait any longer for a commitment to try to bring some sort of order to this dissemination of scientific information?

H.R. 8809 specifically forbids the duplication by the Government of existing systems, because we are not trying to put anybody out of business or make the Government compete with private or other organizations. All we are trying to do is put all of these systems into some sort of an orderly national system where their information can be readily available to whoever needs it.

Do you care to express an opinion?

Dr. ROTHMAN. A limited opinion, limited by the fact I am not in the natural sciences and have never been a user of any of the systems. My only familiarity with them has been to see what individual institutions have done in the automatic information retrieval field, to see what I could beg, borrow or steal from them for our system.

You used a term in your discussion just now that rang a very familiar bell with me and that was the term network. My own idea is that a single monolithic service coming out of a single computerized system covering all possible disciplines, is probably beyond the technology of the immediate future.

There is also this to be said about this single, giant, comprehensive facility. This is very good when someone wants to browse the field or fields. It is not that good when someone has a very specific question aimed at a special item.

These are the two main conflicting user interests, the specialist who has the one thing in mind that he wants as against the person who does not know exactly what he wants or who wants a retrospective survey.

So I would favor the network concept, whereby someone searches one system, and if he does not find there what he wants, that system steers him elsewhere—What you really want is related information—and he is switched automatically, if possible, into a compatible system having cognate information.

I think that the main search tools, dictionaries, thesauruses, instructions, the programs, should be compatible, definitely. Whether it would be absolutely necessary to house all the information in a single warehouse or to make it accessible——

Mr. PUCINSKI. The Soviets have a single warehouse and our studies have indicated that this is not the best way to do it. We, on the other hand, encourage a network of all types of selected information.

We don't want to disturb these systems or put them out of business or compete with them. All we want to do is make sure what they are doing is available readily to whoever needs that information.

Dr. ROTHMAN. On a network basis, I would definitely be in favor of it. We have talked at times, among the members of the committee and with our management, about the possibility of eventually linking our system to related systems. These are not in the planning stage. I don't know whether they will within my lifetime come to fruition.

This depends on many factors that are now beyond our control, that are not now within our control. But I would think for instance, that it should be possible for someone to browse the New York Public Library's catalog or the main catalog of the Library of Congress or perhaps a union catalog, for information and then find that some of this is in the archives of the New York Times.

And then flip a switch and switch over into our system and search it. And conversely it should be possible for someone to search the Times for information, find there is background information, possibly at the New York Public Library, and automatically switch over to their catalog.

Mr. PUCINSKI. Don't you think, Doctor, that there is an urgency to legislation such as is before this committee, although perhaps not in its present form. I am not wedded to the language and the provisions of this particular bill. But what I do believe very strongly and I would like to get your reaction to this—at this point, there ought to be at least a clearinghouse of information to cope with the proliferation of systems that are being developed all over the country. Millions upon millions of dollars, billions of dollars are being invested in information retrieval. Unless given some guidelines in compatibility, we will never be able to tie these systems together. And it seems to me that the key word in 1969 ought to be "compatibility."

We do not want to tell people the manner in which they are supposed to run their system. You made an excellent presentation today, and I am impressed with the way you are moving in this system, and I don't want somebody looking over your shoulder and telling you how to do it.

We leave that to private enterprise and to your good judgment. But we would like you to know what others are doing in terms of compatibility, so that as you spend the millions of dollars that you are spending, by 1975 you will not find that you are all by yourself unable to tie into any other system. We did that in the poverty program. Millions of dollars were spent on setting up some 127 information centers around the country, and then it was discovered that they do not fit.

Today they are totally useless to us. Because they cannot work, they cannot integrate with one another in terms of information exchange. For that reason, I do feel there is a certain urgency in the subject we are talking about.

If for no other reason than with the huge breakthroughs that are being made all over the country, some which should provide a clearinghouse of information so we can make some effort toward compatibility. Is there any basis for that statement, Doctor?

Dr. ROTHMAN. Again speaking as a private individual, I would endorse that wholeheartedly; yes.

Mr. DELLENBACK. Would you yield, Mr. Chairman?

I think this would be helpful in clarification of the chairman's objectives. You are not talking about a system whereby the Government would do the retrieval?

Mr. PUCINSKI. Oh, no.

Mr. DELLENBACK. You are not talking about a system where the Government would do the cataloging and the digesting and the translating but would merely be a service organization that would help other groups like the New York Times, private enterprise in some situations, or chemical society groups or other disciplines, in their efforts to set up their own systems. We would merely stand back, exchange information, act as a clearinghouse and try to aid voluntary efforts rather than to do it ourselves.

Mr. PUCINSKI. Absolutely. This bill contains very simple language. For example:

In order to avoid unnecessary and costly duplication in scientific research and to assure quick assess to, and a constant inventory of, all science research data, such a nationwide system shall include close voluntary cooperation with, and utilization of, on a contract basis wherever practicable, all existing science research data processing and information retrieval facilities in the United States and its possessions including Government agencies, private and public universities, private and public laboratories and libraries, abstracting societies, professional organizations dealing with specific scientific disciplines and any other facilities dealing with dissemination of scientific research information.

The purpose of this Act is to implement, not substitute, existing information retrieval facilities. Therefore, it is specifically prohibited under this Act for the National System to establish any Government-owned or operated science research data processing or information retrieval facility where such a facility already exists under either private or public ownership. The National System shall use every voluntary means to arrange for an orderly cataloging, digesting, and translating, with the aid of electronic devices, if necessary, of all scientific research data produced in the United States or available in the United States from other nations and through the national science research data processing and information retrieval system, make such information readily available to any scientist or researcher, either privately, publicly, or self-employed, through an appropriate communications network. The national system shall arrange for appropriate financial payment for all science data provided into the national system by private source.

All we are saying here is that neither the New York Times nor the Sperry Rand Corp. nor anyone else in this country is in a position at the present to try to provide the tie strings, the tie rods, to put all these systems on a common network.

Our purpose is to bring together the private resources and help them set up communications among each other. That is the purpose of this bill.

Mr. DELLENBACK. The purpose of the bill, then, for clarification again, Mr. Chairman, is not actually to create any system to do this actually. It is merely to be an aid in and supplement to voluntary private systems which are attempting to come into being and creation.

Mr. PUCINSKI. I think that is properly and correctly stated. The gentleman is correct.

Mr. RUTH. As I listen to this gentleman talk and listen to you, there is no question about the value of the information retrieval in Government and everywhere else, where you learn that time is money. But the thing I was most impressed with is when we talk about a commission or committee which needs to get to the bottom of this.

Before we get to the language of the bill, I am thinking in terms of the study of the possibility to integrate the current methods, to define the purpose of the system, and investigate both limitations and possibility of the system and to evaluate it both as to cost and to timing.

I don't see how you can get into something like this without a commission or committee or somebody doing this research prior to the time that we try to put the language of the bill into effect.

Mr. PUCINSKI. Mr. Ruth, I have been here long enough to know if you want to kill something, appoint a committee to study it.

Mr. DELLENBACK. So they created a committee which worked on it for 4 years and then moved.

Mr. PUCINSKI. We discussed that earlier today.

I am perfectly willing to consider rewriting this legislation. Perhaps Dr. Carter gave us a good suggestion yesterday when he suggested that rather than try to define the system as we do in the H.R. 8809, perhaps we ought to establish a national commission that will then spell out the system.

I am not too sure that this is not a better way to do it.

Mr. RUTH. As you point out, you have been here a long time and I just got here but since we have the committee system of Government in the House of Representatives, I am a little suprised to hear you say we should not put a project like this in a committee. I am completely aware it has been said if you want to lose something, give it to the committee, but let us give it to the proper committee and let us not be ineffective because we are afraid we are going to lose it.

Mr. PUCINSKI. I don't want to disscuss the procedures in Congress, but the longer you stay here, the more you find out how frustrating the committee system can be. Mr. Bell?

Mr. BELL. No comment, except a camel is a horse put together by a committee.

Mr. PUCINSKI. Dr. Rothman, we are really grateful to you gentlemen for your testimony. You have given us an insight into a system that is now under development. To that extent I think we are all better qualified to study the legislation before us and I am very grateful to you. I congratulate the New York Times for again, as it has for 100 years, taking the initiative. This is a major breakthrough for America. I do not think the American people are aware yet what you are doing. But they will be aware when you get started. Thank you very much.

Our next witness is Dr. J. C. R. Licklider, director, Project MAC at the Massachusetts Institute of Technology. Dr. Licklider is a graduate of Washington University of St. Louis and received his Ph. D. at the University of Rochester.

From 1942 to 1950, he was a member of the Psycho-Acoustic Laboratory and the Psychology Department at Harvard. He was associate professor of psychology of communication at MIT from 1950 to 1957. During his career, he was head of the psycho-acoustic department, engineering psychology department, and information research department of Bolt, Beranek & Newman, Inc., of Cambridge, Mass., later becoming vice president of this firm.

From 1962 to 1964, he was Director for Behavioral Sciences and Information Processing Research of the Advanced Research Projects Agency of the Department of Defense. He served as consultant to the director of research of IBM from 1964 to 1967.

He returned to MIT in 1967 as professor of electrical engineering and is now director of Project MAC.

Dr. Licklider, we are very pleased to have you here. I believe you have a formal statement. It will go in the record at this time, if you have one. Otherwise we will let you proceed in any manner you wish. You have heard a good deal of the testimony. You have a good idea of what members are particularly interested in so I would suggest you proceed in your own manner.

We want to welcome you to the committee.

TESTIMONY OF DR. J. C. R. LICKLIDER, DIRECTOR, PROJECT MAC, MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Dr. LICKLIDER. Thank you, Mr. Chairman, and members of the subcommittee.

I appreciate the honor and the opportunity of talking with you about this very important topic. I would like to express my compliments to the gentelmen who preceded me, Mr. November and Dr. Rothman of the New York Times, and express my admiration for not only their testimony but also the information system they are building at the New York Times.

If I may, I would like to continue a bit with my own "station identification" to give you a picture of the interests I have in this field and the points of view from which I report.

I was connected with the first multiple access or timesharing computer systems. With great interest and some amazement I lived through the period of their research and development and came to see in a surprisingly short time, say from 1959 to 1965 or 1966, the emergence of a new approach to interaction with digital computers.

That became a very successful thing in the marketplace, in commercial application, and in the stock market. It is changing the way research is done in industry and parts of Government and in universities.

Now, I saw that as just a first wave of the development of methods and techniques and language that let people communicate with digital computers in a fairly free and natural way, that can facilitate problem solving, decision making, teaching, learning, and so on.

I have been very much interested in the last 2 or 3 years to be living in the second wave in this development of multiple access computers that make it possible to work intellectually with computing machines. And I think I see the coming now of systems in which truly comprehensive informational services will be provided to research people, to managers, to students, teachers, to decisionmakers in Government. I am not sure exactly when that will be but I sense it will be very soon now.

I have been much interested to see a third wave start to build up, the wave of digital computer networks that will link together general purpose, multiple access computers in all parts of the country.

On the one hand such networks will interconnect the branches of industrial and commercial concerns, and on the other hand such networks will interconnect most of the major universities. And this is coming along although it is just now in a research and development phase.

I have had a strong interest in information networks. By making a distinction between computer networks and information networks I make the distinction: one, having the main interest in the processing of information within the computer; the other having the main interest in vast stores of information within the computer with which one can interact.

Processing would be involved in information networks as well as in computer networks, but heavy emphasis would be placed, in information networks, on storage and on dissemination of information.

With that background I am very much interested in what you gentlemen are talking about here in H.R. 8809 and in the National Science Research Data Processing and Information Retrieval System.

I have been connected during these years with several organizations and committees and so on. Only for a short time, only for 8 or 10 months have I been Director of Project MAC, to which you referred. But let me say another word or two about it.

The acronym MAC stands for several things. *Men and Computers* working together. *Machine Aided Cognition*, facilitation by the computer of man's understanding. And *Multiple Access Computers*, computer systems used simultaneously by several or many people.

At MIT I have been connected with, but am not now directly participating in, Project INTREX on which Professor Overhage once gave testimony, I think, to your committee.

INTREX stands for Information Transfer Experiments. That is a directly pertinent project at MIT.

Also I have had an association with Project TIP which stands for Technical Information Program. That is a project of Dr. Kessler's. He is associate director of MIT libraries and is using computers in, I think, a very sophisticated and interesting way in information retrieval.

I have been participating in the informational activities of two or three technical societies. I don't know whether Dr. Riegel and Dr. Cairns have testified in relation to SATCOM, the Committee on Scientific and Technical Communications of the two national academies, but I have been associated with them, and with the Scientific Information Council of the National Science Foundation.

Perhaps what I can do is to provide to the staff a sampling of things I have written that I think are pertinent to your work. Perhaps I may contribute to your own committee's information explosion slightly in that way.

Now I think I need not waste any time by opposing the concept of the monolithic warehouse in which all the knowledge would be centralized and from which it would be dealt out.

Mr. DELLENBACK. Mr. Chairman, I am not quite sure that statement comes through without a certain amount of ambiguity. Please make clear your position.

Dr. LICKLIDER. I am opposed to the concept of the monolithic warehouse in which all of man's knowledge is brought together in one place. Perhaps I am not surely opposed to such a concept as it might be implemented in the very distant future. But I do not like it as a basis or strategy for proceeding now.

Mr. PUCINSKI. I might say I am glad you are not going to waste any time on that because I don't know of anyone on the committee that is suggesting that, so I think we will move right along.

Dr. LICKLIDER. I would like to take a position in favor of the activist spirit that I have detected in the work of Chairman Pucinski and would like to say something about the need for activism in the present situation in scientific and technical information—about the need for an appreciation and also for an implementation of the role of the new technology in the field of scientific and technical information.

Mr. BELL. May I break in, does this mean you support the Pucinski bill?

Dr. LICKLIDER. I think that I would not like to make that statement at this time. Perhaps it is just I would like to have a hand in the writing of a description of what should be done.

Mr. PUCINSKI. May I at this point, Doctor, may I make this point clear to the committee and to the witness. H.R. 8809 is before this committee as a vehicle for a dialog on this whole problem. I am not at all convinced that H.R. 8809 is the best way to deal with the problem. And I am perfectly prepared to work with the committee and with witnesses to try to restructure this bill or any other bill in a manner that meets the problem. But we had to have a vehicle in order to get this dialog going. As the testimony unfolds on this subject, new concepts will be developed.

I must say in all honesty and state publicly, 8 years ago when I first got into this thing, I thought the best way in the world to handle this was through a single warehouse of knowledge. As the testimony was given before our committee and as learned scholars came before this committee and presented their views, it very quickly became apparent that the worst thing we could do would be to build a central warehouse.

So we rewrote the bill completely. As further testimony was presented we discussed other alternatives.

Yesterday for instance, Dr. Carter quite properly pointed out that the prohibition of the present bill against duplication of existing facilities is too restrictive because an existing facility might not be a very good one and the mere fact that it is existing but is not doing a job well should not preclude a competitive system.

I am interested in the testimony dealing with concepts. Eventually the committee will collate these concepts into what I hope will be some sort of a consensus opinion of the committee in moving forward.

Mr. BELL. I assume from this though that the witness does in principle or philosophy agree with thoughts expressed in H.R. 8809?

Dr. LICKLIDER. Mr. Bell, I support the bill as a vehicle for discussion. I am pleased to have an opportunity to engage in the discussion, and I am interested in moving forward.

Mr. DELLENBACK. So there be no misunderstanding, may I also state that I think this is a healthy clearing of the air because I don't think there is anybody on this committee—if I don't speak for anyone else, let me speak only for myself—I think there is an immense amount of knowledge from which we could benefit if it could be brought in to a coherent form so that that which is known and written about in one area could somehow be made available to other people working in the same area who knew nothing about this piece of knowledge. I think the statement you just made now, Dr. Licklider, is representative of probably all of our views. There is something that we ought to be doing. We ought to be looking very hard at the problem and the question is exactly what should we be doing.

What should the Nation be doing? What should be done voluntarily? What, if anything, should be done in the way of legislation?

I commend the Chairman for introducing this vehicle for purpose of discussion. We welcome your testimony. There is no question of your advising us whether it fits 8809 or not, but as to what the Nation should be doing and what should, if anything, Congress be doing to coordinate efforts.

Mr. PUCINSKI. This country now is spending $17 billion a year on research. Some of this is Government money, some of this is private money. But in the United States today, within our country, there is $17 billion being spent annually on research.

A vast amount of research is being generated all over the country and it is good research. There are major breakthroughs being made.

Unless we find a better means of communications among the scientific community, there is going to be a continuing pressure by the public against these large Federal expenditures for research. As I have said many times, the way I got into this is when a proposal was made on the floor of the House to impose limitations on a scientist and I said at that time, I am incapable of sitting in judgment on what a scientist is to do or is not to do. I want that scientist to be his own judge of his research efforts.

The only way he can do that is if I make available to him a system of information retrieval which will provide him with the information that others have gathered so that he can be the final judge as to whether he wants to pursue his subject further or whether he is satisfied with the research to date, or whether he wants to duplicate it.

If the day ever comes when this country is going to interfere with the research efforts of its scientists, then that is the beginning of the end for this country.

If it is agreeable to the committee, we are going to go into session in just a few minutes, and I have to be on the floor at noon.

Would you like to go on, John, and continue? We are going to resume at 1.

Mr. DELLENBACK. I am going to have difficulty again in being here later this afternoon and I would like to hear what the witness says.

(At this point Mr. Pucinski withdrew from the hearing room.)

Mr. BELL (presiding). Proceed.

Dr. LICKLIDER. Thank you, Mr. New Chairman. Mr. Dellenback, I will go almost directly to a discussion of what I think we ought to do. I would like before doing that to try to give you gentlemen a picture of my sense of something approaching a malaise, a lassitude in the field of scientific and technical information. This is something that I greatly regret because I think this is an extremely important field. I agree with the comments that have been made about how important it is to make good use of the information we have won at great cost.

It is something I think we can do something about. So I am really very sad to see what I think is an insufficiently active field. Now, I think it is in part lack of a clear set of goals, lack of clear direction.

Let me say I am wholly in favor of pluralism in our Government, in our Nation, in our society. But I am afraid that in this field we have pluralism without clear goals and therefore suffer many of the disadvantages of pluralism and that we would do much better if we had more clearly defined objectives and stronger leadership and the funding to make a program go.

I sense frustration on the part of some of my colleagues, and certainly in myself. In my own case it is tempered by the fact I happen to work in a part of this field in the computer part of it, which is more active, better funded, happier than most of the other parts. So I do not really come to cry because of my own lot, but rather because I see not enough being done to solve the problem of the inundation of scientific and technical information in which we are drowning.

Because of the lack of definite goals, I think, we focus upon and deal with relatively minor local issues and do not really get going on something that will move us forward in a major way.

The whole thing is regenerative. Because we do not plan boldly, we do not get the funds. Because we do not get the funds, we see that we cannot do great things. And because we see we cannot do great things, we do not plan boldly.

I should say a few things now about organizations or classes of organizations. I really do not mean to be critical of them as organizations or even as classes, but critical of the general system within which we are operating.

My friend here, Andrew Aines, in the Office of Science and Technology, I consider to be a hero. Yet I cannot imagine that this highest scientific office in our executive branch should not have more staff. Perhaps it is not and should not be a major funding agency, but I am unhappy that it does not have more leverage to move so much that needs moving.

COSATI, the Committee on Scientific and Technical Information, is doing an excellent job for a committee of representatives of many individual departments. But it does not have that fulcrum that would let it move the world.

The National Science Foundation, including the Office of Science Information Services, seems to me to be doing a good job within the prevailing context. But it is not to be equipped with the funds or with the clear definition of goals that would let it lead us to embark upon what I want to see us embark upon.

The work in the National Library of Medicine on the Biomedical Communication Network is still in a formulative phase, and so I cannot say much about that—except that I think the field of medicine is a good field in which to conduct pilot work in information transfer.

The Committee on Scientific and Technical Communication of the two national academies, on which Dr. Cairns and Dr. Riegel will report, is not primarily focused upon how to move forward boldly to take advantage of the new technology. I think it is doing an excellent job within the conservative context, within the conservative formulation of the problem, but I am here really opposing the conservative formulation of the problem.

The professional societies and institutes, such as the American Institute of Physics, are moving. The Chemical Abstract Service, I think, is doing a wonderful job within the constraints of its funding. Considering that now is the time when we are trying to move from a Guttenberg technology, a technology of print on paper, into new technologies, partly microform but mainly digital computer and digital communication technology, however, it is not within the capacity of such an organization to make the bold steps firmly and rapidly to get over that transition. So the Chemical Abstracts Service, too, is somehow held in a period of difficult transition longer than it should be, longer than such a pioneering organization should be held.

The profitmaking corporations fall into several categories. The publishers are just now coming out of a frightful scare which held them in a defensive posture for several years, and I think they are now realizing that the new technologies are not so much a threat as a coming way of life. The publishers are adjusting, but they have not made the steps that should be made.

The computer companies have not seen in scientific and technical communication a sufficiently hot market. They have so many hot, ripe markets that they can hardly be expected to divert their attention in sufficient amount to solve the problems of this field.

In communications, in information transmission, one has, of course, primarily the telephone company. It is stuck with a tremendous investment in a system that is not technically quite right for digital communications. It is doing a great job of trying to get into the new world of digital transmission, but it has its difficulties, and so it has not taken the lead in development of a digital network for scientific and technical communication.

I have only compliments to offer my predecessors in testimony—the gentlemen from the New York Times—and I wish they were able to be doing more of what they are doing.

The library world has chronically been short of funds, has not really been able to keep up with the purchase of books and new shelves to put them on, and it is understandable that libraries have been essentially conservative to adjusting to the new technology.

Since I come from a university, I shall not refer to the universities other than to say that obviously they have not done the major job either.

I will say that one particular Government agency—one that I was once connected with, the Advanced Research Projects Agency of the Department of Defense—has pushed forward vigorously within its particular chosen area, the area of interactive computing and computer networks. Perhaps you gentlemen happen to be familiar with that agency, and what it is doing. I would love to see for this whole field the vigorous, goal directed, purposeful kind of program that ARPA has been engaged in during the period following my departure.

Now the crucial importance of this bill that you are dealing with, that we are all dealing with, H.R. 8809, seems to me to be that it just possibly could structure the whole situation in information transfer. It could be the point of discussion, the point of trying to create the concept of what ought to happen, trying to make a plan, trying to set out to implement the plan—that would revitalize this thing, that would energize it, that would get people all working together toward a goal.

When people work together toward a goal, people, organizations, groups, they do not seem to notice the frictions among them. They do not divert their attention toward the frictions, they keep working mainly toward the goal.

On the other hand, this bill could just further confuse the picture and increase the debility of it. It could do that if we all got to fighting about it. Or if it were misinterpreted as being a cast-in-concrete definition of exactly how to proceed, because one has to have a considerable amount of flexibility in his plan if his main aim is to facilitate the interactions of many elements that are already operating in the picture, to make them work together coherently with compatability and consistency, to keep each from building up his own subsystem in such a way that it will not interact properly with the others.

I think it will take forceful leadership to get this field moving. It is going to take a lot of money. But I think it has the great advantage of a technology which is in part, as was said earlier here, readier to be used than we are to use it. So I am eager to do whatever I can to help formulate a way for us to move forward.

Now, here is my thesis: That we—I shall not say the United States because I think the whole thing has an international flavor, but from a budgetary point of view, we almost necessarily mean the United States right now—should proceed now to formulate and begin to implement a plan to restructure and modernize our scientific and technical communications. I think the bill can be an important focus in doing that. I think it is very important to state some definite goals. (I shall try to do so in a minute.) And I particularly advocate making a commitment early to a method, making a commitment to the use—not just as an appurtenance but as a basic skeleton for the whole thing (in a way I shall try to describe)—of modern digital technology.

Now, I emphatically do not say that the technology is all ripe and ready to go and all we have to do is let a contract to build an information system. What I advocate is a plan that includes research and development, and pilot activities, as well as efforts to make certain things operational. What I advocate is a way of putting a modern digital information skeleton into a system or network that includes many existing operations, that involves the paper and ink technology and the microform technology as well as the digital one.

I am talking about a time scale that may displease some of you gentlemen. I am thinking that we might achieve an initial operating capability of an obviously modernized and much more efficient system in 10 years, but that it would take 20 years essentially to redo the way we handle our scientific and technical information and make it thoroughly modern and efficient.

Now, in order to proceed, I need to make some distinctions that I think are already in your mind, but these are brief.

Let me distinguish among three things:

First, the informal communications in which people—scientists and engineers as well as others—are always engaging in. This can be facilitated, I believe, by improved communications, including digital communications, and including communications with and through computers.

Second, the formal content of publications, of books and journal articles, of documents.

And third, the apparatus of finding and of access control. That includes the indexes, the abstracts, the secondary services through which we get at the basic information that we want to read and understand.

Those three things then—the informal communications, the formal content, and the apparatus for finding and gaining access to the formal content.

The next distinction is among the three technologies I mentioned. The print and paper technology, the microform—including microfilm and microfiche—technology, and the technology of digital computers and digital transmission, in which information is represented in digital codes.

Then, finally, the distinction among the components of our process of scientific and technical communications:

First, the generation of information—from experimentation, from theoretical thinking, and so forth.

Second, the storage of the information in a storage medium.

Third, the processing of it—which, of course, includes both the organizing of it, so that it can be retrieved, so that it can be disseminated, and so that it can be understood, and the actual selection of parts of it and the retrieval or dissemination of those parts.

Fourth, the transmission of the information from its store to its user.

And fifth, the interaction of the user with the information presented to him through some kind of display—here I would include print on paper as a kind of display—through some kind of control—which in the case of a book is merely thumbing the pages, but which in digital technology involves keyboards, switches, buttons, and so on.

Now, given those distinctions, what I advocate, and urge upon your consideration, and see as consistent with my understanding of H.R. 8809, viewed as a vehicle of discussion, is a plan which has many parts but is nevertheless simple and brief.

The plan deals first with the mechanism or apparatus for finding, for achieving access. Here I think there must be research and development, focusing on a pilot network for finding and achieving of access that uses the digital technology. If there is any most essential part of what I have to say, it is that we proceed strongly to insert into the existing way of working, which has a very sluggish "nervous system" if it has a nervous system at all, a new nervous system: a new digital storage, processing, and transmission of the information that is now contained in abstracts, indexes, and bibliographies—the information that lets us find what we are looking for.

That first part of the plan is something that can be done in the fairly near future through digital technology. We are used to finding fault with the methods of retrieval based on descriptors and the like. And indeed, they do not work very well if you have to lay out your full description and then see what you get back. But an essential feature of what I am talking about is interactive information processing, interaction between the user and the system, through which he can "negotiate" his description of what he wants to find and "shape it up" as the system tells him what he would get if it processed the request as he initially stated it. He sees that he would retrieve too many documents or documents in the wrong area, and he revises his request and narrows it down.

That is the first part of the plan, and if there is one major part, that is it.

The second is to incorporate the new digital "nervous system," based on research and development and experimentation with a pilot system, into the operational system that we now have for finding and for achieving access. The present operational system consists of abstracts such as *Chemical Abstracts*, indexes such as *Index Medicus*, and so on. I do not mean to displace immediately or precipitously the print and paper ways we have. Far from it. I don't mean to displace the ways we have of asking advice over the telephone, which is one of the best ways we have now. But I do think we can place this digital nervous system, this crucial digital subsystem, into the whole at a fairly early date—and then let it take over functions at a natural rate, as fast as the digital technology permits, and as fast as the economics permit, as fast as the inherent advantages of that way of doing it make themselves felt and win people over to that way.

The third part of the plan is to foster use in other kinds of work—in decisionmaking, problem solving, and so on—of the terminal equipment; for example, consoles, that are an essential part of the digital nervous system. This is important because it means we won't have to make the whole investment in digital equipment just for the retrieval function. We will be using equipment that is also used by scientists, engineers, research people, educators, and administrators in other parts of their work. For the sake of brevity, I shall say only "scientists and engineers" henceforth.

The fourth part is to engage in research and development toward a pilot digital network for informal communication among scientists and engineers. Earlier, I stressed the importance of informal communication. The reason the digital network will be important is that there will be computers in the network, and the communication among the scientists and engineers will be facilitated by direct reference to and processing of stored information, with the aid of computer programs, during the discussions. This will be very much more effective for many purposes than just talking over the telephone. I see this as making a second use of the digital "nervous system" that I am advocating.

Fifth, the digital finding and communications network now would grow in use at a natural rate without much artificial stimulation.

The sixth part of the plan calls for strong research and development on the use of computers in abstracting, indexing, summarizing, and modeling the essential information science and technology. Now, as you know, there has been some work—not really very much, but some—in using the computer to help in building up the indexes, to help in extracting the most significant sentences, the key elements, that are important bases of the apparatus for finding the content that we want. This use of the computer is very important because, if you project into the coming years the task of processing all the content of documents in order to build the indexes and the abstracts, you get into something like, perhaps not quite as overwhelming, but something like what the telephone companys got into when, back in the twenties, it projected its need for telephone operators on the basis of the expected growth of the telephone system. It is just necessary eventually to find automatic ways of indexing and abstracting, and current work is quite promising, at least for indexing. That is a good field.

The seventh step is actually to incorporate this use of computers—perhaps not wholly automatic, but interactive, with men working closely with computers—into indexing and abstracting, into that part of the system that is concerned with finding and achieving access.

The eighth part I consider to be slightly diversionary but necessary: to develop storage and dissemination in microform, and to try to bring about a situation in which many people actually have the convenience of microform readers at arm's length. Such readers are not terribly expensive, machines for converting microfiche and microfilm into readable images. They may be necessary for an intermediate operating system. They are not digital. For a long time it may be too difficult and expensive to handle all the content of science and technology in the digital form. We are being overwhelmed by our efforts to handle it in paper and pencil form. So I make this concession. Microform does not offer an elegant or even a very good solution, but it may be necessary to go through a microform period.

The ninth step is, then, to incorporate the microform techniques into the operational network and let them prosper if indeed they do so naturally.

The 10th step is research and development on storage of real content—the content of documents and of the more advanced carriers of knowledge that we hope to develop—in digital stores and the transmission of that information to the user in digital form. Why digital? Why not just pictures? The important reason is that the main bottleneck in scientific and technical communication is not in the process of getting your hands on information. I have far too much information. My colleagues have far too much of it. The real bottleneck is in assimilating information after you have it in your hands.

That is my conviction, at any rate. That bottleneck or barrier is hidden from us by now. The barrier that is more easily seen is the difficulty of obtaining precisely the information you need. But I am sure that if we really fixed it so everybody could obtain all the information that is directly pertinent to what he does, he would just have to shrug his shoulders and say, "I cannot contend with it." We need help not just in finding and acquiring but in processing, in understanding, and in interacting with information. That help will come from digital computers and will therefore require the information to be in digital form. So I think we should press hard, with research and development, to master the storing and processing of the content of science and technology in digital form.

The 11th step would be to turn the research and development just mentioned into progress toward a pilot digital information subsystem, a pilot subsystem that might serve two or three fields of science and technology, perhaps almost sufficient of itself but immersed in, fitted into, the operational system that uses the other technologies also. I would like to see the digital subsystem put on its own, as it were, to see whether it could support itself economically. It would be so attractive in many respects, I think people would be surprised how well that did, but it would for a long time require supplement from the other technologies.

The final step will be—and it won't come for many years—the move from the older technologies to the all-digital computer-based technology.

What I have been trying to describe is a way to get the digital system immersed within the present system without causing great dislocation of everything. I want a way that will offer the advantage of solving our problem of finding and our problem of access, and then do something about the problem of understanding.

Given that, I would of course like to see careful attention to all the problems that presently occupy people—to the problem, for instance, of the interaction between Government-supported information agencies and private information agencies, to the problem of compatability, to the problem of consistent format (how to set forth the authors' names and titles, and so forth). The suggested plan would provide a focus for solution of those problems. It would provide the nervous system that would link together the many agencies that are involved, and it would make it unnecessary for someone in Washington to write letters saying, "Why don't you fellows get together and try to do so and so." They would be feeling the necessity of getting together and doing it because they would be linked together and communicating.

According to the plan, we would be dealing at first only with the bibliographic control information and not with the whole content of science and technology.

I think it would develop naturally that within the suggested network—within the distributed and highly pluralistic system—there would be some centralization of leadership. If there is any place in which I disagree with the tone of the bill, it is where the bill goes, I think, too far away from centralization of leadership. Let me be clear: not centralization of information but centralization of leadership.

I think there should be one dedicated man or one small dedicated group of men who really want to see such a plan put into effect and succeed. They have to have close connections with the people who do the work—and with the Government. They have to have some control over funding, not control of all the funds but of enough to make things actually happen. They have to have the authority that goes with the responsibility.

It has been said that good things will happen eventually if we just let the situation alone because we have this God-sent new technology that is so great. I think that is true, but the time scale on which good things will happen will be much too slow, and we shall have been engulfed in this wave of information that is inundating us now, and the result will be bad. I think it is possible to make it good, but I think it will take the fairly vigorous and systematic approach that I advocate.

Will the technology really be able to support such a plan? Now some of the technology exists. We heard testimony earlier about excellent current technology. But I cannot say that I would embark upon the plan if I thought the technology would rest at its present level, if I thought we would always be using the model 2314 disk files the gentlemen mentioned. They are excellent disk files, but the cost level of a comprehensive service based on present-day technology would be high and the performance would not be great.

But let me talk a minute about what happens in the computer field, what has been happening since the early 1940's. If one measures the amount of information processing that can be done for a dollar, according to almost any reasonable engineering measure, he finds that we have been getting twice as much processing per dollar about every 2 years. The cost per unit of processing has been halving about every 2 years.

Now one does not see that if he buys a computer system and develops a software system because he gets on one step of the technology and stays there for 6 or 8 years. He certainly does not see it if he tries to compete with somebody who has bought a later model computer.

This ideed has been one of the frustrating things in the computer field. It has for a long time now been economically necessary to move on to a new generation before you have really mastered the old one.

Many of our applications have therefore been in continual chaos. To some extent we are learning to live with the problem. As one of you gentlemen mentioned, we are not really throwing away the old system. We are amortizing it over more and more years. We are thinking of its lifetime—of a "generation" as 8 years or 10 rather than 2 or 3 or 4, and we are learning to add new equipment to old systems, to supplement and modernize and improve the old rather than to replace it.

But the point is that what makes it possible to think boldly now is that we have a technology that is doubling in power every 2 years. After 10 or 20 years you really notice such an advance. The gain is a factor of 32 in 10 years, a factor of 1,024 in 20 years.

I have been in the computer field long enough to feel the advance. I remember my second computer, the one I really fell in love with. As just a basic computer it cost $150,000. By the time we had a system, the total cost was half a million. A computer of the same capability can now be bought for $15,000. The other parts of the system—the appurtenances—have not come down that fast, but the general trend is really a fact.

The other face of that coin is that the functional capabilities of computers are going up rapidly. The speed of a processor is doubling about every 2 years. The amount of memory that can be introduced into a system is doing the same. The vast stores of "secondary memory" are growing even faster than that.

The display field did not get started until a few years ago. It is really only 3 or 4 years old as a commercial field, but it is moving very rapidly. It is almost impossible to buy a display console without having the company say, "We are sorry, you delayed your order, and the price is now down 20 percent." The time it takes to place orders is long compared with the time between price cuts.

Will there be people capable of implementing such a plan as I describe? Here I do speak from the privileged position of a university professor. At last the universities are starting to graduate a new generation of professionals in the computer and information sciences. The new generation has great new capabilities. All of us old fellows are practically obsolete. The young ones do it naturally and fast. We have to sit around and ponder and think and hesitate, but to them it comes quickly, and they are starting to flow. Many of the major universities now have important programs in just the area we are talking about: interactive computing, computer science and engineering, information science and engineering.

Perhaps I might mention a few of the universities, other than my own: University of California at Berkeley, Stanford University, University of California at Los Angeles, University of California at Santa Barbara, University of California at Irvine, University of Utah, University of Illinois, Washington University in St. Louis, Carnegie Mellon University. There are more, but that is enough to indicate that something is happening. Four or 5 years ago there was no such thing. There were no "native" professionals in this field. They are all from somewhere else. I, for example, am from psychology. My predecessor as director of Project MAC is from the field of communication.

Is there any precedent on the basis of which one can suppose that, if we do the work to implement such a plan as I propose, something would really happen—or is it just a hope? In the field of multiple-access interactive computing—often called "time sharing"—it was just a few short years between when there was none at all and when there were more than 200 commercial concerns in the United States providing on-line multi-access computer service. Thousands of people now sit at typewriters and type to computers, and the computers solve problems and print out answers.

I was overwhelmed by the rate at which multiple-access computing developed. I did not suppose anything in our country could move that rapidly. But I was not fully appreciating what a combination of Government supported research and development, education, and the profit motive can do.

What became commercially prevalent and very successful was only the first step. It provides only a very primitive kind of problem solving at the computer console, but more is coming.

Incidentally, it is clear that such things can be done without the expenditure of billions of dollars. I am talking about millions, not billions.

Earlier, I said something about the trends of the economics of digital information processing. What I said referred mainly to hardware. Let me say something about software, that is computer programs and data.

Our worst problems now are software problems, problems of programing very complex systems. The network of which I spoke will be complex, but not horrendous. One can see what has happened in the software field by looking at the development of programs called "compilers."

The first compiler took 300 man-years to produce, ran miserably slow, was very long and involved. Now two or three young fellows in a software house, working for 3 months, can make a better one. In just a few years, what was an ad hoc empirical art turned into something approaching a science.

Other parts of the software field are advancing in the same general way. Although I am not sanguine at all about developing complex software systems that have to work the first time—for example, software for a missile-guidance system that had to work the first time it was fielded—in this case I am sanguine. I think the software for information systems can be mastered.

Now to a few other topics that I consider pertinent:

I hear discouraging statements from my colleagues in the book-publishing business about how much it would cost to store the contents of a library on magnetic tape. Such statements drive me up the wall because nobody in his right mind would store the contents of a library on magnetic tape. What he might store them in is a digital storage system of the kind IBM delivered in 1967 to the Lawrence Radiation Laboratory. Actually IBM delivered two of them, one to Livermore and one to Berkeley. The system—which represents just the first stage of development of this technology—is based in part on writing with an electron beam on a small chip of film in a vacuum and in part on handling the little chips of film pneumatically, putting them in little celluloid or plastic containers and blowing the containers from place to place. The system is fast and reliable, and it gets the storage costs down to something like this:

Let us think of a book as consisting of say 250 pages of 4,000 characters per page, just to have a simple visual image in mind. Such a book contains about 1 million characters. The contents of 100,000 such books could be stored in one of the IBM systems. In 1967 such a system cost about $1 million. That figures out to about $10 to store the contents of a book. Well, if you go to a bookstore, you see it costs about $10 to store the contents of a book in a book. So there is one part of the digital technology that is here now.

Not many of the film-clip systems were made, but more could be made. The technology will be easy to improve it. Another step will make it much better. At the end of another step, it will be less expensive to store information in such a system than it will be to build the building in which to put an equivalent collection of books.

I must mention the problem of "critical mass." Many things in the computer and communication fields are expensive to do in small quantity but inexpensive to do in the mass. If we could ever get to running a nationwide information system that was mainly electronic, mainly digital, so that we could fill up the channels with information, then we could speak as though we were one of the broadcasting systems.

We could talk with the telephone company about channels, and the telephone company would say, "We will give you 4.5 megahertz bandwidth (through which a good engineer could transmit about 1 million characters a second) for a dollar per mile per hour." That is the rule of thumb in the broadcasting industry. At that rate, to transmit a book from New York to Chicago costs about 30 cents. That is very, very much less than the cost of transmitting a book over a voice grade line.

Where we are headed, costs are not great. The problem is to get there. The difficult thing is the period of transition and growth.

I mentioned the way the price of displays is going down. My predecessors mentioned "line printers" that turn out printed copy. Now you can actually get a little line printer for $5,000 or $6,000. It prints at a pretty good clip. It has only capital letters, but it could have lower case letters and all the punctuation marks for another thousand dollars. Taking $7,000 price as the cost of a printer, and figuring on the basis of its present printing speed, one concludes that he can duplicate books of 1 million characters for 50 cents apiece—if not in the reader's office, in the building where the reader has his office. It is something you can look forward to without straining the technology.

That is probably enough examples. What I am saying is that I almost agree with the gentleman who said the technology is here. I agreed when he said that it is readier than we are, and that the problem is to master it and put it to use.

In all the foregoing, I have spoken as though the document, the formal content of the document, is really the thing in which we are fundamentally interested. But all you can do with that is read it, and human reading is very slow and unsatisfactory. If you watch a computer take in information, you get a terrible inferiority complex about human reading rates. You are driven to think, and you realize that, if you had a friend who knew what is in a given book, and you went to your friend and talked about your problem with him, he could tell you what you need to know in a much shorter time than you could get it by scanning and reading the book.

So I want to mention some of the things that are now under research and that are moving along fast enough that they will come into the national information network within a decade or so.

Let me mention "Hypertext." Hypertext is a concept developed by a young information scientist named Ted Nelson and also by a young computer scientist named Van Dam. Van Dam is at Brown University, and Hypertext is demonstrated on a computer there. If you get a chance to drop by and see it, do so. A related approach is being developed by Doug Engelberg at Standford Research Institute.

The idea here is that you really do not want to work with just linear strings of words or characters as they are printed in a book. You might like, for example, to point to a word in the text and immediately be shown more about the idea it suggests or conveys. As implemented with the aid of a computer and a display, Hypertext lets you do that. It lets you interact with the information. It suggests new approaches, and it makes it easy to realize that you do not want to move into the future with the limited concept of document that you were brought up with. It is not going to be necessary to accept such limitations.

The other concept I want to mention is the concept of computer-program model. What is written in a document is static, and the only way to see what it means in terms of behavior or action or process is to read it, and think about it, and to understand it, and then imagine it to happen. But when you store information in terms of models in computer programs, then there are two forms. First, there is a static form. You can read the program, and if you are a computer buff and know the language you can tell what it is about. Second, there is a dynamic form. If you put the programed model into a computer and push the start button, the model comes to life, as it were; it behaves, and you can interact with it.

If the model is a model of the special theory of relativity, and if you are trying to understand it in the ordinary way, you have to read it, look at formulas and graphs, and try to imagine what it would be like to go near the speed of light, to see every thing contract, to expend more and more energy in an effort to accelerate yet to accelerate less and less.

On the other hand, if the model is programed, if the theory is modeled in a computer, you can sit before a display and watch yourself drive a simulated vehicle swiftly through space. You watch the mileage markers go by, see everything you pass get smaller as you speed up, ever look at the speedometer and odometer of a friend's vehicle going in a different direction at a different speed, chase him if you like, get a feel of how it is to operate under the Fitzgerald-Lorenz transformations.

The two concepts suggest that, when we get into this domain I am talking about, information will not be stored in the way it is stored now in documents. The whole process is going to change.

I have a friend at MIT, Joel Moses, who works in mathematics in the field of integration. His computer programs carry out symbolic integration about as well as a good mathematician does. The knowledge of integration is built into the programs. It is not written in a document. It is incorporated into the programs. That is the way it will be, to an every increasing extent, in the future.

A reason for wanting to move scientific and technical communication into this new world, and a reason for thinking it will be possible to do so, is that there is a strong trend toward use of computer-program methods in research, in problem solving, in thinking about data. Computer-program modeling does not have to depend upon its applications in scientific and technical communication for its support because modeling is used throughout science and engineering in developing theory and testing theory against data. We shall be having these computer-based facilities built up in universities and other research organizations, and they will be there to support the library and the document room as well as the laboratory and the office.

About standards and coherence in scientific and technical communication, the two things that are most important to say are: First, they do not develop by themselves, of their own accord. Second, they tend not to develop if the situation is allowed to grow piecemeal. Piecemeal growth produces the Tower of Babel phenomenon, chaos. On the other hand, defines and adopts goals for overall systems, then the people who make subsystems think of themselves in the subsystem role. They do not always bow to the higher-level leadership and try to meet its requirements, but they know about the overall system, and they interact with their peers, with people at the same level, in such a way as to minimize the friction among the subsystems, to avoid incompatibility.

Standards tend to come more or less automatically if you have goals for the overall system or network.

At present, we do not have clear system goals, and our subsystems lack compatibility. We are in poor condition vis-a-vis standards.

Finally, about the relation of all this to young people: I work with young people at MIT. My son is a senior at Harvard, so I know some Harvard students. Most of those young people are superb when judged in terms of what they accomplish, what they are capable of doing, how they are getting along with their work. But they are, as you well know, in a state of unrest and dissatisfaction. I think a lot of it comes from the feeling that, throughout the adult world, and certainly in the world of scientific and technical communication, things are slipshod and disorganized, and nobody is really doing much about it. They see the fabulous facilities with which their professors do their research, and they have a notion of what could be done with such facilities. Indeed, they have ideas about how to accomplish great things, but they see few great things being accomplished. That may be just a part of the cause of the unrest, but it is a real part.

In my own son's case, it is a big part. I think we are at a crux: whether to let the generation that is now coming up build such a network as we have been talking about, or whether to pass the opportunity by and let the new generation of information and computer scientists wait until it occupies the key decisionmaking positions.

I mentioned the regenerative character of the information system. It is the system that ought to help us think and solve problems, including problems concerning the information system. The better it is, the faster we can make it better still.

I think the information system is the nervous system of society. I think that in the long term, it is the most important single subsystem, though there may be more crucial things this year or next. For the long pull, over the next 20 years, it is the most important single thing.

To develop a national information network would be a wonderful national project. It would provide a goal worthy of the energies of the new generation of information and computer scientists. Some of the older people have to contribute to the creation of the plan, of course—the younger people are not used to making national plans yet. That will come.

I know there are pitfalls. I cannot give you any guarantee. But I close by saying that my humble, earnest advice is to put a major effort into scientific and technical communication. Make it a national effort with a carefully phased plan and a sufficient long-term commitment. Take advantage of digital technology. And take advantage of the enthusiasm and capability of the younger generation.

Mr. BELL. Thank you very much, Dr. Licklider. This is one of the best testimonies I have seen come before this committee. The thoroughness with which you described the problems at hand and the language which you used made it understandable, at least partially.

I have a couple of questions, Doctor: Would it be correct to describe our present situation as a kind of giant octopus with an excised nervous system, aimlessly flapping its tentacles, exhausting its energies without making any headway at the present time?

Dr. LICKLIDER. Not quite; though nearly. I want to revise that a little bit. It is not as bad as a system would be if it once had a nervous system and that nervous system were removed. That would leave no local control.

It is more like a multicellular organism that never had much of a nervous system and depends mainly on local interactions, that does not have a well-developed forebrain, or any brain at all. It is not making much progress.

Mr. BELL. You are saying we are making some progress, but not enough progress and that part of the problem, as I get from what you mentioned, is the need for a little greater leadership.

As you mentioned in your testimony there is going to have to be some force or some group of men or group of people or one person that is going to have to take the lead.

Dr. LICKLIDER. I did not mean a czar, of course. I meant a dedicated leader. Goals, funds, organization—tempered with respect for pluralism.

Mr. BELL. Is it needing a great deal of pliability and operational divergence to make it possible for it to work and I assume this leadership must come from the Federal Government. Is this what your thought is?

Dr. LICKLIDER. I would suppose that it must. I think it would come into the Federal Government, in large part, from the private sector. If the leadership is in the Federal Government now, it probably came initially from the private sector. I think the situation requires a small group of people dedicated to the concept of an advanced information network, people who behave neither like career civil servants nor like private entrepreneurs. They would have to give a good part of their lives to definition and achievement of a national goal.

Mr. BELL. Could you give in a kind of brief capsule form a kind of visual picture of just practically how this kind of program ideally should be set up. Physically, are we talking about? Obviously we are not talking about a central storage area for retrievable information. We are talking about the various areas of it. Can you describe in general how you get all of these segments into it and just generally how, what one picture might be in this?

Dr. LICKLIDER. There are two kinds of organizations in such a system. First, there is the organization of the people who bring it about. That is complex because the people are already in organizations, and what is required is an organization of the organizations. And that is difficult to effect. It is probably unwise to point to some particular Government agency and say the leadership should come from it. These things depend a lot upon immediate circumstances, upon who has or can get money, upon who has the allegiance of many of the people who are already working.

The second organization is that of the system or network itself. It is complex because, as I described it, it involved research and development and pilot networks as well as—at all times—the currently operating system. There must be a continual movement from research to development to pilot operation and into the operating system, or back through further research and development.

I think one good rule to keep in mind is that information ought to reside near the people who generate and use it. Information is a living thing. If it is just left idle, it dies. Even the meanings of words change. If an index, for example, is not updated from time to time, it loses its value.

One uses the phrase, "a network of networks," to describe the kind of system I have in mind. It would not be a monolithic or tightly integrated system, designed by a single firm, laid down with the help of "Mother Bell," and forced upon everybody. It would be a loose—but planned and synergic—confederation of subsystems and subnetworks, some operated by business and industry, some by universities, some by the Government. They would be linked together. Most people think immediately in terms of common-carrier linkage, but also in the picture are satellite interconnections and even privately owned coaxial cable and microwave facilities.

The configuration of the "network of network" changes from moment to moment. Switching reconfigures the system. Computers are extremely good at bookkeeping. They can remember who used what and how much he owes. They can handle the billing, even though the network be complex.

Mr. BELL. Mr. Dellenback?

Mr. DELLENBACK. I think there is a lot that is most provocative in what you said. I wonder when you set up goals, and set up objectives that you feel we ought to be reaching for with anything we do, have you ever sought to reduce this to legislative language or have you ever faced this type of problem, because, while 8809 is admittedly by all concerned a springboard and while you at several points in your testimony set up a series of goals that you feel we ought to move in the direction of, we still have the translation problem of taking that and reducing it, if we are to do anything legislatively to the bill.

Now, I don't mean this should be your task; this is essentially our task after we sort out objectives, but I wonder if you have done anything like that in facing this problem so that you will not only be able to talk specifically as Mr. Bell just asked you to talk, but talk in the field of concepts as you did with your testimony. Have you faced this last transitional step?

Dr. LICKLIDER. No, sir; I have not. It sounds fascinating, but I have not tried to reduce any such thing to legislative language.

Mr. BELL. We appreciate very much the testimony. I am sure Mr. Pucinski will review it as soon as it is available to him. I intend to go back over it myself and read the translation step and see where we should go next.

I thank you very much for your testimony again. It is an excellent job you did.

(Dr. Licklider submitted the following material for the record:)

[An article from Science and Technology, a Conover-Mast publication, 205 East 42d St., New York 17, N.Y.]

(When computers are coupled to communication lines it changes the meaning of communciation. This occurs in two ways. The first is that the communication line is used to carry data instead of voices, and thus the power of computing machinery can be brought to anyone who needs it, wherever he may be. The second is only just coming into sight, and is far more important. It is the use of the computer as a communication device in itself—as an intermediary between people. Surprisingly, this promises to bring a new depth of intellectual interchange to the fine old art of face-to-face communication. Indeed, although authors J. C. R. Licklider and Robert W. Taylor worked face-to-face with senior editor Evan Herbert to prepare the section that follows, they foresee a day when people of similar interests will work with each other through a network of computers—even when they are in the same room.)

In a few years, men will be able to communicate more effectively through a machine than face to face.

That is a rather startling thing to say, but it is our conclusion. As if in confirmation of it, we participated a few weeks ago in a technical meeting held through a computer. In two days, the group accomplished with the aid of a computer what normally might have taken a week.

As you can see from the photo on the next page (and we shall talk more about the mechanics of the meeting later), we were all in the same room. But for all the communicating we did directly across that room, we could have been thousands of miles apart and communicated just as effectively—as people—over the distance.

Our emphasis on people is deliberate. A communications engineer thinks of communicating as transferring information from one point to another in codes and signals.

But to communicate is more than to send and to receive. Do two tape recorders communicate when they play to each other and record from each other? Not really—not in our sense. We believe that communicators have to do something nontrivial with the information they send and receive. And we believe that we are entering a technological age in which we will be able to interact with the richness of living information—not merely in the passive way that we have become accustomed to using books and libraries, but as active participants in an ongoing process, bringing something to it through our interaction with it, and not simply receiving something from it by our connection to it.

To the people who telephone an airline flight operations information service, the tape recorder that answers seems more than a passive depository. It is an often-updated model of a changing situation—a synthesis of information collected, analyzed, evaluated, and assembled to represent a situation or process in an organized way.

Still there is not much direct interaction with the airline information service; the tape recording is not changed by the customer's call. We want to emphasize something beyond its one-way transfer: the increasing significance of the jointly constructive, the mutually reinforcing aspect of communication—the part that transcends "now we both know a fact that only one of us knew before." When minds interact, new ideas emerge. We want to talk about the creative aspect of communication.

Creative, interactive communication requires a plastic or moldable medium that can be modeled, a dynamic medium in which premises will flow into consequences, and above all a common medium that can be contributed to and experimented with by all.

Such a medium is at hand—the programmed digital computer. Its presence can change the nature and value of communication even more profoundly than did the printing press and the picture tube, for, as we shall show, a well-programed computer can provide direct access both to informational resources and to the *processes* for making us of the resources.

COMMUNICATION: A COMPARISON OF MODELS

To understand how and why the computer can have such an effect on communication, we must examine the idea of modeling—in a computer and with the aid of a computer. For modeling, we believe, is basic and central to communication. Any communication between people about the same thing is a common revelatory experience about the informational models of that thing. Each model is a conceptual structure of abstractions formulated initially in the mind of one of the persons who would communicate, and if the concepts in the mind another, there is no common model and no communication.

By far the most numerous, most sophisticated, and most important models are those that reside in men's minds. In richness, plasticity, facility, and economy, the mental model has no peer, but, in other respects, it has shortcomings. It will not stand still for careful study. It cannot be made to repeat a run. No one knows just how it works. It serves its owner's hopes more faithfully than it serves reason. It has access only to the information stored in one man's head. It can be observed and manipulated only by one person.

Society rightly distrusts the modeling done by a single mind. Society demands concensus, agreement, at least majority. Fundamentally, this amounts to the requirement that individual models be compared and brought into some degree of accord. The requirement is for communication, which we now define concisely as "cooperative modeling"—cooperation in the construction, maintenance, and use of a model.

How can we be sure that we *are* modeling cooperatively, that we are communicating, unless we can compare models?

When people communicate face to face, they externalize their models so they can be sure they are talking about the same thing. Even such a simple externalized model as a flow diagram or an outline—because it can be seen by all the communicators—serves as a focus for discussion. It changes the nature of communication: When communicators have no such common framework, they merely make speeches *at* each other; but when they have a manipulable model before them, they utter a few words, point, sketch, nod, or object.

The dynamics of such communication are so model-centered as to suggest an important conclusion: Perhaps the reason present-day two-way *tele*communication falls so far short of face-to-face commnication is simply that it fails to provide facilities for externalizing models. Is it really seeing the expression in the other's eye that make the face-to-face conference so much more productive than the telephone conference call, or is it being able to create and modify external models?

THE PROJECT MEETING AS A MODEL

In a technical project meeting, one can see going on, in fairly clear relief, the modeling process that we contend constitutes communication. Nearly every reader can recall a meeting held during the formulative phase of a project. Each member of the project brings to such a meeting a somewhat different mental model of the common undertaking—its purposes, its goals, its plans, its progress, and its status. Each of these models interrelates the past, present, and future states of affairs of: (1) himself; (2) the group he represents; (3) his boss; (4) the project.

Many of the primary data the participants bring to the meeting are in undigested and uncorrelated form. To each participant, his own collections of data are interesting and important in and of themselves. And they are more than files of facts and recurring reports. They are strongly influenced by insight, subjective feelings, and educated guesses. Thus, each individual's data are reflected in his mental model. Getting his colleagues to incorporate his data into their models is the essence of the communications task.

Suppose you could see the models in the minds of two would-be communicators at this meeting. You could tell, by observing their models, whether or not communication was taking place. If, at the outset, their two models were similar in structure but different simply in the values of certain parameters, then communication would cause convergence toward a common pattern. That is the easiest and most frequent kind of communication.

If the two mental models were structurally dissimilar, then the achievement of communication would be signaled by structural changes in one of the models or in both of them. We might conclude that one of the communicating parties was having insights or trying out new hypotheses in order to begin to understand the other—or that both were restructuring their mental models to achieve commonality.

The meeting of many interacting minds is a more complicated process. Suggestions and recommendations may be elicited from all sides. The interplay may produce, not just a solution to a problem, but a new set of rules for solving problems. That, of course, is the essence of creative interaction. The process of maintaining a current model has within it a set of changing or changeable rules for the processing and disposition of information.

The project meeting we have just described is representative of a broad class of human endeavor which may be described as creative informational activity. Let us differentiate this from another class which we will call informational housekeeping. The latter is what computers today are used for in the main; they process payroll checks, keep track of bank balances, calculate orbits of space vehicles, control repetitive machine processes, and maintain varieties of debit and credit lists. Mostly they have *not* been used to make coherent pictures of not well understood situations.

We mentioned earlier that the photo of the meeting at the beginning of this article showed us interacting with each other through a computer. This meeting was organized by Doug Engelbart of Stanford Research Institute and was actually a progress-review conference for a specific project. The subject under discussion was rich in detail and broad enough in scope that no one of the attendees, not even the host, could know all the information pertaining to this particular project.

FACE TO FACE THROUGH A COMPUTER

Tables were arranged to form a square work area with five on a side. The center of the area contained six television monitors which displayed the alphanumeric output of a computer located elsewhere in the building but remotely controlled from a keyboard and a set of electronic pointer controllers called "mice." Any participant in the meeting could move a nearby mouse, and thus control the movements of a tracking pointer on the TV screen for all other participants to see.

Each person working on the project had prepared a topical outline of his particular presentation for the meeting, and his outline appeared on the screens as he talked—providing a broad view of his own model. Many of the outline statements contained the names of particular reference files which the speaker could recall from the computer to appear in detail on the screens, for, from the beginning of the project, its participants had put their work into the computer system's files.

So the meeting began much like any other meeting in the sense that there was an overall list of agenda and that each speaker had brought with him (figuratively in his briefcase but really within the computer) the material he would be talking about.

The computer system was a significant aid in exploring the depth and breadth of the material. More detailed information could be displayed when facts had to be pinpointed; more global information could be displayed to answer questions of relevance and interrelationship. A further version of this system will make it possible for each participant, on his own TV screen, to thumb through the speaker's files as the speaker talks—and thus check out incidental questions without interrupting the presentation for substantiation.

Obviously, collections of primary data can get too large to digest. There comes a time when the complexity of a communications process exceeds the available resources and the capability to cope with it; and at that point one has to simplify and draw conclusions.

It is frightening to realize how early and drastically one does simplify, how prematurely one does conclude, even when the stakes are high and when the transmission facilities and information resources are extraordinary. Deep modeling to communicate—to understand—requires a huge investment. Perhaps even governments cannot afford it yet.

But someday governments may not be able *not* to afford it. For, while we have been talking about the communication process as a cooperative modeling effort in a mutual environment, there is also an aspect of communication with or about an uncooperative opponent. As nearly as we can judge from reports of recent international crises, out of the hundreds of alternatives that confronted the decision makers at each decision point or ply in the "game," on the average only a few, and never more than a few dozen could be considered, and only a few branches of the game could be explored deeper than two or three such plies before action had to be taken. Each side was busy trying to model what the other side might be up to—but modeling takes time, and the pressure of events forces simplification even when it is dangerous.

Whether we attempt to communicate across a division of interests, or whether we engage in a cooperative effort, it is clear that we need to be able to model faster and to greater depth. The importance of improving decision-making processes—not only in government, but throughout business and the professions—is so great as to warrant every effort.

THE COMPUTER—SWITCH OR INTERACTOR?

As we see it, group decision-making is simply the active, executive, effect-producing aspect of the kind of communication we are discussing. We have commented that one must oversimplify. We have tried to say why one must oversimplify. But we should not oversimplify the main point of this article. We can say with genuine and strong conviction that a particular form of digital computer organization, with its programs and its data, constitutes the dynamic, moldable medium that can revolutionize the art of modeling and that in so doing can improve the effectiveness of communication among people so much as perhaps to revolutionize that also.

But we must associate with that statement at once the qualification that the computer alone can make no contribution that will help us, and that the computer with the programs and the data that it has today can do little more than suggest a direction and provide a few germinal examples. Emphatically we do *not* say: "Buy a computer and your communication problems will be solved."

What we do say is that we, together with many colleagues who have had the experience of working on-line and interactively with computers, have already sensed more responsiveness and facilitation and "power" than we had hoped for, considering the inappropriateness of present machines and the primitiveness of their software. Many of us are therefore confident (some of us to the point of religious zeal) that truly significant achievements, which will markedly improve our effectiveness in communication, now are on the horizon.

Many communications engineers, too, are presently excited about the application of digital computers to communication. However, the function they want computers to implement is the switching function. Computers will either switch the communication lines, connecting them together in required configurations, or switch (the technical term is "store and forward") messages.

The switching function is important but it is not the one we have in mind when we say that the computer can revolutionize communication. We are stressing the modeling function, not the switching function. Until now, the communications engineer has not felt it within his province to facilitate the modeling function, to make an interactive, cooperative modeling facility. Information transmission and information processing have always been carried out separately and have become separately institutionalized. There are strong intellectual and social benefits to be realized by the melding of these two technologies. There are also, however, as will appear later in this issue, powerful legal and administrative obstacles in the way of any such melding.

DISTRIBUTED INTELLECTUAL RESOURCES

We have seen the beginnings of communication through a computer—communication among people at consoles located in the same room or on the same university campus or even at distantly separated laboratories of the same research and development organization. This kind of communication—through a single multiaccess computer with the aid of telephone lines—is beginning to foster cooperation and promote coherence more effectively than do present arrangements for sharing computer programs by exchanging magnetic tapes by messenger or mail. Computer programs are very important because they transcend mere "data"—they include procedures and processes for structuring and manipulating data. These are the main resources we can now concentrate and share with the aid of the tools and techniques of computers and communication, but they are only a part of the whole that we can learn to concentrate and share. The whole includes raw data, digested data, data about the location of data—and documents—and most especially models.

To appreciate the importance the new computer-aided communication can have, one must consider the dynamics of "critical mass," as it applies to cooperation in creative endeavor. Take any problem worthy of the name, and you find only a few people who can contribute effectively to its solution. Those people must be brought into close intellectual partnership so that their ideas can come into contact with one another. But bring these people together physically in one place to form a team, and you have trouble, for the most creative people are often not the best team players, and there are not enough top positions in a single organization to keep them all happy. Let them go their separate ways, and each creates his own empire, large or small, and devotes more time to the role of emperor than to the role of problem solver. The principals still get together at meetings. They still visit one another. But the time scale of their communications stretches out, and the correlations among mental models degenerate between meetings so that it may take a year to do a week's communicating. There has to be some way of facilitating communication among people without bringing them together in one place.

A single multiaccess computer would fill the bill if expense were no object, but there is no way, with a single computer and individual communication lines to several geographically separated consoles, to avoid paying an unwarrantedly large bill for transmission. Part of the economic difficulty lies in our present communications system. When a computer is used interactively from a typewriter console, the signals transmitted between the console and the computer are intermittent and not very frequent. They do not require continuous access to a telephone channel; a good part of the time they do not even require the full information rate of such a channel. The difficulty is that the common carriers do not provide the kind of service one would like to have—a service that would let one have ad lib access to a channel for short intervals and not be charged when one is not using the channel.

It seems likely that a store-and-forward (i.e., store-for-just-a-moment-and-forward-right-away) message service would be best for this purpose, whereas the common carriers offer, instead, service that sets up a channel for one's individual use for a period not shorter than one minute.

The problem is further complicated because interaction with a computer via a fast and flexible graphic display, which is for most purposes far superior to interaction through a slow-printing typewriter, requires markedly higher information rates. Not necessarily more information, but the same amount in faster bursts—more difficult to handle efficiently with the conventional common-carrier facilities.

It is perhaps not surprising that these are incompatibilities between the requirements of computer systems and the services supplied by the common carriers, for most of the common-carrier services were developed in support of voice rather than digital communication. Nevertheless, the incompatibilities are frustrating. It appears that the best and quickest way to overcome them—and to move forward the development of interactive communities of geographically separated people—is to set up an experimental network of multiaccess computers.

Computers would concentrate and interleave the concurrent, intermittent messages of many users and their programs so as to utilize wide-band transmission channels continuously and efficiently, with marked reduction in overall cost.

COMPUTER AND INFORMATION NETWORKS

The concept of computers connected to computers is not new. Computer manufacturers have successfully installed and maintained interconnected computers for some years now. But the computers in most instances are from families of machines compatible in both software and hardware, and they are in the same location. More important, the interconnected computers are not interactive, general-purpose, multiaccess machines of the type described by David (see SHARING A COMPUTER, June 1966) and Licklider (see MAN-COMPUTER PARTNERSHIP, May 1965). Although more interactive multiaccess computer systems are being delivered now, and although more groups plan to be using these systems within the next year, there are at present perhaps only as few as half a dozen interactive multiaccess computer *communities*.

These communities are socio-technical pioneers, in several ways out ahead of the rest of the computer world: What makes them so? First, some of their members are computer scientists and engineers who understand the concept of man-computer interaction and the technology of interactive multiaccess systems. Second, others of their members are creative people in other fields and disciplines who recognize the usefulness and who sense the impact of interactive multiaccess computing upon their work. Third, the communities have large multiaccess computers and have learned to use them. And, fourth, their efforts are regenerative.

In the half-dozen communities, the computer systems research and development and the development of substantive applications mutually support each other. They are producing large and growing resources of programs, data, and know-how. But we have seen only the beginning. There is much more programming and data collection—and much more learning how to cooperate—to be done before the full potential of the concept can be realized.

Obviously, multiaccess systems must be developed interactively. The systems being built must remain flexible and open-ended throughout the process of development, which is evolutionary.

Such systems cannot be developed in small ways on small machines. They require large, multiaccess computers, which are necessarily complex. Indeed, the sonic barrier in the development of such systems is complexity.

These new computer systems we are describing differ from other computer systems advertised with the same labels: interactive, time-sharing, multiaccess. They differ by having a greater degree of open-endedness, by rendering more services, and above all by providing facilities that foster a working sense of community among their users. The commercially available time-sharing services do not yet offer the power and flexibility of software resources—the "general purposeness"—of the interactive multiaccess systems of the System Development Corporation in Santa Monica, the University of California at Berkeley, Massachusetts Institute of Technology in Cambridge and Lexington, Mass.—which have been collectively serving about a thousand people for several years.

The thousand people include many of the leaders of the ongoing revolution in the computer world. For over a year they have been preparing for the transition to a radically new organization of hardware and software, designed to support many more simultaneous users than the current systems, and to offer them—through new languages, new file-handling systems, and new graphic displays—the fast, smooth interaction required for truly effective man-computer partnership.

Experience has shown the importance of making the response time short and the conversation free and easy. We think those attributes will be almost as important for a network of computers as for a single computer.

Today the on-line communities are separated from one another functionally as well as geographically. Each member can look only to the processing, storage and software capability of the facility upon which his community is centered. But now the move is on to interconnect the separate communities and thereby transform them into, let us call it, a supercommunity. The hope is that interconnection will make available to all the members of all the communities the programs and data resources of the entire supercommunity. First, let us indicate how these communities can be interconnected; then we shall describe one hypothetical person's interaction with this network, of interconnected computers.

MESSAGE PROCESSING

The hardware of a multiaccess computer system includes one or more central processors, several kinds of memory—core, disks, drums, and tapes—and many consoles for the simultaneous on-line users. Different users can work simultaneously on diverse tasks. The software of such a system includes supervisory programs (which control the whole operation), system programs for interpretation of the user's commands, the handling of his files, and graphical or alphanumeric display of information to him (which permit people not skilled in the machine's language to use the system effectively), and programs and data created by the users themselves. The collection of people, hardware, and software—the multiaccess computer together with its local community of users—will become a node in a geographically distributed computer network. Let us assume for a moment that such a network has been formed.

For each node there is a small, general-purpose computer which we shall call a "message processor." The message processors of all the nodes are interconnected to form a fast store-and-forward network. The large multiaccess computer at each node is connected directly to the message processor there. Through the network of message processors, therefore, all the large computers can communicate with one another. And through them, all the members of the supercommunity can communicate—with other people, with programs, with data, or with selected combinations of those resources. The message processors, being all alike, introduce an element of uniformity into an otherwise grossly nonuniform situation, for they facilitate both hardware and software compatibility among diverse and poorly compatible computers. The links among the message processors are transmission and high-speed *digital* switching facilities provided by common carrier. This allows the linking of the message processors to be reconfigured in response to demand.

A message can be thought of as a short sequence of "bits" flowing through the network from one multiaccess computer to another. It consists of two types of information: control and data. Control information guides the transmission of data from source to destination. In present transmission systems, errors are too frequent for many computer applications. However, through the use of error detection and correction or retransmission procedures in the message processors, messages can be delivered to their destinations intact even though many of their "bits" were mutilated at one point or another along the way. In short, the message processors function in the system as traffic directors, controllers, and correctors.

Today, programs created at one installation on a given manufacturer's computer are generally not of much value to users of a different manufacturer's computer at another installation. After learning (with difficulty) of a distant program's existence, one has to get it, understand it, and recode it for his own computer. The cost is comparable to the cost of preparing a new program from scratch, which is, in fact, what most programmers usually do. On a national scale, the annual cost is enormous. Within a network of interactive, multiaccess computer systems, on the other hand, a person at one node will have access to programs running at other nodes, even though those programs were written in different languages for different computers.

The feasibility of using programs at remote locations has been shown by the successful linking of the AN/FSQ-32 computer at Systems Development Corporation in Santa Monica, Calif., with the TX-2 computer across the continent at the Lincoln Laboratory in Lexington, Mass. A person at a TX-2 graphic console can make use of a unique list-processing program at SDC, which would be prohibitively expensive to translate for use on the TX-2. A network of 14 such diverse computers, all of which will be capable of sharing one another's resources, is now being planned by the Defense Department's Advanced Research Projects Agency, and its contractors.

The system's way of managing data is crucial to the user who works in interaction with many other people. It should put generally useful data, if not subject to control of access, into public files. Each user, however, should have complete control over his personal files. He should define and distribute the "keys" to each such file, exercising his option to exclude all others from any kind of access to it; or to permit anyone to "read" but not modify or execute it; or to permit selected individuals or groups to execute but not read it; and so on—with as much detailed specification or as much aggregation as he likes. The system should provide for group and organizational files within its overall information base.

At least one of the new multiaccess systems will exhibit such features. In several of the research centers we have mentioned, security and privacy of information are subjects of active concern; they are beginning to get the attention they deserve.

In a multiaccess system, the number of consoles permitted to use the computer simultaneously depends upon the load placed on the computer by the users' jobs, and may be varied automatically as the load changes. Large general-purpose multiaccess systems operating today can typically support 20 to 30 simultaneous users. Some of these users may work with low-level "assembly" languages while others use higher-level "compiler" or "interpreter" languages. Concurrently, others may use data management and graphical systems. And so on.

But back to our hypothetical user. He seats himself at his console, which may be a terminal keyboard plus a relatively slow printer, a sophisticated graphical console, or any one of several intermediate devices. He dials his local computer and "logs in" by presenting his name, problem number, and password to the monitor program. He calls for either a public program, one of his own programs, or a colleague's program that he has permission to use. The monitor links him to it, and he then communicates with that program.

When the user (or the program) needs service from a program at another node in the network, he (or it) requests the service by specifying the location of the appropriate computer and the identity of the program required. If necessary, he uses computerized directories to determine those data. The request is translated by one or more of the message processors into the precise language required by the remote computer's monitor. Now the user (or his local program) and the remote program can interchange information. When the information transfer is complete, the user (or his local program) dismisses the remote computer, again with the aid of the message processors. In a commercial system, the remote processor would at this point record cost information for use in billing.

WHO CAN AFFORD IT?

The mention of billing brings up an important matter. Computers and long-distance calls have "expensive" images. One of the standard reactions to the idea of "on-line communities" is: "It sounds great, but who can afford it?"

In considering that question, let us do a little arithmetic. The main elements of the cost of computer-facilitated communication, over and above the salaries of the communicators, are the costs of the consoles, processing, storage, transmission, and supporting software. In each category, there is a wide range of possible costs, depending in part upon the sophistication of the equipment, programs, or services employed and in part upon whether they are custom-made or mass-produced.

Making rough estimates of the hourly component costs per user, we arrived at the following: $1 for a console, $5 for one man's share of the services of a processor, 70¢ for storage, $3 for transmission via line leased from a common carrier, and $1 for software support—a total cost of just less than $11 per communicator hour.

The only obviously untenable assumption underlying that result, we believe, is the assumption that one's console and the personal files would be used 160 hours per month. All the other items are assumed to be shared with others, and experience indicates that time-sharing leads on the average to somewhat greater utilization than the 160 hours per month that we assumed. Note, however, that the console and the personal files are items used also in individual problem solving and decision making. Surely those activities, taken together with communication, would occupy at least 25% of the working hours of the online executive, scientist or engineer. If we cut the duty factor of the console and files to one quarter of 160 hours per month, the estimated total cost comes to $16 per hour.

Let us assume that our $16/hr interactive computer link is set up between Boston, Mass., and Washington, D.C. Is $16/hr affordable? Compare it first with the cost of ordinary telephone communication: Even if you take advantage of the lower charge per minute for long calls, it is less than the daytime, direct-dial station-to-station toll. Compare it with the cost of travel: If one flies from Boston to Washington in the morning and back in the evening, he can have eight working hours in the capital city in return for about $64 in air and taxi fares plus the spending of four of his early morning and evening hours en route. If those four hours are worth $16 each, then the bill for the eight hours in Washington is $128—again $16 per hour. Or look at it still another way: If computer-aided communication doubled the effectiveness of a man paid $16 per hour then, according to our estimate, it would be worth what it cost if it could be bought right now. Thus we have some basis for arguing that computer-aided communication is economically feasible. But we must admit that the figure of $16 per hour sounds high, and we do not want to let our discussion depend upon it.

Fortunately, we do not have to, for the system we envision cannot be bought at this moment. The time scale provides a basis for genuine optimism about the cost picture. It will take two years, at least, to bring the first interactive computer networks up to a significant level of experimental activity. Operational systems might reach critical size in as little as six years if everyone got onto the bandwagon, but there is little point in making cost estimates for a nearer date. So let us take six years as the target.

In the computer field, the cost of a unit of processing and the cost of a unit of storage have been dropping for two decades at the rate of 50% or more every two years. In six years, there is time for at least three such drops, which cut a dollar down to 12½ cents. Three halvings would take the cost of processing, now $5 per hour on our assumptions, down to less than 65¢ per hour.

Such advance in capability, accompanied by reduction in cost, lead us to expect that computer facilitation will be affordable before many people are ready to take advantage of it. The only areas that cause us concern are consoles and transmission.

In the console field, there is plenty of competition; many firms have entered the console sweepstakes, and more are entering every month. Lack of competition is not the problem. The problem is the problem of the chicken and the egg—in the factory and in the market. If a few companies would take the plunge into mass manufacture, then the cost of a satisfactory console would drop enough to open up a mass market. If large on-line communities were already in being, their mass market would attract mass manufacture. But at present there is neither mass manufacture nor a mass market, and consequently there is no low-cost console suitable for interactive on-line communication.

In the field of transmission, the difficulty may be lack of competition. At any rate, the cost of transmission is not falling nearly as fast as the cost of processing and storage. Nor is it falling nearly as fast as we think it should fall. Even the advent of satellites has affected the cost picture by less than a factor of two. That fact does not cause immediate distress because (unless the distance is very great) transmission cost is not now the dominant cost. But, at the rate things are going, in six years it will be the dominant cost. That prospect concerns us greatly and is the strongest damper to our hopes for near-term realization of operationally significant interactive networks and significant on-line communities.

ON-LINE INTERACTIVE COMMUNITIES

But let us be optimistic. What will on-line interactive communities be like? In most fields they will consist of geographically separated members, sometimes grouped in small clusters and sometimes working individually. They will be communities not of common location, but of *common interest*. In each field, the overall community of interest will be large enough to support a comprehensive system of field-oriented programs and data.

In each geographical sector, the total number of users—summed over all the fields of interest—will be large enough to support extensive general-purpose information processing and storage facilities. All of these will be interconnected by telecommunications channels. The whole will constitute a labile network of networks—ever-changing in both content and configuration.

What will go on inside? Eventually, every informational transaction of sufficient consequence to warrant the cost. Each secretary's typewriter, each data-gathering instrument, conceivably each dictation microphone, will feed into the network.

You will not send a letter or a telegram; you will simply identify the people whose files should be linked to yours and the parts to which they should be linked—and perhaps specify a coefficient of urgency. You will seldom makes a telephone call; you will ask the network to link your consoles together.

You will seldom make a purely business trip, because linking consoles will be so much more efficient. When you *do* visit another person with the object of intellectual communication, you and he will sit at a two-place console and interact as much through it as face to face. If our extrapolation from Doug Engelbart's meeting proves correct, you will spend much more time in computer-facilitated teleconferences and much less en route to meetings.

A very important part of each man's interaction with his on-line community will be mediated by his OLIVER. The acronym OLIVER honors Oliver Selfridge, originator of the concept. An OLIVER is, or will be when there is one, an "on-line interactive vicarious expediter and responder," a complex of computer programs and data that resides within the network and acts on behalf of its principal, taking care of many minor matters that do not require his personal attention and buffering him from the demanding world. "You are describing a secretary," you will say. But no! Secretaries will have OLIVERS.

At your command, your OLIVER will take notes (or refrain from taking notes) on what you do, what you read, what you buy and where you buy it. It will know who your friends are, your mere acquaintances. It will know your value structure, who is prestigious in your eyes, for whom you will do what with what priority, and who can have access to which of your personal files. It will know your organization's rules pertaining to proprietary information and the government's rules relating to security classification.

Some parts of your OLIVER program will be common with parts of other people's OLIVERS; other parts will be custom-made for you, or by you, or will have developed idiosyncracies through "learning" based on its experience in your service.

Available within the network will be functions and services to which you subscribe on a regular basis and others that you call for when you need them. In the former group will be investment guidance, tax counseling, selective dissemination of information in your field of specialization, announcement of cultural, sport, and entertainment events that fit your interests, etc. In the latter group will be dictionaries, encyclopedias, indexes, catalogues, editing programs, teaching programs, testing programs, programming systems, data bases, and—most important—communication, display, and modeling programs.

All these will be—at some late date in the history of networking—systematized and coherent, you will be able to get along in one basic language up to the point at which you choose a specialized language for its power or terseness.

When people do their informational work "at the console" and "through the network," telecommunication will be as natural an extension of individual work as face-to-face communication is now. The impact of that fact, and of the marked facilitation of the communicative process will be very great—both on the individual and on society.

First, life will be happier for the on-line individual because the people with whom one interacts most strongly will be selected more by commonality of interests and goals than by accidents of proximity. Second, communication will be more effective and productive, and therefore more enjoyable. Third, much communication and interaction will be with programs and programmed models, which will be (a) highly responsive, (b) supplementary to one's own capabilities, rather than competitive, and (c) capable of representing progressively more complex ideas without necessarily displaying all the levels of their structure at the same time—and which will therefore be both challenging and rewarding. And, fourth, there will be plenty of opportunity for everyone (who can afford a console) to find his calling, for the whole world of information, with all its fields and disciplines, will be open to him—with programs ready to guide him or to help him explore.

For the society, the impact will be good or bad, depending mainly on the question: Will "to be on line" be a privilege or a right? If only a favored segment of the population gets a chance to enjoy the advantage of "intelligence amplification," the network may exaggerate the discontinuity in the spectrum of intellectual opportunity.

On the other hand, if the network idea should prove to do for education what a few have envisioned in hope, if not in concrete detailed plan, and if all minds should prove to be responsive, surely the boon to humankind would be beyond measure.

Unemployment would disappear from the face of the earth forever, for consider the magnitude of the task of adopting the network's software to all the new generations of computers, coming closer and closer upon the heels of their predecessors until the entire population of the world is caught up in an infinite crescendo of on-line interactive debugging.

Man-Machine Information Systems

(By J. C. R. Licklider, Advanced Research Projects Agency, Office of the Secretary of Defense)

TWO KINDS OF INFORMATION-PROCESSING POWER

The "information explosion" poses the general problem. The modern digital computer and the rapidly developing technology of information processing offer powerful tools for solving the problem. However, the tools have only one kind of "power" in marked degree, and a blend of two kinds is required.

The two kinds of information-processing are *algorithmic power*, which is the capability of folowing rules, executing pre-programmed procedures, and performing routine, clerical operations, and *heuristic power*, which is the capability of charting courses toward the solution of problems, formulating useful rules, setting the guidelines and arranging the procedures for algorithmic power to follows.* Present day information-processing machines have great algorithmic power, but only the heuristic power built into their programs by human programmers. Present day machines have almost no capability of devising new heuristics. Life is as yet the only significant repository of heuristic power, and men—who are, in comparison with computers, miserably slow and fallible at algorithmic operations—constitute at present the only significant source of heuristics in information-processing systems. Now, therefore, and probably throughout this decade, any mechanized information system that is truly a system and not just a component must of necessity be a man-machine system.

SEPARATION OF HEURISTIC AND ALGORITHMIC FUNCTIONS

In designing and programming the several large-scale semi-automatic systems that are in operation today or that are nearing completion—the SAGE system for air defense, the SACCS for control of strategic aircraft, the SABRE system for airline reservations, the Defense Documentation Center, and the MEDLARS (Medical Literature Analysis & Retrieval System) systems for defense and medical information storage and retrieval, etc.—a tremendous amount of heuristic power was expended. The types of problems to be solved and the types of questions to be answered by the systems were carefully analyzed, effective procedures were invented or discovered, and efficient arrangements were made for executing the procedures during the operation of the systems. In the procedures, there are many choice points, and many of the decisions are made by men during the time the procedures are being executed on the basis of current information. A considerable amount of flexibility is gained by leaving decisions to human operators, and it is noteworthy that the newer systems achieve more flexibility in that way, by and large, than do the old ones. An outstanding fact about these systems, nevertheless, is that most of the heuristic power was expended in design and programming, whereas most of the algorithmic power is expended (or will be expended) in operation.

Separation of the heuristic from the algorithmic parts has been, in fact, a striking characteristic of almost all the large information-processing systems developed since the advent of the digital computer. The separation has not been complete, as just acknowledged, but it has been dominant. Stemming from the separation, I believe, is the fact that preparation of the programs for the large computer-based systems proved to be extremely expensive and time-consuming. In some instances, the software cost more and took longer to develop than the hardware. That is understandable if one acknowledges that the heuristic part of the programming task is large and difficult and if he notes that the algorithmic part—also large and difficult—was left to the programmers, themselves, who had to work without close or constant machine support. As mentioned earlier, the algorithmic power of men is low and the efficiency of a group of programmers in handling the voluminous, complex clerical work involved in development of a large computer program is very low indeed.

*This use of the terms *algorithmic* and *heuristic* is itself heuristic: the terms are associated with separate concepts that need to be contrasted and are employed to give force to the distinction. So, to oppose the terms runs counter to a current trend toward the use of *heuristic* to embrace all methods, including the employment of appropriate algorithms, that facilitate discovery or solution.

Putting so much of the heuristic work into the pre-operational software programming phase not only increased cost and development time, but—much worse—made some of the large computer-based systems alarmingly unresponsive to changes in purposes and needs, to variations in the environments within which they operate, and even to the wills of their managers and commanders. Disenchantment with large, monolithic computer-based systems has, in fact, been widespread and vociferous. Often the disenchantment has expressed itself as disappointment in the digital computer. The cause, however, was certainly not the computer *per se*, but the unnatural separation of the heuristic from the algorithmic parts that characterized the dominant style of system design during the 1950's the style that has been called "man-machine dissociation."

MAN-COMPUTER SYMBIOSIS

Flexibility, adaptability and responsiveness to change are now high on most lists of information-system requirements. In the field of command and control, the watchword for two or three years has been "evolutionary development," and now one can begin to make out what it is that is evolving. It is tight interweaving of heuristic and algorithmic threads, close coupling of men and computers, intimate man-machine interaction.

The main steps toward "man-computer symbiosis" (as the desired partnership may be termed in analogy with the intimate, cooperative association that exists in nature between such dissimilar species as the fungas and the alga of lichens) are:

1. To overcome the economic obstacle that arises from the fact that a digital computer is fast and expensive; whereas, in information processing, a man is slow and (relatively) inexpensive. The currently most promising approach is to share the processing time and memory space of the computer among several or many men, working at typewriters or consoles that may be remote from the computer.
2. To improve the man-computer interface by devising better input-output arrangements—better displays from computer to man and better controls from man to computer.
3. To develop more powerful languages for programming and controlling computers and computer-based information systems. Under this heading fall (a) problem-oriented languages embodying the main concepts and operations of a substantive field or problem area, (b) procedure-oriented languages, more abstract or general languages designed to facilitate development of widely useful procedures or to handle diverse problems, and (c) system-oriented languages, to be used in requesting services of the computer, controlling its modes, and establishing communication through the computer with other people in the system.
4. To improve the organization and to increase the size and availability of computer memory. The requirements of highly interactive multiman-computer systems for information storage and access will be tremendous. It will not be tolerable to let n-1 registers of an n-register memory stand idle while one register is being used. Nor will it be tolerable to make m-1 users wait 10^5 memory cycles (say, 0.1 second) for 10^5 words to be transferred from secondary to primary memory so that one user can work with them for a few milliseconds. And so on: there is much to be done in the memory field.
5. To explore and solve the problems, some of which are not yet clearly foreseen or formulated, that will arise when several or many man-computer systems are linked together into a network. Computer-based systems will be linked into networks in military command and control, not only because military operations must be both distributed and interrelated, because properly designed (redundant) networks promise a degree of "system survival" despite the loss of modes or branches. Networks can be expected to arise, also, in connection with the storage, organization, retrieval and use of technical information, for the corpus of such information is much too great to be handled by any one computer that may be built in the next 20 years. As an example of computer network problems that may arise, consider how to connect three multi-user systems (A, B and C) together in such a way that, simultaneously, user A_1 can ask a question of user B_2, computer B (nearly overloaded) can request computer A to process B_3's data with programs stored in C's disk file, and C_4 can search those files of A and B for which he has owner's permission, security clearance, and "need to know."

TIME AND SPACE SHARING

Interest in moment-by-moment sharing among several users of computer time and memory space began to develop in 1959 and 1960 in connection with the speed-cost mismatch between men and computers. More recently, the interest has grown, and much of it has focused upon what may be termed "community use" of computers. Since there is not time or space, now, to go deeply into either aspect, it will have to suffice to express the general aim and to describe some of the functions that it is hoped to implement.

The general aim or aspiration is to bring great algorithmic information-processing power into the office and onto the desk (or into the laboratory, library, classroom, or post) of every creative person in the upper echelons of science, technology, education, administration, management, and command—to put enough purely clerical capacity at his constant disposal to eliminate the obstacles and delays now associated with the accomplishment of routine, specifiable tasks. At least 85 per cent of the allegedly productive time of a researcher goes into purely routine manipulation of information necessary to provide the basis for decisions and insights, but not itself involving them, according to one estimate. The aim, in terms of that estimate, is to let the creative intellect be creative about 85 percent of the time instead of 15 percent of the time.

MAN-COMPUTER INTERACTION FUNCTIONS

Among the mechanizable functions and operations to be put under human control are:

1. Information storage, organization, and retrieval. An approach to implementation of these functions will be described.

2. Dynamic modeling and simulation. Suppose, for example, that you are designing an electronic circuit, that you have a configuration in mind and want to see what the response will be to a complicated but specifiable input. Don't construct an actual circuit in "breadboard" form. Sketch the configuration with a "light pen" on the cathode-ray screen of your console, specify the circuit constraints in clear handprinted letters or, by via your console typewriter, sketch the input wave or specify it symbolically, and have the computer display the output. (This kind of modeling is being developed by the Computer-aided Design Group at M.I.T.)

3. Mathematical calculations and logical deduction. Suppose that you want to integrate $3y^2$ (t) exp y(t) with respect to t. Just call *Dr. James Sagle's program named "Saint," type the expression, and look at what the computer types back to you. Then, if you want a definite integral, specify the limits and request a numerical answer.

4. Drafting assistance. Suppose that you are a civil engineer and want a line-drawing lantern slide of a bridge girder in a hurry to illustrate a talk. Call Sutherland's "Sketchpad" program, sketch the girder, tell the program the lines should be straight, indicate which lines are supposed to be vertical and which horizontal, point to the riveted intersections, watch the computer straighten up the drawing, and then pull down the camera boom, snap the picture, wait 10 seconds, etc. If you want to stress the girder, sketch the supports and a load, specify the weight of the load, and ask the program to display the tensions and compressions. They will appear in numerical form, superposed upon the sketch.

5. Teaching-Learning. Suppose that you want to learn some Spanish in preparation for a trip. Call the vocabulary teaching program, specify Spanish-to-English, and settle down to a drill session on your typewriter. The computer will select material appropriate to your level of mastery, concentrate on words that cause you trouble, and tell you (immediately after each response) whether you were right or wrong.

6. Communication with colleagues. Telephone Bill Jones through the computer system. If he is available, have the system display on both your screens the diagram about which you need advice. Point with your light pen to the part on which your interest is focused; it will be pointed to by an arrow on his screen. And so on, coordinating visual with auditory communication and making use of other functions, such as those described, as you need them.

*Presently at Lawrence Radiation Laboratory.

7. Computer Programming. Suppose you are a programmer working on a large program system with several colleagues. Prepare your part of the program "at the console." Use, of course, a powerful programming language. When you have written some statements, compile and execute them, applying them to test data you have previously supplied or retrieved.

Examine the output on the console screen, from files. If the statements "run" successfully, continue. If not, go into "debugging mode," watch the content of specified lists or tables change as the program is re-run slowly, step-by-step. See where the trouble is. Change the incorrect part. Recompile and retest. The compiler will redo only that part of the program affected by your emendation (Perlis). If you violate a system convention or fail to supply explanatory comments, the programming system will tell you so and refuse to cooperate until you mend your ways. If you use a symbol a colleague has already used, it will warn you or attach a suffix. If you wonder whether there is not already a sub-routine that fulfills a function you need fulfilled, you may search for it with the aid of the retrieval sub-system. And, if you do not know how the retrieval system works, call the teaching-machine program and it will give you a lesson on the retrieval sub-system. (If you do not know how to use the teaching-machine program, telephone the System Advisory Service.)

Some of the foregoing examples refer to programs already prepared and running on one computer or another. Others refer to programs that are within the state of the art but not yet written. The aspiration is to collect and/or prepare the many programs required to implement the functions described (and others not mentioned here) and to integrate them into a coherent system. That is a very large undertaking. It will take several years to accomplish. The resulting system will not be economic for many operational applications until certain advances have been made in computer design and organization, but it seems likely that they can be achieved in about the same time as the software.

LANGUAGE

Some of the needs for an advanced system-oriented language are evident from consideration of the examples in the foregoing section. It is evident that the language must have terse and fully explicit modes, or controllable degrees of terseness, to meet the needs of users with diverse amounts of experience. No operator-to-computer messages should ordinarily be more highly abbreviated than computer-to-operator messages. But this is just the beginning of the man-computer language problem.

Interactive Information Processing

(By J. C. R. Licklider)

INTRODUCTION

At a conference of this kind, the keynote speech usually focuses upon the principal topics to be discussed in the conference. This keynote speech is unusual because it does not do so—or at least does not do so directly. Most of the papers in the conference deal with adaptive or self-organizing or learning information sytems. This keynote talk, however, is about "Interactive Information Processing." My first obligation, therefore, is to explain why I think it is appropriate to discuss interactive information processing as a leading into, or as a keynote of, this conference. To put it into a nutshell: I think that interactive information processing is the key to the understanding and synthesis of systems that adapt, organize themselves, learn, and do the other sophisticated things that we shall be discussing in this conference.

Our field—the field of computer and information sciences and technology—is an extremely reflexive, regenerative field. It is concerned in large part with development and understanding of tools and techniques for dealing with information. Thus it is in a sense the science and technology of processes fundamentally involved in the advancement of science and technology. Every accomplishment makes it easier to make further accomplishments—in other branches of science and technology as well, but particularly in the science and technology of computers and information.

Now, the problems with which this conference will be directly concerned are, in the main, extremely difficult problems. We have been attacking them mainly with conventional methods, tools, and techniques. Indeed, until very recently, we have been attacking them exclusively in conventional ways. We have made progress, as the papers of this conference will attest. However, the progress has been, by and large, the slow and hard-won progress that one is happy enough to make when he is working on a difficult problem.

In the process, we have found out something about what it is that makes certain problems difficult and we have formulated ideas about the nature of problem-solving techniques and facilities that would make them less difficult. One of the things that makes a problem difficult, of course, is to have a large space of possible solutions. Another thing that makes a problem difficult is not to have a structure, known *a priori*, that relates partial solutions to complete solutions, that organizes hypotheses, or that suggests or limits or constrains approaches. Some problems that have the two properties just mentioned have also a third property that makes them extremely difficult. They are penetrated only a little way by any hypothesis, and—to make matters worse—a great deal of detailed and necessarily precise information processing is involved in testing any hypothesis. Such a problem one cannot "think his way through," because he cannot in a reasonable time, without the aid of a computer, carry out the precise, detailed calculations. Nor can one, working on such a problem, simply prepare a massive program and turn it over to a computer, because the result of the testing and information processing is usually only to indicate that the hypothesis has to be revised, and at best it is to produce a small increment in understanding and set the stage for a new formulation which will lead to further testing and further processing of information.

In what I referred to as the "conventional approach" to solving problems—the approach based on conventional methods, tools, and techniques—the formulation of hypotheses and the having of hunches, together with the evaluation of the results found by testing and calculating, have been almost pure brainwork, aided little if at all by computers, and the execution of the algorithms involved in the precise, detailed information processing to which I referred has been assigned largely either to clerks or to computers. It has been in large part the slowness and inefficiency of the shifting from one kind of informational activity to the other that has held progress in the solution of problems in this class to its relatively slow pace.

During the last few years, there has been, as you know, a growing sense of excitement in several quarters of our field, an excitement kindled by the prospect of a significant advance in our way of dealing with such recalcitrant problems. It is exciting to "sense" the promise of a new approach and even more exciting to become convinced that one is participating in an intellectual revolution. I have a feeling that the excitement dulls the critical faculty, and that is quite dangerous to "recognize" great advances while they are in incipient stages. I am aware that some such "great advances" turn out only to be fads. Nevertheless, I am willing to be honest and to admit that I believe that we are indeed participating in an intellectual revolution, that the approach to the solution of difficult, complex, recalcitrant/ problems offered by on-line man-computer-interactive information processing will during the next decade or so revolutionize an important part of our collective intellectual process. At any rate, that is what I want to talk about, and I think that it is clear enough that, if is promise is borne out, interactive information processing is appropriate as a keynote to this conference.

THREE STAGES IN THE DEVELOPMENT OF INTERACTIVE INFORMATION PROCESSING

The first stage in the development of interactive information processing is the achievement of effective man-computer interaction. In that statement, both the "man" and the "computer" are singular. The purpose of the interaction is to couple closely together—to interleave or to blend or to meld—the man's heuristic capabilities and the computer's algorithmic capabilities. When those capabilities are brought into close interaction, the difficulty associated with the shifting back and forth between the two aspects of the intellectual process discussed earlier is in large part overcome. I shall not say that highly effective man-computer interaction has yet been achieved, but I think there have been instances in which the interaction has been sufficiently effective to prove itself—at least to those who have had the experience—and I shall mention some of those instances later. It is evident, however, that to provide facilities for effective man-computer interaction over a wide range of problems and decisions will require significant advances in hardware (e.g., displays and controls) and a very large and coherent effort in software (e.g., problem-oriented languages and libraries of generalized subprograms).

The second stage in the development of interactive information processing might be termed the achievement of "men-computer interaction." By that, I mean to imply more than multiple access to a computer, more than quaisi-simultaneous interaction between a number of individual men and a large-scale time-sharing computer. As I see it, the value that emerged from the pioneering experiments with time-sharing computers—that emerged, for example, at the Massachusetts Institute of Technology and the Systems Development Corporation, without being fully expected—was the value of community cooperation in developing a sufficiently large and comprehensive software base to support man-computer interaction in a variety of fields. It appears that that value will emerge of its own accord when multiple-access interactive computing is introduced into a creative intellectual community. It is evident, however, that the techniques for facilitating cooperation and fostering a coherent community software effort have to be experimented with and deliberately developed if the evident potential value is to be realized in full in a fairly short time.

In the third stage of the development of interactive information processing, "computers" appears in the plural as well as "men." This is the stage of networks of geographically distributed computers, the stage of what are coming to be called "information networks." Although there are no general-purpose networks of geographically distributed computers to point to as examples, there is already a considerable amount of enthusiasm for information networks. I shall mention the EDUCOM Summer Study on information networks here and say a few sentences about it later. The main points I want to introduce now are (1) that the technologies of computation and communication seem ripe for the kind of fusion that would make it possible for geographically separated computers to "talk" with one another and thereby permit geographically separated users to communicate and cooperate with one another in interaction with both stores of information and proecssors of information and (2) that the effect of bringing geographically distributed users into network-mediated interaction seems likely to be greater than the effect that can be achieved through multiple-access interaction in any local community. The reasoning underlying the latter part of that statement is that it is difficult to achieve a "critical mass" of intellect in a single organization or even in a single city. It is practicable to develop excellent facilities for fifty or a hundred of the best men working in a particular problem area, but not for five or ten. It is practicable to get five or ten of the best men to come together in a given geographical area, but not fifty or a hundred. A promising aspect of the information-network idea is that, through information networks, intellectual community may be achieved despite geographical distribution.

The key note that I want to sound is that achievement of effective interactive information processing at the most advanced of the three stages just described will markedly improve our effectiveness in working on the difficult problems with which this conference is concerned, and that advances toward the solution of those problems will augment the effectiveness of the interactive information processing. Eventually, if we are successful in actually solving the problems, it may be that the amount of interaction required in problem solving and decision making will decrease, but I am not very sanguine about seeing that conclusion proved at any early date. I think that, for a long time, advances in adaptive, self-organizing, and learning systems will have mainly the effect of making computers better partners for men—and, of particular significance to this conference, better partners for men engaged in research in the computer and information sciences.

FACILITIES FOR INTERACTIVE INFORMATION PROCESSING

The facilities required for the first and second stages of man-computer interaction are widely known through the experiences in on-line interactvie computing at Bolt Beranek and Newman, the Carnegie Institute of Technology (Carnegie University), Dartmouth College, General Electric Company, IBM Corporation (Mohansic Laboratory and Thomas J. Watson Research Center), the Lincoln Laboratory, Computation Center, Research Laboratory of Electronics, and Project MAC of Massachusetts Institute of Technology, the Systems Development

Corporation, Stanford Research Institute, Stanford University, the University of California (Berkeley, Los Angeles, and Santa Barbara), and several other places. The storage requirements for interactive processing are not greatly different from the storage requirements for batch processing, the main difference being the relatively greater emphasis upon rapid, quasi-random access and on-line storage of large libraries of public programs and data. The processing requirements evidence a somewhat greater departure: memory protection and control of access to memory are absolutely essential, as are arrangements for switching from one user to another (interrupting, time slicing, poling, etc.), and arrangements for segmenting, paging, and dynamic relocation of programs and data are highly desirable if not absolutely essential. The console area—the area of display and control—is the one in which interactive computing poses new and difficult requirements. Large character sets, choice of hard and soft copy; graphical display, pointing, sketching, and writing with a light pen or stylus, and speech input and output are all judged highly desirable by most of those who have developed sophistication in interactive information processing, and all but speech input are commercially available. The main difficulties stem from the fact that the area of displays and controls has received only for a short time the devoted attention and intense effort that most other areas of computer hardware have been given for 15 years or more. In setting up a system with several hundred consoles, which is n–1 or n–2 more consoles than comparable systems had only two or three years ago, one can expect to face painful compromises between capability and cost, and some interactive users may detect room for improvement in the domain of human engineering. Despite these limitations, it can be said that the facilities now exist for fairly sophisticated man-computer interaction in stages one and two.

As we turn toward stage three, the stage characterized by the netting of geographically distributed computers, we find ourselves with a significant base of experience with special-purpose computer networks, but with essentially no experience with general-purpose computer networks of the kind that will come into being when multiple-access systems such as those at M.I.T. and the Systems Development Corporation are linked by digital transmission channels. The difficulties involved in establishing computer networks appear not to be difficulties of hardware design or even of hardware availability. Rather, they appear to be difficulties of social and software organization, of conventions, formats, and standards, of programming, interaction, and communication languages. It is a situation in which there now exist all the hardware facilities that can be said to be required, yet in which there do not now exist any general-purpose networks capable of supporting stage-three interaction.

There is a serious question in my mind, whether the potential of interactive information processing can be sufficiently realized on a wide scale without the development of information networks. Looking backward in time, one can see that a significant level of man-computer interaction was achieved in stage one—with dedicated computers and without multiple access. One can also see, however, that that achievement was not made on a wide scale. It was the movement to stage two, through the development of multiple access (via time sharing) that—if I may again use the analog of critical mass—let the interaction go critical. However, it has gone critical only in a few places, and in those places at the expense of prodigious effort in software development.

If the next step is to be, as it is in the expectation of many, to broaden greatly the availability of on-line information and on-line information processing, then it has to be faced that the potential users are geographically distributed, that the potential sources of information are geographically distributed, and that the talent is geographically distributed too—the talent required to convert the vision into reality. Thus, in my assessment of the situation, it seems likely that achievement of stage three is a necessary condition for widespread exploitation of stage-two (multiple-access) man-computer interaction.

SOFTWARE FOR INTERACTIVE INFORMATION PROCESSING

In the foregoing, although my remarks about facilities dealt mainly with hardware, I meant to emphasize that the preparation of the software and the preparation of the people for interactive information processing are the major tasks, and that they are large tasks indeed. The general nature of the software requirements is fairly clear from experience with multiple-access systems. The plan of the software organization will be complicated somewhat by the addition of computer-to-computer and user-to-user communication to the list of functions that have to be served, but that comes under the heading of "systems programming," which need not involve a very large number of people and can therefore be (relatively) tightly and efficiently organized. At the opposite pole from systems programs, of course, are "problem programs" prepared by individual users to meet their own individual needs. In the past, those two classes have constituted a dichotomy, a two-category model that has fit reality fairly well. With the advent of on-line interactive communities, however, a third class of program has appeared. In this class are programs prepared by sophisticated users—not members of the systems programming group of the computer center; but on a par with members of that group in programming competence—who are concerned not with individual problems but with problem areas or with programming techniques applicable over a fairly wide problem area or even across several disciplinary fields. When such programs prove to be useful to several users, they tend to move from the files of individual users to a public file or program library. They may be taken into the set of programs—the set of superprograms, programs, and subprograms—imbedded within the "system," or they may remain separate from the system programs yet be publicly available and callable through the system. Indeed, in some systems the distinction between system program and non-system public program effectively disappears, and in effect, the system itself is augmented through use. It is this augmentation that is the focus of the following remarks on software for interactive information processing.

The key to achievement of a dynamic, self-augmenting system for interactive information processing is of course to design the initial system to foster creative use and to facilitate self-augmentation. Thus the initial system should provide a proper framework, one that will discourage piecemeal proliferation yet be flexible and open-ended enough to invite creative augmentation. That is a difficult compromise. Surely the initial system should provide basic file-handling services and should define basic formats, structures, and conventions. At the same time, it should be capable of accepting new or alternative list, ring, plex, and tree structures and new or alternative coding, packing, and "hashing" techniques. That is to say, the initial system must dominate the functions of storage and retrieval strongly enough to inhibit individual users from incorporating idiosyncratic file-handling subprograms within their own programs and to attract their creative efforts to augmentation of the general-purpose file-handling system. That is important because, for example, in a network of N computers with, on the average K users each, it will be difficult enough to arrange for communication among N different filing systems and quite prohibitively difficult to arrange for communication among N times K different filing systems.

This line of thought should be extended into the areas of display and control and interaction language, computer-programmed instruction in the use of the system, editing, and perhaps other areas also. It is problematical, however, whether or not the initial system should be designed in such a way as to dominate the pattern of use of programming languages. In the interest of simplicity, one basic procedural language should perhaps be given a preferred position within the system. On the other hand, giving one language a preferred position would tend to inhibit competition among languages and such competition appears as desirable from some points of view as it appears undesirable from others.

The basic software functions within the area under discussion may be placed under three headings: language-processing programs, logistic programs, and substantive programs. Within the class of language-processing programs the initial system should handle one or two procedure-oriented languages and several problems-oriented languages—enough of the latter to illustrate what can be done in representative problem and disciplinary areas. Augmentation by users should greatly increase the number of problem-oriented languages. I am not sure how many problem-oriented languages would be too many, but evidently there is a danger of a Tower of Babel effect. I like the idea of having only a few language respect or language families, homogeneous in respect of syntax but adjusted in respect of vocabulary to the diverse substantive fields in which they are used. I like, also, the idea of a general-purpose language, in some ways approximating English, within which the various special-purpose, problem-oriented languages are imbedded—but the feasibility of such a thing is doubtful and, in any event, it would be very difficult to implement.

Within the class of logistic programs, the main functions are file handling (storage, organization, retrieval, updating, etc.), display, control, communication, editing, dissemination, accounting, and what Oliver Selfridge has described as "the *alter ego* in the machine." All but the last are probably sufficiently self-explanatory for present purposes. Selfridge's concept, which appeals to me greatly, is that each user will have a program that buffers him from the outside world and that represents him, insofar as a program can within the current state of the art, in his absence. I am not sure that it is correct to classify that program as logistic, but it is certainly not a system program and it seems more logistic than substantive.

To the list of useful and desirable substantive programs, I can see no end. I think that augmentation through use will lead to a continually increasing number of publicly accessible and widely useful functions. I am convinced that a very large number of such functions can be realized with a controllably small number of basic building blocks, and I think a large part of the software problem lies in the organization of the programs in such a way as to provide broad and diverse capabilities with not too large a set of subprograms. Among the fields in which especially interesting substantive programs can be expected to be introduced through the augmentation process are computer-assisted instruction, natural language processing, mathematics and logic, and the modal field of this conference—adaptive, self-organizing, and learning systems. Extremely interesting programs can be expected, also, in the field of libraries and in the field of dynamic modeling. Those programs will have a partly logistic and partly substantive character.

ILLUSTRATIVE EXAMPLES OF INTERACTIVE INFORMATION PROCESSING

As I have admitted, the vision I have been describing is complex, and a great effort will be required to turn it into reality. I am convinced, however, by the fact that so many parts of it already exist and operate, that it is a realizable vision and not merely a dream. The fact is, much significant, substantive work is being done in the interactive mode at the present time. One does not have to deal only with unsubstantial hopes or unguaranteed promises. There is not time to describe any large number of illustrative examples in detail.

A COMPUTER-PROGRAM SYSTEM TO FACILITATE THE STUDY OF TECHNICAL DOCUMENTS

(By Daniel G. Bobrow, R. Y. Kain, Betram Raphael, and J. C. R. Licklider)

ABSTRACT

Symbiont is a computer-and-program system for use in research on computer-aided study. It stores, retrieves, and displays documents and parts of documents. It "semi-automates" the taking of verbatim notes. It facilitates the manipulation and intercomparison of graphs. And it conducts searches for passages of text that contain specified words or phrases. Experience with Symbiont and plans for its improvement are described.

INTRODUCTION

The purpose of this paper is to describe a system, consisting of a digital computer [1] and a computer program, intended for exploration of man-machine interaction and computer assistance to man in the study of technical documents.

The system provides a physical study situation that includes a desk, an electric typewriter,[2] a display screen, and a light-sensitive pointer or stylus ("light pen").[3] The user of the system, whom we shall call "the student," requests services and controls operations by typing command characters or symbols on the typewriter or by touching illuminated areas of the display screen with the light pen. The computer and program system, which we call "Symbiont" because we hope to develop it into a truly symbolic partner of the student, displays information to the student via the typewriter or the display screen. The display screen, which is a 10-inch-square area on the face of a cathode-ray tube, presents alphanumeric symbols and graphs. Whenever part of a displayed pattern is

[1] Programmed Data Processor 1 (PDP–1), manufactured by the Digital Equipment Corporation, Maynard, Massachusetts.

[2] IBM Executive Electric Typewriter (Model B), modified for use with digital computer by the Soroban Engineering, Inc., Melbourne, Florida.

[3] The display screen and light pen are parts of the PDP–1 system, supplied by the Digital Equipment Corporation.

touched by the tip of the light pen, the computer can tell what part was touched and when. The combination of computer-controlled cathode-ray display and computer-signaling light pen is a convenient and flexible arrangement for man-computer communication.

Symbiont is an early stage of what we hope will be a continuing evolution. However, a sufficient set of functions has been implemented to lead us to take stock and gain experience in their use before modifying existing functions or adding new ones.

Inasmuch as Symbiont is an exploratory tool, for use mainly by students who are at the same time experimenters, we have not considered it necessary to perfect or polish. For example, the display flickers. With the aid of character-generation and display-buffering equipment, we could achieve a steady display: the technology is far enough advanced to fulfill the display function well. At present, however, the equipment required for flicker-free display is expensive, and we prefer to put available funds into other things. Our reasoning is that, in due course, good, steady displays will become relatively inexpensive, and in the interim we can make allowances for a bit of flicker. The same argument applies to text storage capacity, text searching rate, and production of permanent copy. In short, our aim has been to realize several interesting functions now, even though in ways for which certain allowances have to be made, in order to gain early experience in using the functions and to provide a basis for practical system design when advances in technology make it possible to implement the functions effectively and economically.

OPERATIONS AND FUNCTIONS IMPLEMENTED

A study session with Symbiont starts with the computer turned on, the basic program running, and the text and graphs of several technical documents already punched into machine-readable paper tape. The text is represented character-by-character in a standard alphanumeric code. The curves of the graphs are represented numerically by coordinate values at selected points along the abscissae, and the calibrations, labels, and legend are represented alphanumerically in a prescribed format.

At the beginning of his study session, the student loads, from an input tape into the computer memory, representations of the documents he plans to study. Then, typically, he calls for a document and reads or scans it. He calls for it by typing any part of its standard bibliographic citation that specifies it uniquely—the author's name, for example, or a major part of the title, or the name (and perhaps volume or year) of the journal in which the document was published. Symbiont finds the specified document and presents the first screen-page of it. (A screen-page is about 150 words in length. Lines and pages have to be shorter on presently available display screen than full lines and pages are in most document-pages.) The student turns pages in the forward direction by hitting the space bar of the typewriter. He may back up a page at a time by hitting the backspace key.

While reading or scanning, the student comes upon a passage that he wants to record verbatim for future reference—a passage he would ordinarily copy onto a note card. With the aid of Symbiont, he records it on paper tape or in the note-file part of the computer memory. To punch it on paper tape, he touches the initial printed character or characters of the passage with the light pen and then types "b" (for "begin"). Underlining thereupon appears beneath the character(s) touched. Then he touches the final printed character(s) of the passage and types "e" (for "end"). Underlying thereupon appears beneath the ending of the passage, and immediately spreads back to the beginning. The passage is thus singled out for inspection by the student and for action by the computer. When the student types "p" (for "punch"), Symbiont punches the passage into paper tape. If the student next underlines the bibliographic-citation string that appears at the head of the document, Symbiont appends the citation to the note, thus handling a chore that ordinarily plagues the conscientious notetaker when he takes his notes and the unconscientious notetaker when he tries to use his notes. The student can string any number of passages together by underlining them and punching them one at a time, in groups, or all at once.

If the student prefers to note the passage in the computer memory instead of paper tape, he needs to specify a "tag" with which to retrieve it. He specifies the tag (before underlining the passage) by typing "t" (for "tag") and then any symbol, or indeed any string of printing characters and spaces, terminated by a carriage return. He then underlines the passage and types "n" (for "note"). Alternatively, he can assign to the passage a "label," which is functionally equivalent to a tag, but specified initially by underlining a string of characters on the screen with the light pen and then typing "l" (for "label"). The procedure for connecting the label to its passage is the same as the procedure for connecting a tag. Tags and labels go into a "glossary" of retrieval terms associated with the note file. To see what the glossary holds at any time, the student types "g" and looks at the screen. If the glossary is more than one page long, he turns its pages as though it were text.

Often the student wants to retrieve notes, and sometimes he wants to emend or combine them. To retrieve a note, the student types "r" for "retrieve" and then types the tag or label (or if more convenient, designates a corresponding string of characters by underlining them with the light pen). In emending and combining retrieved notes, the student is constrained by the present system to serial designation and concatenation of passages and subpassages. Under these constraints, editing is like operating a switch engine. However, it will be easy to introduce the operations of deletion and insertion.

Verbatim notetaking and retrieval of notes are admittedly minor matters. More vital is retrieval of primary information. In the present context, since the student is assumed to be working with a small collection of documents known to be relevant to the topic under investigation, the retrieval problem is not primarily one of finding documents. It is primarily one of finding passages in documents that discuss particular ideas, passages that are relevant to particular tecnical points. The approach of Symbiont to this problem is to automate the scanning of text for specified configurations of retrieval terms.

Symbiont carries out searches with reference to one, two or three sets of retrieval terms. Each set may contain any number of terms of any length. For retrieval purposes, all the members of a set are assumed to be synonymous: Symbiont considers that it has found the set as soon as it finds any member of a set. Symbiont looks for members of the three sets within a "neighborhood" of text. A neighborhood is n lines in length, and the student can set n to any value he likes. Five lines make a good neighborhood.

Before conducting a search, the student types "t" (for "terms"), then types the strings of characters that constitute the alternate terms of the first retrieval set, and then types "1" to designate this set as the first. Then the student types "t," the term of the second set, and "2," and finally "t," the terms of the third set, and "3." The three sets might be, for example:

1

cigarette	cigars	tobacco
cigarettes	pipe	tobaccos
cigar	pipes	nicotine

2

lungs	preliminary	lungs

3

cancer	carcinoma

The student then decides whether he wants a passage (neighborhood) dealing with one of the three, two of the three, or all three ideas (sets), and he initiates the search for typing "f1," "f2," or "f3" (for "find one," etc.). Symbiont thereupon searches serially through the text until it either comes to the end or finds a neighborhood that meets the specifications. If it comes to the end, it displays "not found." If it finds a neighborhood that meets the specifications, it displays on the screen the text containing the neighborhood, showing a small amount of preceding text and a large amount of succeeding text. The student may turn pages, copy passages, etc., in the ways described earlier, or he may type "f1," "f2," or "f3" and have Symbiont look for another passage that also meets the specification.

Although the idea-retrieve technique just described is primitive, it is surprisingly effective if the student is clever in setting up the sets of terms. Typically, the student starts with a loose retrieval prescription and tightens it as he akes his way through his collection of documents.

Graphs are composed by the computer from tabulated data and presented on the screen as graphs. They are displayed separately from text. They have keys that associate labels with curves; they have calibrated and labeled axes; and they have legends. Curves are approximated by straight-line segments, dashed and/or dotted in eight patterns. A family of curves can have any number of members, but in the present system, only one label. Up to eight families of curves can be superposed upon one grid. Two grids can be set side-by-side to facilitate comparison. If the graphs are fundamentally comparable but different in scale factor, the student can, with the aid of the light pen, expand or compress the scales of one or the other until the two presentations are directly comparable. He adjusts the length or position of a line segment of the coordinate frame by touching one of its ends with the light pen (which "picks up" the end-point) and then moving the end-point to the desired location. If necessary, he repeats the procedure with the other end-point. The computer then re-scales and relocates the entire graph. If the graphs are displayed side-by-side, one of them can be moved and superposed upon the other, or curves can be transferred from one to another. These operations facilitate synthesis of a composite picture from results obtained by diverse investigators.

Symbiont makes it easy to modify not only the size of a frame but also the grid structure, the structure of the subdivision of the area within the frame. When it changes a grid, it changes, also, the numbers associated with the grid lines (i.e., the numbers associated with the scale-calibration points).

At the bottom of the screen, there is a display of numerals and control symbols. By pointing with the light pen to individual numerals in proper sequence, the student can build up any number he needs. Then, designating with the light pen the control symbol "SCALE" and a scale-calibration point he can substitute the assembled number for a number theretofore associated with the scale-calibration point. As soon as new numbers have been associated with two calibration points on a linear axis scale, the computer substitutes new values at all the other calibration points on the axis.

If he wants to change the number of grid lines that subdivide (say) the "pressure" scale of a graph, the student points with the light pen to the control symbol "GRID" and then to the label "PRESSURE" and then to the appropriate numeral corresponding to the desired number of grid lines. The computer immediately redraws the grid, leaving the extreme grid lines unchanged, and substitutes the appropriate new numbers near the intersections of the new grid lines and the horizontal axis. With these procedures, the student may experiment rapidly with various frames and grids, for he need specify only the essential parameters of each coordinate system. As soon as they are specified, Symbiont develops the detailed pattern.

EVALUATIONS AND PLANS FOR IMPROVEMENT

Our experience in using Symbiont has been limited by shortage of input tapes and by smallness of the computer memory. A semi-automatic tape-preparation subsystem and an arrangement for moving information automatically between primary (core) and secondary (drum) memory are the items of highest priority in the plans for Symbiont II. Even on the basis of the limited experience, however, it seems clear to us that the functions provided by Symbiont I (the system thus far implemented) are effective as aids in technical study. The function of searching for ideas, as primitive as the implementation is in Symbiont I, is little short of powerful. The automation of verbatim notetaking, despite shortcomings in human engineering, seems capable of serving as the foundation for efficient personal documentation systems.

In Symbiont I, however, too many of the graph-handling functions deal with frames, grids, and labels, and not enough deal with curves. The limitation to linear transformations is highly constraining. We must admit, therefor, that the graph-handling functions of Symbiont I do little more than (a) afford convenience in the few parts of the over-all process of graph manipulation that they subsume and (b) make it seem plausible that a fuller set of functions (involving perhaps ten times as much programming) would be truly useful.

The plans for Symbiont II call for the following modifications of, and additions to, Symbiont I:

1. A subsystem to "semi-automate" preparation of input tapes of textual and graphical information. Because performance of the system during study does

not depend upon how the tapes were prepared, we deferred work of a tape-preparation subsystem and relied upon manual production of input tapes. Manual production proved not to be satisfactory. For Symbiont II, we plan to take text mainly from monotype and linotype tapes and to use computer film-reading techniques in converting graphical data to tabular form.

2. Extension of the storage areas, confined to core memory and supplementary paper tape in Symbiont I, to the magnetic drum (22 times 4096 18-bit words) now associated with the PDP–1, and perhaps also from the drum to magnetic tape units.

3. Substitution of light-pen for typewriter control of most operations that deal with information displayed on the screen.

4. A descriptor-and-thesaurus system for retrieving documents from store. Symbiont I retrieves documents with the same searching system it uses in finding passages. (A bibliographic designation precedes each document in the store of text.) That will be too slow when the store becomes large.

5. A scheme for turning several or many pages at a time or for going immediately to a particular page specified by page number.

6. More reliance upon predetermined sequences of manipulation and less upon control characters. For example, to underline a segment of text, it should suffice to point with the light pen to an "underline" light button, then to the beginning of the passage, and then to the end of the passage. It is an unnecessary nuisance to have to specify "end" after having specified "begin." However, streamlining the procedure in this way will make it necessary to provide a way of reminding the student when he forgets where he is, in a sequence of operations, and a way of letting him linger upon (or return to) a particular operation long enough to correct a mistake in specifying it.

7. Handling of notes precisely as though they were documents. Notes will be permitted to contain graphs. The note-retrieval glossary will be associated with the document-retrieval system.

8. Acceptance of notes phrased by student. This now seems essential even though it is easy for him to record verbatim notes.

9. Provision for extraction from text of individual words, individual phrases (delimited by punctuation marks), individual sentences, and individual paragraphs merely by pointing. It is an unnecessary nuisance to underline (i.e., to point to both ends of) a segment unless one wants to extract a sequence of characters that does not constitute a formal unit.

10. Labeling of individual curves, as well as of families.

11. Labeling near the curve as an alternative to associating label and curve by key.

12. Search for more than three sets of terms, and for other combinations (such as 1 and 2 or 1 and 3) than any m of n.

13. Storage and retrieval of the sets of terms used in searching text. It is not good to have to type a set of terms more than once, and it will be easy to store them for future reference. The student will be able to retrieve a set by typing any term in the set. Symbiont II will display all the sets that contain the typed term and let the student select the one he wants by pointing to it.

14. In designating parts of graphs to the program for action, more pointing to the parts, themselves, and less pointing to their names.

15. Transformation between linear and logarithmic coordinates.

16. Fitting of curves (specified by type, such as sine, exponential, and power series) to tabulated numerical data, and determination of goodness of fit.

17. Weighted averaging of curves.

The present plan is to effect the foregoing improvements, to gain further experience, and then, in proceeding to the third generation of study facilities, to meld them with arrangements, not described, to facilitate the organization and retrieval of notes and data and the preparation of technical papers.

The On-Line Intellectual Community

(By J. C. R. Licklider)

Mr. Chairman, distinguished colleagues, fellow engineers, Mr. Cisler, that was a very sobering experience for me. You ended on a high note, but otherwise I'm not sure I'm still happy about all that. Thank you anyway for saying "an active career" and not a "chequered career."

I have a chance for some minutes now to redeem myself, and I shall try. It's a great pleasure and a great honor to have this opportunity.

As a title "The On-Line Intellectual Community" worries me a bit. "On-line" is jargon—it means "operating in direct, concurrent interaction with." It implies that the thing thus interacted with is probably a digital computer. "Intellectual" is intended in the sense of "endowed with intellect or understanding"—"intellect" means simply "power or faculty of knowing." It is not meant to imply any invidious attitude toward any other kind of community than intellectual. "Community" is used to mean a body of people having common organization or interests" and not necessarily "a body of people living in the same place." The phrase worries me because it presents so many opportunities for misinterpretation or non-interpretation. Nevertheless, the intended interpretations of its several words blend together to yield precisely the concept I wish to talk about: A body of people working in direct, concurrent interaction with storers and processers of information and thereby endowed with the power of knowing.

The on-line intellectual community is a young, but not a new, concept. Particularly, it is not new to you, not new to the Engineers Joint Council, which has been, as you well know, the focus of much advanced thinking about information systems and networks. The on-line intellectual community is, however, a currently significant concept, for it embraces two of the main themes of current discussions of library and information systems—the computer and the network—and it is setting the direction of much thinking and planning, even though some parts of the concept are not ready for implementation on a large scale in the immediate future. The phrase, "the on-line intellectual community," gained considerable currency, at least within a small group, this summer at Woods Hole, Massachusetts, where M.I.T. had a planning conference on information transfer experiments, called project INTREX. I shall mention that the book called, "INTREX, A Report of a Planning Conference on Information Transfer Experiments," was published by the M.I.T. press last week or the week before last. and I shall also mention that, if what I say about the on-line intellectual community is unclear or insufficient, you will find a chapter in this book, chapter IV I believe, which might also be unclear or insufficient, but which at least is longer than what I intend to tell you here.

As I listened to Bill Knox this morning mention "$300 million dollars" and say "computer-based information system" several times, my mind leaped ahead to a future time by which Bill has already been almost wholly successful in moving the mountains that he is moving, when there is indeed a vast computer-based information network. In fact, this network is being dedicated. A measure of Bill's success in moving these mountains is provided by the fact that the nation's attention to matters of space technology, and perhaps also to wars in distant countries, has been encroached upon considerably by the effort to set up the vast information network for science and technology. The President, on the verge of inaugurating the network, is really worried about the space program and the war situation, and you can see this worry come through in his question to the great information machine before him. He says, "What shall we do in order to make sure that we master our own world and establish peace throughout it and complete the conquest of space and, in the name of mankind, remain, masters of the universe forever?" The machine says, "Pull out my power cord right away."

When I referred to "the computer," I had in mind not quite such a device. I had in mind information processing devices and systems in a variety of applications, but I wanted to focus attention mainly on on-line interactive information-processing systems. These systems are typified by the Compatible Time-Sharing System of Project MAC at M.I.T. and the Time-Sharing System of the Command Systems Laboratory of the System Development Corporation, or more precisely, the future second or third generations of such systems. When I referred to "the network," I had in mind networks of central, regional, and local libraries and networks for the distribution of catalogs, indexes, and abstracts, and the like—for example on magnetic tape. But I want to focus attention mainly on networks of coaxial cable, microwave transmission facilities, and the like, connecting multiple-access computers in various parts of the country, or indeed, the world, into a coherent system spanning disciplines and application areas, and perhaps languages as well as geography.

Since this is a luncheon talk, I am feeeling free to let wishes and hopes have some influence in shaping the concept, but I shall not wholly disconnect the discussion from considerations of technical and economic feasibility. I want to talk about the facilities, functions, and services of the on-line network and then to mention a few principles, a few techniques and a few problems. That is all.

Hopefully, I can paint a picture that will be useful as one of several influences upon our thinking about information systems and networks. Now, many influences on our thinking have the form of extrapolations from existing experience. This one has some elements of that. Indeed this picture I want to paint is made out of subimages, out of schemata, that one can see operating now in one place or another, in primitive ways. But the thing does not exist yet as a whole, and it may never exist in quite the form in which I shall describe it. I think the over-all concept may be useful as an attraction, a pulling force, that may influence to some small extent the direction of thinking about the problems that are under discussion at the meeting today. But, as I said, this is just a luncheon talk, and you don't have to take it as a statement of a plan or as a revelation.

Now, about facilities and services: Let me start from the user's point of view. The user sits at a console. In my picture, the console is essentially the desk. The desk has become an active thing. The desk has displays built into it. They are displays of hard copy and of soft copy They are displays of alphanumeric strings (that is to say, of letters, characters, words, and the like) and also of graphs and diagrams, and also of pictures. The pictures are either TV-like pictures reproduced with the aid of scanning from pictures in a respository or projections of microimages delivered from the repository to the console. The other displays are driven by electronics, and the information presented exists in computer-processible form in the central or in the local store.

Besides the displays, the user, the man at the desk, has a keyboard and a device like a pencil or a pen (in the current technology. It is usually a "light pen" or a stylus) with which he can write on the display surface and—if he writes very clearly, or perhaps if he prints—be understood by the computer; the computer can tell where he points and can make parts of the displayed image follow the pointer.

This potentially very "powerful" and convenient interaction between man and computer stems from early work mainly at M.I.T. and the Lincoln Laboratory. There are, in operation at a dozen or more places in the country, several systems for computer-aided graphical design, descendants of Ivan Sutherland's "Sketchpad." I hope that some of you have seen Sketchpad or its descendants in action, either directly or in motion pictures. They contain many of the images that I want you to have in mind as I talk about the facilities of the on-line community.

At any rate, with the aid of systems such as Sketchpad, you can sketch to the computer, and it records and sharpens up your sketch and "understands" the structure you have conveyed to it.

Besides the pen and display we have been discussing, there is, in the idealized console of my mental image, also a keyboard, of course and perhaps some mode or function buttons and switches, a headset or loudspeaker, and a microphone. The microphone is not for free, natural-language communication from the user to the computer, but for comments of a very simple sort in a very constrained language. When you draw a line through something and say "erase," the computer distinguishes that from your drawing a line through the same thing and saying "underline"—that level of speech recognition.

Besides the desk equipped with these devices, and of course a projector if you work for micro-images, there is an "interaction language." I do not know exactly what form the interaction language will take. Calvin Mooers tells me that he does . . . and I should ask him to tell you about it. However, I am here at the microphone and he is not, and possession is nine points of the law, So I shall state the essential characteristic of the interaction language by saying that it is natural enough for the user and formal enough for the computer. The part of the interaction language that flows from the computer to the man is quite different from the part that flows from the man to the computer. The language "spoken" by the computer is largely pre-recorded and stored in the computer's memory—in which case it is essentially unconstrained English plus graphics. I shall not take time to go into the problem of generation of responses by the computer except to say that such a capability, based on advances in computation linguistics, has been demonstrated in primitive forms and is by no means an exclusive feature of science fiction. Indeed, computers now "speak" recorded sounds in practical applications and computer-synthesized sounds in the laboratory, and one can count on auditory as well as visual presentation of the messages that flow from the computer to the user.

The more difficult and more interesting part of interaction language is the part that flows from the user to the computer. This part must be easy for the user to learn and to employ. It must not pose any implicit requirement that the user be skilled in computer programming or knowledgeable about the internal workings of computers, but—since programmability is a very basic and powerful feature and since elementary programming will find its way into the lives of many members of the on-line intellectual community—the interaction language should include, or provide a bridge to, or at the very least be compatible with, computer-programming languages.

The man-computer part of the interaction language carries the user's expressions of commands, queries, and declarations. He uses it in calling for the various services afforded by the computer and in controlling and interacting with them. Since his expressions are made partly through keys, buttons, and switches, partly through stylus or light pen, and partly through speech, the interaction-language subsystem must meld those diverse but correlated incoming signals into a unified message stream. Thus interaction language is a large field, full of problems, some of which are unsolved, some almost unformulated.

Finding the right structure for, and then achieving an effective implementation of interaction language will require much work, but I am now assuming that the effort will be successful—or, to put us back into the future, that it has been successful. The next thing the user sees, beyond the console and the interaction language, is the set of services that he calls and with which he interacts. Because I want to move on to the library-document-information network aspect of the on-line intellectual community, I shall not discuss the other services in any detail. I shall merely name them. Let me name the retrieval and dissemination service first—the essential basis of the aspect upon which I wish to dwell—for it is, in my opinion, the first and foremost of the services. The second is simulation. The simultation that I picture in my mind is different enough from conventional computer-program simulation—different particularly in making extensive use of dynamic displays—that I am inclined to refer to it by another name, "dynamic modeling." The dynamic-modeling service facilitates one's expression, one's formulation, of ideas, lets him develop his formulations in a progressive way that involves trial and error—lets him play his ideas back in graphic form and study them to find implications and consequences that otherwise would be hidden.

Although I said I would merely name the services, I cannot resist saying a few more words about this one. To appreciate the potential of dynamic modeling, it is almost essential to see examples a word picture may convey some of the force of the idea. Let me go back to Sutherland's Sketchpad. In one of Sutherland's demonstrations, he drew a bridge—a simple box structure. He drew a support under each end of the bridge, a schematic pillar on which the bridge then rested. In the center, he drew a weight, representing the load on the bridge. Then he typed to the computer the value of the weight. The computer already knew the strengths of the linear elements of which the bridge was constructed. (It had been programmed to work on the assumption that the cross-sectional areas were proportional to the lengths.) In any event, the data necessary to support calculation of the behavior of the bridge were already in the computer. The displayed picture of the bridge therefore sagged. Then, at Sutherland's command (pressing a button), the computer superposed upon each element the compression or tension to which it was subjected. I think you will agree that you do not have to be brilliant to design a successful bridge with the aid of such an "assistant."

Dynamic modeling in connection with the design of vehicles and structures is so promising and attractive a field that many programs are under way and many examples, more complex and sophisticated but perhaps not fundamentally more dramatic than the one I just described, are now available. One involves a ship's hull, sketched by the designer at the console, analyzed and re-expressed in terms of coefficients in a system of equations by the computer, and then displayed from varying points of view under the control of the designer so that he can assess it, appreciate it, or modify it. I have not seen the following with my own eyes, but I understand that the modelled ship hull can be towed through a simulated tow tank, that the impedance of the water to the motion of the ship can be measured, and that the designer can, through a blend of history and trial and error, progressively improve the performance of his design. Other examples are found in automobile design and in the design of electrical circuits.

The third service is assistance in the generation and editing of text. It facilitates generation, format control, editing, and updating. Nothing in the on-line intellectual community is ever retyped by human hands. After the original typing, the record in the computer's store is modified. When clean copy is required, the computer presents it.

The fourth service is arithmetical and logical assistance. Whenever the user is working with data that are in the system, he can bring already prepared programs to bear upon the data. Thus he can work "at arm's length"—he need not read every character of the information with which he works if he can define explicitly the procedures that he wishes to apply or if he can specify them by name or function and retrieve them from the library.

Further services includes: language processing (for example, analysis of text to discover syntactic ambiguities), data-bank services (which will be increasingly important, I believe, because more and more information is being collected and recorded in forms that are amenable to arms-length processing), communication among people with reference to stored information (a combination of telephone and television, with a computer in the circuit), assistance in the preparation, "debugging," and specialization of computer programs (specialization being especially important because most of the programs available from the library are written in very general forms, and it is often worthwhile to speed them up by re-tailoring them for the application at hand), and computer-assisted instruction (in a wide variety of subjects, including, of course, how to use the console and the various services available through it).

The foregoing list of services is to some, no doubt, just a list of phrases in some kind of a jargon. To others, or perhaps I should say particularly to me, it is a list—not a complete list but a fairly complete list—of the elements of the intellectual processes in which scientists, engineers, administrators, managers, lawyers, doctors, and several other groups of people engage. Perhaps the list is less complete for humanists than for other members of university communities, less complete for experimental scientists than for theoretical scientists. In the latter case, I should have made it more complete by including assistance in the conduct of experiments, which is a genuine application of on-line information processing, currently the focus of considerable interest.

Let me turn, now, to the functions that lie within the realm of the library, the document room, the information system, and the information network.

Having just now mentioned the experimenter in the laboratory, I am inclined to adopt a very broad approach to this part of the discussion and to note that the whole process of acquiring, distilling, storing, retrieving, disseminating, and using information is facilitated and integrated in the on-line intellectual community. As the research scientist conducts his experimental work through the computer system, monitoring and guiding the probing of nature from his console, he acquires data in computer-processible form. He couples statistical analysis closely to the acquisition of data, sometimes using the results of one minute's experimentation to determine what question to ask in the next. He may come to a point at which data from the library, or from a data bank, should be compared with data newly acquired through experimentation and—since both kinds of data are accessible through his console, and not only accessible but also processible with the aid of the same set of analytical programs—he is likely to join the laboratory and library parts of his work more closely together than they are joined in our present-day ways of working.

The theoretical scientist works often with data and often with documents, but his favorite approach involves the dynamic modeling programs to which I referred in the discussion of services. Some of his models are simply computer-program implementations of conventional mathematical models. Most, however, involve as much logic or decision making as mathematics, and most are too complex or too nonlinear to be treated in the same way as mathematical models that can be represented in a few equations and solved with the aid of paper and pencil. In any event, the theoretician draws some of his models from the library and some from the on-line files of his colleagues—with their permission, of course. Other models he prepares with the aid of modeling and simulation languages. (Even at the present time, there is a profusion of such languages, and a few of them are operating within multiple-access computer systems.) He explores the several models that seem to him to be competitors in the explanation of some range of facts by setting them into operation upon data—data drawn from data banks and files—watching their behavior through graphical displays, and measuring their performance with the aid of specially designed programs that make observations upon the models as they run and even conduct "experiments" with the models as subjects. The work is often characterized by changes of direction, by modification of one or another of the models to test out a new idea, and by consultation with colleagues during which two or more scientists, each one in his own office, examine together instances of model behavior that one of them considers to be particularly significant.

When the experimenter or the theoretical worker is at a point at which he wishes to prepare a report, he prepares his report at his console. He draws upon data and models and partial representations of results that he has already developed. He assembles those existing pieces and generates new material to create a document. In some respects, the document is similar to the documents with which we deal today, and in other respects it is quite different. In its primary form, it consists of computer-processible code and is stored in a secondary memory of the information network. At any time, by any user authorized to have access to it, it can be converted into hard copy—ink on paper—and that is an excellent and much-used form, even in the on-line community.

In order to suggest what I have in mind about the main difference between a conventional document and a document in the on-line system, let me take just one example: the concept of "figure." In a print-on-paper document, a figure is a fixed, static thing. It consists perhaps of curved lines against a coordinate framework, or perhaps of diagrams, together with some alphanumeric information. In the on-line network, however, a figure is likely to be dynamic. When the reader interacts with it, pressing a selected button or touching the light pen to a selected spot on the screen, parts of the figure move. If the figure contains a sketch of a device, the device operates. If the figure contains summary statistics, the over-all means break down into component means in response to a query.

In the on-line community, publication will include the placing of data in data banks and models in model collections as well as the placing of documents in journals or libraries. Actually, I think, there will be a fusing of the several kinds of repositories and a general integration of the over-all information system, but in the present connection the important point is that, in the on-line network, "publication" has a somewhat expanded meaning. I should mention, by all means, that as much prestige is attached to the publication of highly regarded and widely used computer programs as to the publication of anything else. Before leaving publication, let me mention that footnotes and references are, like figures, potentially active, dynamic data structures. Point at a reference in the proper way, for example, and you will see an abstract on the article cited.

In the process of talking about documents, I moved into a discussion of publication before finishing what I had to say about the preparation of the report. Preparation is facilitated, of course, by the package of programs for preparing and editing text. The editing programs are used when the document is criticized by colleagues, when it is reviewed by editors, when—if it is a review article or handbook—it is brought up-to-date. There is, indeed, a great lot of modifying and editing, because the document is available to the "invisible colleges" of which the author is a member as soon as the author is willing to permit access to it.

Within the information network, there are several "levels" of publication. Inasmuch as the document is created within the system, a document is published, in a sense, as soon as it is given a tag that permits wide accessibility. In that informally published state, the document accumulates comments, criticisms, and appendages, put there by others who are interested in what it says. The public files of each multiple-access computer system within the information network are guarded by an editorial committee. Acceptance by that committee marks a higher level of publication, one at which the bibliographic citations, the dynamic footnotes, and the like are guaranteed to be in working order. Beyond that level there is formal publication in journals—but note, of course, that one form of the journal will be that referred to earlier as the primary form, computer-processible code stored within the network. The motivation for publishing in a journal will be related to the desire for wide dissemination—the information network does not yet extend all over the world—and also to the desire to have one's article well catalogued, abstracted, and reviewed.

That phase of a library's operation that is called "acquisition" is much different for a library associated with the information network than it is for a conventional library of the present day. The computer-processible files of the library are part of the network, and the computer-processible files of the network are part of the library. Data, documents, and models are therefore acquired essentially as they are generated, or at any rate as soon as they are tagged for access outside the author's immediate circle. Working at consoles within the network are professional cataloguers, indexers, abstracters, organizers, and converters of format. Some of them organize the stores of computer-processible information to facilitate retrieval and to effect dissemination of sets of data, of models, and of documents. Others strive to extract information from the data forms just mentioned and to incorporate it into newer structures designed to support what is sometimes called "information retrieval" in contradistinction to "document retrieval."[1]

The facilities of the information network permit a much more direct interaction between the professional documentationalists and the generators and editors of documents than is possible today. Very close interaction between people with substantive interests and competence in the various fields of knowledge and specialists in the information sciences will be necessary if a truly effective organization of knowledge—an organization both broad and deep and also both coherent and correct—is ever to be achieved. Perhaps I should say again that what I am describing is only a concept, for I should like to emphasize the basic importance of reorganizing and restructuring the body of knowledge. Almost surely, natural language is not the preferred form, and neither is natural language intermixed with expressions in one or another language of mathematics or logic. Other ways of organizing and structuring information are being explored, and it seems likely that formalisms will be developed that will facilitate distillation and crystallization of knowledge, that will permit more compact storage, that will be amendable to processing, and that will be more expressive than the natural languages are. I realize that the dream is rather far from realization, but I think it is a realizable dream, and a very attractive one that will invite much effort during the coming years.

Now, the functions of announcement and dissemination. The online intellectual community is an excellent testing ground for systems of selective information dissemination. Needless to say, several good systems have been tested, and the best of them are in fairly widespread use within the network. When a user sits down at his desk (console) in the morning, he finds a "message of the day." It is tailored to his special interests, which of course are known by the system. The message of the day tells him briefly what has happened within the network that is likely to affect him. The first part of the message concerns changes in operating procedure and in the set of services available. The second part concerns acquisitions of information. The message is in a sense a combination of a news bulletin and an index. It contains "pointers" which, when activated by a user, lead to additional information. With their aid, he can explore in depth any items that prove to be of particular interest. The announcement of library acquisitions and the disseminations of abstracts and documents are coupled, as I have indicated, to the message of the day. At any time, however, a user can request to see the announcements or to receive his "dissemination" allotment, and many users prefer this compromise between retrieval and dissemination to unsolicited dissemination.

The retrieval function is, in my opinion, absolutely fundamental. The language through which retrieval specifications are formulated is the interaction language, itself. It permits convenient expression of boolean queries and questions in higher-order formal languages. If what the user specifies is a reasonable prescription, the retrieval system sets to work to deliver the requested information, and it usually provides rapid service. If the prescription is not reasonable, the retrieval system enters negotiation with the user and helps him pin down his description of what he wants through conversational interaction. The information network extends into the array of national resources, and perhaps international resources, discussed by Bill Knox. The picture I am trying to paint assumes that Bill and his colleagues in the Office of Science and Technology and on the Committee on Scientific and Technical Information have been successful, that the national and international informational resources are well organized and effective. In the interest of concreteness, however, I shall use the present-day names of some of the agencies as I try to describe briefly the kinds of service available to a user at his console.

[1] It is unfortunate that "information" is used sometimes in a generic sense to cover all forms and types and at other times has a lower-echelon heading, but so it is.

The user interrogates the Science Information Exchange to find out who is working, under government support, on a particular problem of immediate interest to him. He interrogates National Referral Center to find out who holds documentary information about the problem. The National Referral Center may direct him to the appropriate Scientific and Technical Information Evaluation Center, and he may communicate through the network with an expert there who may agree to work up a bibliography and a technical summary—provided, of course, that a governmental agency that supports one or the other of them, or preferably both, will foot the bill. Getting down to brass tacks—actual documents and data—the user interrogates the Clearing House for Scientific and Technical Information, which starts immediately to fulfill his requests and bill him through the network, but the user comes to just in time and diverts his inquiry to the Defense Documentation Center and the Information Facilities of the Atomic Energy Commission and the National Aeronautical and Space Administration, with which his institution has research contracts. Actually, behind the facade of agency names, there is (in this conceptual picture, but not yet in actuality) just one large computer-based information system, but it keeps books and respects authorizations in such a way as to maintain the illusion of departmental organization.

Let me return to the topic of "question answering." I am not sure whether or not I should include a question-answering service within my picture of the information network. Of course, I have not associated a definite date with the picture, and I might therefore go ahead and include question-answering capabilities with impunity, but the fact is that I am both greatly fascinated by the problem and greatly impressed by its difficulty. Let me compromise by saying that the information network will probably provide a limited question-answering service. It will be based on ways of representing [illegible] quite different from those we use now.

A basic technique for question answering [illegible] several years ago—first, I believe, by Fisher Black, but also [illegible] oth[illegible] information on the basis of which questions are to be answe[illegible] pre[illegible]nted in the language of a predicate calculus. Information in such a form is processible by computer, and the computer can, with the aid of appropriate programs, make deductive inferences from the information. Questions are posed as tentative assertions in the same formalism. In the case of yes-no questions, the computer determines whether the question statement or its negative can be deduced from the information base. If the assertion can be deduced, the answer is "yes." If the negative of the assertion can be deduced, the answer is "no." If neither can de deduced, the answer is, "I don't know." Questions other than yes-no questions involve variables. The procedure for answering those questions is more complicated, but in fact the computer comes forth with lists of values corresponding to the variables or with "I don't know."

Thus far, question-answering systems have encountered two difficulties. First, it is very difficult to program a computer to translate from natural language into the formalism of predicate calculus—very difficult even in instances in which the translation is theoretically possible. Second, it takes a fantastic amount of computing to answer even very simple questions.

In one of his demonstrations, Fisher Black solved a problem called the "Airport Problem," posed several years earlier by John McCarthy. Many of you know the problem. For any of you who do not know it, I shall state it simply in a rough English approximation to predicate calculus of the information base and of the question:

I am at home. My car is in the garage. The garage is at what I call "my home." I can walk from any place I call "at home" to any other place I call "at home." The airport is in the same county as my home. I can drive from any place in the county to any other place in the county. I want to go to the airport. What do I do?

After spinning its wheels for an embarrassingly long time, the computer produced the answer:

Walk to the garage. Drive to the airport.

Now, that performance is trivial, and yet it is very fundamental. It is fundamental because the computer is not as greatly handicapped as a person would be if there is a large amount of irrelevant information in the information base. The Airport Problem is essentially the basic problem of logistics: With such and such resources, with such and such capabilities, and with such and such an intention, can I succeed? If so, how? If not, why not?

Returning to the functions of the information network, I want to mention again the function of communication among people with reference to, and in interaction with, stored information. Present-day time-sharing systems are already providing a glimpse of how that function will be employed and how important it will be. Typically ones closest intellectual colleagues are not geographically his closest associates. In science, technology, administration, and several other fields, they are likely to be remote. Through information networks—even through teleprocessing in a system with a single central computer—geographically distributed colleagues can work together in interaction with stored information—indeed, through dynamic interaction with models and data—and collaborate as effectively as if they were in a face-to-face conference. I think that that statement is not a severe exaggeration.

Earlier in this talk, I mentioned "arms length interaction" with information. Let me now give a brief illustration. Suppose that the user is trying to determne which, of all the harbors in the world, a particular vessel can enter and reach a dock without running aground. To answer that question, he has to do a considerable amount of calculation. The calculation must take into account the shape and depth of the vessel and also data about the conformations of the bottoms of harbors. If one thinks of executing this task with pencil and paper, he must solve, first, a subordinate problem: how many clerks will it require to carry through the calculation in the time available. Working at a console in the information network, however, one can think and experiment until he figures out how to solve the problem for the given vessel and one harbor, and then he can—if he likes—simulate the passage of the vessel through the harbor to the dock so that he can discover any visible flaws in the method. And then he can command the computer to apply the same procedure to the data for all the other harbors in the data base.

Note that the "data base" is an essential part of the facility for solving this problem. Note, also, that it would not be very helpful to have the data base if all you could get from it were a printout of all the data. The essential thing is to connect the several required services together to integrate them into a unified or coherent system. With such a system, one can solve his problems without having to take in through his eyes and process with his brain every element of informational detail that is required in the solution. The need for such a facility, for such a system, recurs over and over again in business, in military, and in academic thinking.

Now, time flies. There are many more functions, but perhaps I have said enough to suggest to you the nature of the over-all picture. In that picture, if you project yourself into it, you are working at your desk (console) with information that you select, and the processing of which you control, through an interaction language. The information is stored in a system of memories associated with a network of computers, communication links, and display and control devices. Your purpose in interacting with the information is to solve a problem, to come to a decision, to explore an idea, to formulate a question, or something of that general nature. Presumably, you are expert at defining your purpose, pointing to your goal, dreaming up a plausible hypothesis, and telling whether, in the course of your effort, you are on a promising track or not. Almost surely you are not very good at carrying through the detailed clerical operations that are involved. The computers of the network are very good at that, however, and their short suits are your long ones. You and the computer network complement each other neatly and, working together in close interaction, you accomplish your purposes with efficiency and dispatch.

That is, at least roughly, the concept. I have been careful not to advertise it as a goal near at hand, as a thing achievable in the near future. Perhaps I may say, however, that it is amazing to me how many of the elements of the concept are demonstrable now. Insofar as technological capabilities are limiting, I have the feeling that the concept is closer to realization than . . . well, I guess much of science fiction is getting fairly close to realization these days . . . and I should turn from this line of thought to my final endeavor, which is to set forth a few statements that I consider to be principles that are relevant to information networks and to the concept of the on-line intellectual community.

The first principle deals with interaction, with the direct "on-lineness" of man-computer interaction. The principle is that it is truly essential to receive service "within the thought cycle." That is to say, it is important not only to get what you ask for but to get it while you are still thinking about the problem—and not tomorrow or the next day. I think I have told some of you about my interaction with a hunter on an airplane a couple of weeks ago. It just happens that, as I was on my way to make a talk about information retrieval, I sat down next to a man who was an avid huntsman and who owned a retriever. He was vehement on his main point: It does not help much for the dog to go to the bird unless the dog brings the bird back at once to you. Immediate delivery of the product is the essence of retrieval. Now, I am not sure why immediacy is so important in hunting, but I think I know why it is important in constructive thinking. Constructive thinking can be analyzed into two elements—two elements that figured in the discussion only a minute or two ago. Man is very good in handling one of the elements. He is very good at guide lines, at formulation, at creating hypotheses, at playing it by ear, setting goals, and at evaluating success in meeting them. In the jargon, these functions are called "heuristic." But man is, as now appears evident to almost everyone a very poor—that is, slow and inaccurate executor of predesigned, pre-prepared procedures. This function is sometimes called "algorithmic." The great success of computers in science and industry has been based mainly on the fact that they are extremely fast and accurate in following prepared procedures, in executing algorithms.

Most constructive thought involves a playing, back and forth, between the heuristic and the algorithmic functions. The interplay, cannot be effective if the "turn-around time" is a day or even an hour. The algorithmic response should arrive within seconds. Indeed it is sometimes frustrating if it takes even seconds.

The second principle I need only mention here, for I have already dwelled upon it at some length. It is the principle of processing information at arms length. Perhaps I may give one more argument for its importance. People read very slowly. If we define a sub-field in such a way as to divide the over all field of science, and technology into about a thousand parts—of which a typical one might be, for example, oceanography—then a man reading the literature of a subfield as though it were a novel, eight hours a day, would finish reading the literature on which he started at a time when the literature had just doubled. It would take him about ten years to read what there was when he started. When he finished, there would be another ten years' worth to start on. After that, of course, he would be in an even worse situation, but we do not have to go into that to see that a man cannot read everything that is relevant to his work. We have to develop ways of processing more of the information we use in intellectual work, ways that are at least roughly comparable to those used by business firms in handling their payrolls and inventories. This may not be a wholly attractive thought, but I think it is a crucial one. We need to progress from the intimate connection that a laborer has with his material to the arms-length connection that an executive has with his.

The third principle, which is, I think, the most important one, has to do with cooperation among people. Most large tasks are too large for one man. When several or many men are required to accomplish a goal, it is essential to organize the effort in such a way as to make the individual contributions fit together. Unfortunately, it seems to be even more difficult to achieve coherent and cooperative interaction in intellectual work than it is in clerical and physical labor. There is, however, at least a reasonable hope that on-line information networks will facilitate cooperative interaction in intellectual endeavors.

In the universities and research organizations that have been accumulating the initial experience with on-line multiple-access systems, most of the effort and most of the interest have been focused upon the problem of improving the effectiveness of individual users. It is now quite evident that close interaction with a well-programmed computer can do great things for the thinking of the individual. However, as more and more people have become participants in on-line information processing, it has slowly dawned upon observers that the facilitory effect may be even greater for group thinking, for the intellectual process of the community, than for the individual members considered one at a time. It is beginning to appear, indeed, that multiple access to an interactive information-processing system is a precondition for coherent intellectual work involving several or many people. In rough analogy, a multiple-access computer system provides a nervous system for a local community and a network of such systems provides a nervous system for a geographically distributed community.

There are two main reasons, I think, why the social implications of multiple-access computers and information nets are starting to become evident only after two or three years of experience with time-shared computers. The first is simply that arrangements for individual access were made before arrangements for access by pairs or teams of people, and that there had been, as yet, very little experience with true information networks. The other reason is that most of the "software base," the collection of programs and data available to users, is generated by users in the course of their day-to-day work. Only after a fairly long period of operation does a multiple-access computer system present to its users a comprehensive set of intellectual tools.

It is interesting to me to project this idea of development through use into the field of documentation. At the present time, most cataloguing, indexing, and abstracting is done by professional documentalists who understand thoroughly what it takes to make a good catalog, a good index, and a good abstract. However, few documentalists are deeply immersed in generating the literature of physics or sociology or marine engineering.

There is always the problem, therefore, of injecting into the bibliographic apparatus the necessary deep understanding of technical substance. Obviously, the problem can be solved only through close interaction between substantive competence and competence in documentation and information science. Ideally, that interaction would take place in the brain of one individual, who would understand both fields thoroughly. But it is unrealistic to try to solve the whole problem with that approach. On-line information networks introduce the possibility of achieving very close interaction between the substantive scientist or engineer and the documentation expert. As suggested earlier, the interaction can take place during the actual preparation of a report and continue on through the process of editing, publishing, and incorporation into the body of knowledge. The interaction does not have to be mainly a matter of conversation; it does not have to waste much time of either party. Most of the contributions of each party can be developed independently. The crucial things made possible through on-line interaction are the occasional brief discussions in the interest of clarification of specific questions and the joint work sessions in which the independent contributions are fused together to produce the final documentation.

Perhaps I should mention explicitly that the work of cataloguing, indexing, and abstracting will be greatly facilitated by preliminary work done by programs operating routinely within the system. These will check citations, produce indexes and abstracts, and so on, for the author and documentalist to use as raw materials. In addition, I should mention explicitly that important contributions to the apparatus of bibliographic control will accumulate as by-products of use of the system. Users will make comments, and (after editorial acceptance and authorization) some of the comments will be appended to published items. Simply by retrieving and using data or models or documents, people will generate "trails" through the information base. These trails will bring about, at long last, a realization of Vannevar Bush's "MEMEX." Proprietary users may choose to erase their trails, but academic users will probably be willing to offer them as a contribution to the public domain. Perhaps an engineer will find himself thinking, "I want to see what so-and-so has been doing. He has been turning out better ideas this last year than I have."

Now, in conclusion, instead of telling a few jokes, as I had intended to do, I should like to touch again upon a few of the points that I have mentioned or discussed, to reactivate a few of the images in your minds.

As I indicated, dynamic modeling seems extremely promising to me. It seems to introduce a whole new dimension into the process of thinking. It promises to let you see the implications and consequences of your ideas—indeed, to let you see whether you have yet formulated a complete idea, capable of "running" in the computer and displaying its behavior to you.

"Pointers" in the text seem to me to have a different level of importance. It is merely a matter of convenience, and not in and of itself a breakthrough, to be able to explore an idea further, in a selected direction, by touching the appropriate one of several buttons or several patches of light on a display. On the other hand, I think that a sufficiently large set of mere conveniences can constitute a major factor in the intellectual process, and I am choosing pointers in the text as a representative of a set of conveniences, which I should like to see developed and polished and made available for widespread use. The other day I spent all morning, and had to work on through the lunch hour, on a list of fifteen references for a paper that was overdue and absolutely had to be put into the mail. Actually, I had to drop three of them because I could not get my hands on the complete citations. (I had read the articles, but I had not taken good notes.) How helpful it would have been to me then to have a console in an information network, to point to a citation in a bibliography and see, immediately, the list of references in the article cited, and then to point to one of those and see the article itself. With such an arrangement, it would not have been so hard to find the final page number of an article for which I had all the other bibliographic information.

"Passage retrieval" is a compromise between document retrieval and question-answering. It is essentially impossible to describe the contents of a book with three or four index terms or even with a dozen descriptors. With no more sophisticated apparatus, however, it is possible to describe the contents of a short passage, a paragraph for example, fairly well. A straightforward pass for progress in the information-retrieval sub-system, therefore, is to progress from document retrieval to passage retrieval.

Question answering seems so desirable to me that I do not want to let my mention of passage retrieval divert attention from the idea of question-answering systems. I think that research on such systems will lead to new ways of structuring and organizing information and perhaps also to a desirable formalization—increasing its expressive power without decreasing its convenience—of language for science and technology.

Four of the problems that stand in the way of realization of the on-line intellectual community are: 1) getting text into computer-processible form, 2) providing wide-band switchable communication channels, 3) providing economical yet adequate graphical displays and, 4) developing a good interaction language.

The best way to get text into computer-processible form is to generate it in that form and keep it in that form. There is no technical obstacle in the way of doing that right now. To convert from print on paper to computer-processible form requires either a human agency or automatic "character readers" or "page readers." Human capabilities are not well matched to the task. Automatic converters are available for limited applications and under development for general applications.

At the present time, wide-band switchable communication channels are not widely available through common carriers, and the available (narrower band or non-switchable) channels place undesirable restrictions upon the flexibility and capability of information networks. It seems desirable to set up, in an experimental way and at an early date, a pilot network with wide-band switchable channels.

Whereas computer output used to be mainly in the form of "printouts"—sometimes high piles of paper covered with numbers and capital letters—computers are now generating, in increasing numbers, graphs, diagrams, and pictures. To produce a dynamic graphical display requires, at the present time, a considerable amount of computing and a considerable amount of data transmission. It seems very important to make dynamic display simple, rugged convenient, and affordable—to place it on the desks of many people. An impressive effort is underway to achieve that goal.

And finally, interaction language: as I indicated, Calvin Mooers says he thinks he has that problem licked. I hope he has. As I see it, the essential problem is to find a formalizable subset of natural language that will seem natural to people, be easy to use—easy to stay within the limits of—and capable of subsumming—being translated into—most of the special-purpose languages that are intrinsic to time-sharing supervisory programs, problem-oriented compilers, and the various service packages that I have discussed.

Thank you very much.

ON-LINE MAN-COMPUTER COMMUNICATION

J. C. R. Licklider and Welden E. Clark

Summary

On-line man-computer communication requires much development before men and computers can work together effectively in formulative thinking and intuitive problem solving. This paper examines some of the directions in which advances can be made and describes on-going programs that seek to improve man-machine interaction in teaching and learning, in planning and design, and in visualizing the internal processes of computers. The paper concludes with a brief discussion of basic problems involved in improving man-computer communication.

Introduction

On-line communication between men and computers has been greatly impeded, during the whole of the short active history of digital computing, by the economic factor. Large-scale computers have been so expensive that -- in business, industrial, and university applications -- there has been great pressure to take full advantage of their speed. Since men think slowly, that pressure has tended to preclude extensive on-line interaction between men and large-scale computers. Inexpensive computers, on the other hand, have been severely limited in input-output facilities. Consequently, the main channel of on-line man-computer interaction, in the world of commerce and in the universities, has been the electric typewriter.

In critical military systems such as SAGE, the economic factor has been less restrictive and the need for man-computer interaction greater or more evident. However, the SAGE System, the pioneer among computerized military systems, is "computer-centered" -- less so in operation than in initial design, but still clearly computer-centered -- and that fact has had a strong influence upon man-computer interaction in military contexts. The computers and their programs have tended to dominate and control the patterns of activity. The scope for human initiative has not been great. Men have been assigned tasks that proved difficult to automate more often than tasks at which they are particularly adept.

For the kind of on-line man-computer interaction required in computer-centered military systems, a console featuring a Charactron display tube, a "light gun," and arrays of display lights and push buttons proved effective. At one time, about four years ago, at least 13 different companies were manufacturing such consoles -- different in minor respects but all alike in basic concept. Until recently, therefore, on-line man-computer communication could be summed up in the phrase: electric typewriters and SAGE consoles.

Increasing Need for Man-Computer Symbiosis

During the last year or two, three trends that bear upon on-line man-computer interaction have become clear. First, the cost of computation is decreasing; it is no longer wholly uneconomic for a man to think in real time with a medium-scale computer. Second, time-sharing schemes are beginning to appear in hardware form; the economic obstacle fades as the cost of a computer is divided among several or many users. Third, more and more people are sensing the importance of the kinds of thinking and problem solving that a truly symbiotic man-computer partnership might accomplish:

1. Military officers are eager to regain the initiative and flexibility of command they feel they lost to the computers in computer-centered command and control systems, but they want to retain the storage and processing services of the computers.

2. A few mathematicians are finding computers very helpful in exploratory mathematical thinking. Working closely with powerful computers and graphic displays, they are able to see at once the consequences of experimental variations in basic assumptions and in the formulation of complex expressions.

3. Several persons responsible for the programming of computerized systems are beginning to believe that the only way to develop major programs

rapidly enough to meet hardware time scales is to substitute, for the large crews of programmers, coders, and clerks, small teams of men with sophisticated computer assistance -- small teams programming "at the console." With statement-by-statement compiling and testing and with computer-aided bookkeeping and program integration, a few very talented men may be able to handle in weeks programming tasks that ordinarily require many people and many months.

4. In war gaming and even to some extent in management gaming, there is a growing feeling that the value of exercises will increase greatly if the pace can be speeded. On-line interaction between the gamers and computers is required to speed the pace.

5. In the planning and design of systems of many kinds, digital simulation is recognized as a valuable technique, even though the preparation and execution of a simulation program may take weeks or months. There is now a growing interest in bringing the technique under direct and immediate control of planners and designers -- in achieving the availability and responsiveness of a desk calculator without losing the power and scope of the computer.

6. In the field of education, some of the far-reaching possibilities inherent in a meld of "programmed instruction" and digital computers have become evident to many.

7. The complex equipment used in exploratory research, now in scientific laboratories and perhaps shortly in space, requires overall guidance by scientists but, at the same time, detailed control by computers. Several groups are currently interested in "semi-automatic laboratories."

The foregoing considerations suggest that man-computer communication will be an active field during the next few years and that efforts to facilitate productive interaction between men and computers will receive wide appreciation.

Man-Computer Complementation

The fundamental aim in designing a man-computer symbiosis is to exploit the complementation that exists between human capabilities and present computer capabilities:

a. To select goals and criteria -- human;

b. To formulate questions and hypotheses -- human;

c. To select approaches -- human;

d. To detect relevance -- human;

e. To recognize patterns and objects -- human;

f. To handle unforseen and low-probability exigencies -- human;

g. To store large quantities of information -- human and computer; with high precision -- computer;

h. To retrieve information rapidly -- human and computer; with high precision -- computer;

i. To calculate rapidly and accurately -- computer;

j. To build up progressively a repertoire of procedures without suffering loss due to interference or lack of use -- computer.

It seems to us that the functions listed, a through j, are the essential ingredients of creative, intellectual work. In most such work, they are not strung together in simple temporal sequence, but intimately interrelated, often operating simultaneously with much reciprocal interaction. For that reason, the conventional computer-center mode of operation, patterned after that of the neighborhood dry cleaner ("in by ten, out by five"), is inadequate for creative man-computer thinking; a tight, on-line coupling between human brains and electronic computers is required. We must amalgamate the predominately human capabilities and the predominately computer capabilities to create an integrated system for goal-oriented, on-line-inventive information processing.

In associating capabilities a through f primarily with human beings and capabilities g through j primarily with computers, we are of course describing the present state of affairs, the technology in which we now must work, and not asserting any essential discontinuity between the domains of human and machine information processing. There is always the possibility that human competence in g through j can be significantly increased, and it is almost certain that machine competence in a through f will develop rapidly during the next decades. At present, however, we think that man and computer complement each other, and that the intellectual power of an effective man-computer symbiosis will far exceed that of either component alone.

Steps Toward Man-Computer Symbiosis

To bring men and computers together in tight synergic interaction, we must make advances in several contributory fields. Among the most important appear to be: time sharing and other possible solutions to the economic problem; memory and processor organization for contingent retrieval of information and programming of procedures; programming and control languages; and on-line input-out equipment, including integrated displays and controls. The groups with which we are associated have been working in those areas. It is disappointing to find that the areas appear to grow more rapidly than we can explore them and to realize how trivial are our accomplishments relative to the requirements. However, we are beginning to have some tangible results, and it may be worthwhile to illustrate briefly the following three:

1. A system for computer-aided teaching and computer-facilitated study.

2. A man-computer system for use in the planning and design phases of architectural and constructional problems.

3. Two programs that display aspects of the internal processes of a computer during execution of programs.

Computer-Aided Teaching and Learning

Exploration of ways in which a computer can facilitate teaching and learning raises several problems in man-computer communication. Effective teacher-student relations involve nearly continuous interchange of information, and anything that interferes with the communication is likely to impair effectiveness.

The importance of rapid, convenient student-teacher communication has demonstrated itself quite clearly in experiments with a simple, automated, language-vocabulary-teaching system. One version of the system, Tutor 1, uses a computer typewriter as the communication link between the student and the machine. Let us examine first the procedure briefly and then the problem of typewriter communication between student and computer.

The typescript of the sample German-English lesson, shown in Fig. 1, illustrates the procedure. In a session with Tutor 1, the student initiates activity by typing "O." The computer then asks him whether or not the student wants detailed instructions. The student replies by typing "s" for "No, start the lesson." The computer selects a German word at random and presents it. The student then types an English word that he thinks is equivalent in meaning and terminates his response by hitting the "centered-dot" key. If the response is acceptable to the computer, the computer types "+" for "correct." (Brevity is crucial.) If it wants another English equivalent, the computer then types the German word again. If it does not want another English equivalent, it types the item score and the cumulative score to date and offers a comment on the student's performance. When the student misses a word, the computer types "-" for "incorrect" and "ta" for "Do you want to try again?" If the student replies "y" for "yes," the computer presents the m[illegible]d German word again. If the studen. replies "n" for "no," the computer types an English equivalent and requires the student to copy it. And so forth, as illustrated.

The first thing we found out about Tutor 1 was that students (children and adults) who type well like to use it, whereas students who do not type well may be attracted at first but soon tire of the lesson. During the development of the program, several variations were tried out. Those that speeded the pace of presentation or streamlined the procedure of response were the most successful. A version that eliminated the requirement that the student type the response -- that allowed him to respond vocally or subvocally and then trusted him to score his answer -- was greatly preferred by students who typed only fairly well or poorly; good typists liked "type-the-answer" versions better. With one type-the-answer program, designed to avoid all possible interruptions, students who type well sat for two or three hours at a time, industriously adding new German, French, or Latin words to their vocabularies, occasionally checking their cumulative scores, but never asking for coffee breaks.

Twenty years from now, some form of keyboard operation will doubtless be taught in kindergarten, and forty years from now keyboards may be as universal as pencils, but at present good typists are few. Some other symbolic input channel than the typewriter is greatly needed.

We make some use of the light pen and "light buttons" associated with multiple-choice questions and answers displayed on the oscilloscope. When the alternative courses of action can be laid out in a tree-like branching structure, it is convenient to let the computer ask a multiple-choice question via the oscilloscope display and to arrange the program in such a way that touching the light pen to the button associated with particular response brings forth a subordinate question appropriate to that response. With four familiar alternatives, the operator can make a selection every second or two (i.e., select at a rate of 1 or 2 bits per second), which is adequate for some purposes, though not truly competitive with ta[illegible]ing or expert typing (up to 20 and [illegible]0, respectively, bits per second in [illegible]ons in which the pace is not li[illegible] by judgmental processes).

In computer-aided teaching, the restriction to a small ensemble of multiple-choice responses sometimes precludes truly convenient, natural communication, and it leads into controversy with those who think that the "constructed response" methods are inherently superior. In our work thus far, it appears that the difference in effectiveness between constructed-response and multiple-choice procedures is small compared with the difference between a convenient, fast response mode and an inconvenient, slow one. Convenience and speed influence markedly the student's enjoyment of his interaction with the computer and the lesson. The most important sub-goal, we believe, is to maximize the amount of enjoyment, satisfaction, and reinforcement the student derives from the interaction. And good student-teacher communication appears to be absolutely essential to that maximization.

Good man-computer communication is important, also, in systems in which the computer serves to facilitate learning without taking the initiative characteristic of most human teachers. We are working on a system, Graph Equation, the aim of which is to facilitate a student's exploration of the relations between the symbolic and graphical forms of mathematical equations.

The program displays, for example, the graph of a parabola (see Fig. 2), and below the graph it displays the equation,

$$y = a(x-b)^2 + c \quad . \qquad (1)$$

Associated with each of the parameters, a, b, and c, is a potentiometer that controls the value of the parameter. The student can vary the parameter values at will and see, directly and immediately, the correspondence between the configuration of those values and the shape of the parabola. We are in the process of substituting, for the potentiometers, "light scales" with pointers operated by the light pen and of displaying numerical coefficients instead of letter parameters on the oscilloscope. Even in the present crude form, however, the system is an effective aid. It presents the linkage between the symbolic and the graphical representation in a dynamic way. It lets the student explore many more configurations than he could explore if he had to plot graphs on paper. And it lets him see "answers" while he is still thinking about "questions" -- something we think may be very important in learning.

We plan, of course, to have the Graph Equation system operate dynamically in the other direction, also. The student will draw a rough parabola. The computer will fit an accurate parabola to the rough one and display the accurate one. At the same time, the computer will calculate and display the coefficients. The completed system, we hope, will provide the student with a flexible, responsive study tool. It will not have much practical value as long as it is restricted to parabolas, of course, but it should be possible, with a faster machine, to handle Fourier transforms, convolution integrals, and the like.

Often the student must manipulate characters of text with reference to pictorial or graphical information. We have been able to handle some of these functions but still lack an integrated system for communication of interrelated symbolic and pictorial information between the student and the computer.

* The work on computer-aided teaching and learning is supported by the United States Air Force under Contract No. AF33(616)-8152 and is monitored by the Training Psychology Branch, Behavioral Sciences Division, Aerospace Medical Research Laboratory, Aeronautical Systems Division, Air Force Systems Command.

Computer-Aided Planning and Design

In starting to explore the field of computer-aided planning and design of systems, we have focused on hospitals. Hospitals pose very interesting and difficult -- and we believe to a large extent typical -- system problems because the relative importance of the various planning factors varies from one local context to another, because so many kinds of interest and experience are relevant and eager to make themselves felt, and because tangibles and intangibles are so intimately interrelated. One of the main aims in setting up a computer system to facilitate hospital planning is therefore to provide a means through which general guide lines and local constraints can interact. Another is to permit several persons with various backgrounds and interests to look at tentative plans from their own differing points of view and to manipulate and transform the plans during the course of their discussion. A third (since the intangible factors must ultimately be converted into tangible, physical form) is to give the planners a way of sketching out their suggestions and then relating them, quickly and conveniently, to all the other considerations that have been introduced.

Coplanner, a computer-oriented planning system with which we have been working, is essentially:

1. The PDP-1 computer with typewriter, oscilloscope, light gun, and magnetic-tape unit.

2. An ensemble of empirical data describing the commerce (communication of information, transportation of objects, and movement of personnel) that goes on in typical hospitals.

3. An ensemble of programs for accepting, storing, retrieving, processing and displaying information.

In our work thus far with Coplanner, we have experimented with hypothetical hospital situations, using two or three members of our own group and an outside expert or two as the planning team. In preparation for a team planning session, we load into core the programs most likely to be wanted first and make ready the tapes containing the rest of the programs, the ensemble of empirical data, and the material generated in previous planning sessions.

The members of the planning team then sit before the oscilloscope. They start to discuss, for example, a hospital that is expanding its plant and must relocate and enlarge its X-Ray Department. They come to the question: Where should the X-Ray Department be located, relative to the other departments and facilities, in order to minimize the cost of its interdepartmental commerce?

One of the members of the team retrieves, through the computer, a record of previous analyses that provides data on the major components of X-Ray commerce:

a. transport of patients,

b. trips by doctors and internes to supervise x-ray examinations, to study x-ray films, and to consult with personnel of the X-Ray Department,

c. communication not involving movement of personnel, and

d. routine personnel activities such as entering or leaving duty stations and taking meals and breaks.

In response to typewriter commands, the computer then prepares and displays several graphs to summarize the quantitative commerce data. The graphs are mainly distribution graphs and histograms. Since they refer to hospitals of the same type and size, but not to precisely the one being planned, intuitive judgment suggests modifications to take into account various features of the local context. Members of the team make the adjustments in the process of discussion. All they have to do to increase the height of a bar in a histogram is to touch the top of the bar with the light pen and lift it to the desired level. Usually there will be discussion of the change and several successive adjustments of the graph. If the graph is a frequency histogram, raising one bar automatically lowers the others. Efforts have been made to create a favorable context for exercise of the planners' intuitive judgment. Provision is made for labeling, filing, and later processing alternative quantitative summaries if the planners do not agree fully on a single summary.

Figure 3 shows two graphs of the type developed in this phase of the planning discussion.

The planners of course have several different ideas concerning the new layout of the hospital. To make these ideas concrete, they display prepared floor plans -- a separate plan for each floor of each version -- or sketch them directly on the screen of the oscilloscope, using the light pen as a stylus. Sketching is facilitated by the computer, which posts a background outline plan having the proper dimensions and showing existing structures that cannot readily be altered. In its "straight-line" mode, the computer plots straight lines even if the sketcher's lines are wavy. In its "preferentially-parallel-to-axes" mode, the computer plots lines precisely parallel to the x axis if the sketcher makes them approximately so, etc. On their sketches, which they can readily file away and recall for revision, the planners label the various departments and the stairs, elevators, dumbwaiters, etc. Each label, typed on the typewriter, appears at the top of the oscilloscope screen, and then is adjusted to desired size, trapped by the light pen, moved to its proper location on the plan, and dropped there. Each label serves as a storage and retrieval tag for the sketch to which it is attached. The plan can therefore be made up in small parts and displayed as a whole. Within a few months, the program will be capable of filing and retrieving assemblies by name.

Having tentatively worked out their ideas about X-Ray commerce and sketched several physical arrangements, the planners now turn to the problem of evaluation. First, they select one of the commerce-distribution hypotheses and one of the physical layouts for examination and designate them as input data to a fast-time simulation program that converts the commerce pattern from a set of statistical distributions to a sequence of individual trips and calls. Then they apply a program that finds the best routes for the trips and calls and computes expected durations and costs. In calculating cost, the amounts of time spent by various categories of personnel are weighted appropriately. The weighting function can, of course, be discussed and varied by the planning team. The calculated cost provides an evaluative measure for the selected layout under the selected commerce hypothesis. Actually, several different evaluative formulas are ordinarily used. The corresponding cost figures are saved for later use.

The evaluative procedure is then applied to other combinations of layout and commerce hypothesis. When all the combinations have been treated, the planners recall the cost figures and compare them. On the basis of this comparison, they usually discard all but the best two or three schemes. They modify the best ones, introduce new considerations developed as a result of the study, and make further simulation and evaluation runs.

Figure 5 shows an output-display prepared by the evaluation program.

If the planners are inclined to go into detail in certain areas, Coplanner is prepared to assist them. An elevator-simulation routine, for example, provides a dynamic display of elevator operation under the loads specified by a selected commerce-distribution hypothesis and a determination of best routes. Direct dynamic simulation has important roles to play in work of this kind because it appeals to non-mathematical planners more directly than does queuing-theory analysis performed with the aid only of symbolic assumptions and equations. Sometimes dynamic simulation is a substitute for the abstract theory; sometimes it is an introduction to the abstract theory; sometimes it is a check upon the abstract theory.

In the preceding discussion, one small facet of the hospital planning problem was used to illustrate the approach we are advocating. We have developed a fairly powerful system to facilitate planning in the area discussed and in related areas. In other areas, the system is only starting to develop. The computer parts of the system are not intended, we should emphasize, to calculate optimal plans or designs; they are intended to provide memory, manipulative, computing, and display functions in such a way that they can be integrated with the more intuitive functions supplied by the human parts of the system.*

Visualizing the Operation of Computer Programs

The covertness of the operation of the programs of electronic computers makes it difficult for us to develop of them the same direct, perceptual kind of comprehension that most of us have of familiar mechanisms, the moving parts of which we can see and touch. The great speed with which the programs run

*Coplanner was developed under USPHS Project W-59, Collaborative Research in Hospital Planning. J.J. Souter, A.I.A., and M.B. Brown, M.D., past and present Project Directors, and J.I. Elkind and W.E. Fletcher participated in the formulation of the system.

adds to the difficulty, of course, but we are in the habit of solving the speed problem -- for example, through "slow motion." Unless a window or a plastic model will provide solution, however, we are in the habit of letting the problem of covertness go unsolved. We tend to be satisfied with extremely indirect procedures for interrogation and for drawing inferences. In the case of the human brain, for example, a neurophysiologist may try to construct a model of an internal process on the basis of waveforms recorded from 10 or 100 of the million or billion neurons involved, plus microscopic inspection of several slices of the tissue prepared in such a way as to render visible one or another feature of its architecture. Our approach to computers is comparable: When trouble arises and the results do not turn out as we expect them to, we may try to figure out what is going on by examining with the aid of a typewriter control program the contents of supposedly critical registers, one register at a time, even though we cannot hope to look at more than a hundred of the thousands or tens of thousands of registers involved. Alternatively, we may ask for a printout of the contents of many registers at some particular point in the running of the program, hoping to reconstruct the dynamic pattern of events from the static view provided by the printout.

Considering the problem posed by covertness leads one to think about the procedure, introspection, used as the basic experimental tool in such early psychological laboratories as Wundt's and Titchener's, and still widely employed in the development, if not in the formal testing, of psychological hypotheses. Human introspection is a useful procedure despite its severe shortcomings. How much more useful it would be if those shortcomings were overcome -- if all the processes of the brain were accessible to the reporting mechanism; if the reporting mechanism could describe all the aspects of those processes; if the reports were detailed and accurate; if introspecting did not interfere with the process under examination.

That thought leads immediately to the idea of a computer analogy to, or improvement upon, human introspection. Clearly, computer introspection can be freed of all the shortcomings mentioned, except the last, and the last one can be turned to advantage. Displaying its own internal processes will of course interfere with the computer's execution of its substantive programs, but only by appropriating memory space and time. Often, there is memory space to spare, and programs normally run too fast for the operator to follow them perceptually. The conclusion, therefore, is that it might be interesting to experiment with programs that display various aspects of the internal operation of the running computer.

Two such programs, written for the PDP-1 computer, are Program Graph and Memory Course. Program Graph was written with the hope that it would facilitate the introduction to computer programming and provide displays through which certain individual or "personality" characteristics of programming style may be seen. Memory Course was intended mainly for use in "debugging" computer programs. Both programs make use of a trace routine that executes the instructions of the object program in normal, running sequence and, after each execution, (a) records in core registers the contents of the accumulator, input-output register, and program counter, (b) does some incidental bookkeeping, and (c) turns control over to the display routines. The display routines develop graphs of types to be illustrated.

The graphs displayed by Program Graph are illustrated in Fig. 6. In Fig. 6A, as each instruction of the object program is executed, its location is plotted as ordinate, and the cumulative number of executions is plotted as abscissa. (Roughly speaking, therefore, the graph represents active memory location versus time.) Both the ordinate and the abscissa scales run from 0 to 1777 (octal). The interpretation of the graph is quite direct: straight-line parts of the graph represent straight-line parts of the program; jumps represent jumps or subroutine calls; serrations represent loops. The subroutine structure is revealed clearly. If the operator knows the general course the program should follow, he can detect and locate gross faults readily.

Figures 6B-6D show, for the same object program, the contents of the accumulator as a function of time. The abscissa scale again runs from 0 to 1777. In Fig. 6B, the ordinate scale covers the range from -2^{17} to 2^{17}; in Fig. 6C, it runs from -2^{13} to 2^{13}; and in Fig. 6D, it runs from -2^{7} to 2^{7}. Evidently, the accumulator is heavily engaged in computations involving small numbers.

Figures 6E-6G show, for the input-output register, what Figs. 6B-6D showed for the accumulator.

Figure 6H displays the instruction codes. Each instruction code is a two-digit octal number. The ordinate scale extends from 02 (and) to 76 (operate, which is an augmented instruction, the augmentation not shown). The most heavily used instructions are 20 (load accumulator with contents of) and 24 (deposit contents of accumulator into).

Figure 6I displays the memory references and the augmentations. Both are shown here; either class may be suppressed.

In Fig. 6J, all the graphs of Figs. 6A-6I are displayed simultaneously. Because the points are shape-coded, it is possible, though difficult, to reconstruct in detail the sequential pattern of a program from graphs of this type. They might therefore find application in historical documentation of very critical computations, such as those concerned with rocket launching and air defense. In any event, the composite representation conveys an impression of the great capability computer's have to introspect upon their internal processes and report about them in detail.

As we leave this topic, we should perhaps mention the phenomenon that appears when Program Graph is equipped for recursive operation and set to display its own operation. The result, of course, is only a recursion of beginnings, terminated by overflowing of the pushdown list. This effect is not entirely foreign to human introspection.

The routine, Memory Course, plots a grid-like map of memory and displays, against the background of the grid, the course through memory taken by the object program. The dots of the grid represent memory registers, and the dot that represents the register containing the instruction presently being executed is encircled. As control passes from one instruction to another of the object program, a line is drawn connecting the corresponding registers. The effect is hard to illustrate in a still photograph because its effectiveness depends largely upon the kinetic character of the display. However, Fig. 7 may convey an approximate impression. Because the photograph integrates over time, it shows a longer segment of the program's course through memory than one sees when he views the oscilloscope directly.

Program Graph and Memory Course are but two of many possible schemes for displaying the internal processes of the computer. We are working on others that combine graphical presentation with symbolic presentation. Symbolic presentation is widely used, of course, in "debugging" routines. If many symbols are displayed, however, it is not possible to proceed through the program rapidly enough to find errors in reasonable time. By combining graphical with symbolic presentation, and putting the mode of combination under the operator's control via light pen, we hope to achieve both good speed and good discrimination of detailed information.*

Problems to be Solved in Man-Computer Communication

Among the problems toward which man-computer symbiosis is aimed -- problems that men and computers should attack in partnership -- are some of great intellectual depth and intrinsic difficulty. The main problems that must be solved to bring man-computer symbiosis into being, however, appear not to be of that kind. They are not easy, but their difficulty seems due more to limitations of technology than to limitations of intelligence.

What we would like to achieve, at least as a sub-goal, is a mechanism that will couple man to computer as closely as man is now coupled to man in good multidisciplinary scientific or engineering teams.

For a psychologist to telephone a mathematician and ask him, "How can I integrate $\int (dx/(1-x^2))$?" required, in one empirical test, 105 seconds, including 65 seconds devoted to dialing and formalities with the mathematician's secretary plus 32 seconds of preamble with the mathematician. To ask the mathematician that particular question is, of course, wantonly to waste his time -- 170 seconds of it, in this case, since all he needed to say was: "Look it up in any table of integrals," and all he did say was that sentence embedded in a context of encouragement and courtesy. (To find a table of integrals, and then to l[illegible] [illegible]ry took the psychologist, who [illegible] [illegible]evant formula on his first [illegible] and [illegible]arted over at the beginning after sc[illegible]ng 569 entries, 7 [illegible] minutes and 25 seconds.)

*Preliminary study of these displays of internal computer processes was supported through a contract with the Council on Library Resources.

What we would like the computer to do for us, in the context of the foregoing example, does not require such a deep solution as an algorithm for formal differentiation; it requires merely good communication and retrieval. We would like to have an arrangement that would let the psychologist write on his desk input-output surface:

$$\int \frac{dx}{1-x^2} = \text{what?} \quad , \qquad (2)$$

and then let the computer replace the "what?" -- in perhaps 2 or even 20 seconds -- by the expression:

$$\frac{1}{2} \log \frac{|1+x|}{|1-x|} \quad . \qquad (3)$$

In the example, our aspiration would not stop, of course, with the display of expression (3) in symbolic form. The psychologist would surely want elucidation. His next request might be "Please plot a graph," or, if the novelty were worn off, simply "Graph." We would then like to have the computer display on the input-output surface a figure such as Fig. 140 in Dwight's Tables.[3] The figure would, of course, be plotted from computed points, not retrieved from storage. It would be no trouble for the computer to calculate and present it in a few seconds. (For the psychologist to plot a rough graph of the integral took 12 minutes. For another person to locate a published figure (Dwight's) took 17 minutes: a little more than 16 to get to the document room and thumb through books that did not contain the figure, and then a little less than 1 to pick up Dwight's book and scan as far as page 29, where the figure is.)

Five Immediate Problems

Consideration of many such examples as the foregoing and of what would have to be done to put the computer's clerical power conveniently and responsively under the control of human initiative suggests that the main essential steps to man-computer symbiosis are the following:

1. For the economic reason mentioned in the Introduction, develop systems for sha[illegible] the t[illegible] digital compute[illegible] am[illegible] users on a split-mill[illegible]. With J. McCarthy and S. [illegible]len, one of us is working on a small-scale prototype of such a system with five user stations.*

2. Devise an electronic input-output surface on which both the operator and the computer can display, and through which they can communicate, correlated symbolic and pictorial information. The surface should have selective persistence plus selective erasability; the computer should not have to spend a large part of its time maintaining the displays. The entire device should be inexpensive enough for incorporation into a remote console. An interesting approach to the man-to-machine part of this problem is being taken by Teagher.[4] We are employing an oscilloscope and light pen to fulfill the function, but they do not meet the cost and selective-persistence requirements.

3. Develop a programming system that will facilitate real-time contingent selection and shaping of information-processing procedures. The system must permit trial-and-error operation based upon "tentative computation": it will often be necessary to go back to the beginning or to an intermediate point and to try a different attack. We are experimenting with interpretive systems for on-line assembly of procedures from sub-procedures,** and we are planning work on console compiling, intermeshed with testing and contingent application of procedures as they are required by the human components of the man-computer partnership.

4. Develop systems for storage and retrieval of the vast quantities of information required to support, simultaneously at several user stations, creative thinking in various areas of investigation. For economic reasons, such systems must almost certainly be hierarchical, moving information from large-capacity, fast-access storage as (or shortly before) the information is needed. To achieve the desired effectiveness, it will probably be necessary to make advances in the direction of parallel-access, associative memory with preliminary activation based upon apperceptive relevance. In this area, we believe, much fundamental study of

---

* The work on time-sharing is supported by Grant R68568 from the National Institute of Health.

** One of the systems is based on a typewriter control program, Process Control, written by D. Park.

information indexing and of memory organization will be necessary before truly satisfactory hardware can be designed, but it appears that quite a bit can be accomplished directly through development of memories -- probably read-only memories -- with very large capacity and moderately fast access and through the application of existing keyword or descriptor techniques.

5. Solve the problem of human cooperation in the development of large program systems. It appears that the development of effective human cooperation and the development of man-computer symbiosis are "chicken-and-egg" problems. It will take unusual human teamwork to set up a truly workable man-computer partnership, and it will take man-computer partnerships to engender and facilitate the human cooperation. For that reason, the main tasks of the first time-sharing computer system with many remote stations may well be in the areas of language and procedure development.

In the five problem areas just mentioned, "to begin is everything," even if it is necessary at first to build research systems along lines that would be uneconomic for widespread application. If we neglect the arguments of economics and elegance we can think at once of ways of solving, or at least starting to solve, the problems. These ways will probably be adequate to test the premise that man-computer symbiosis will be able to achieve intellectual results beyond the range of men alone or of computers programmed and operated in conventional ways.

Four Long-Term Problems

In four other areas, the problems to be solved appear -- if they are not simplified beyond recognition in the effort to make them tractable -- to be deep and intrinsically difficult. The first of these areas is computer appreciation of natural written languages, in their semantic and pragmatic as well as in their syntactic aspects. The second is computer recognition of words spoken in context by various and unselected talkers. The third is the theory of algorithms, particularly their discovery and simplification. The fourth is heuristic programming. We believe that these four areas will in the long term be extremely important to man-computer symbiosis, but that man-computer partnerships of considerable effectiveness and value can be achieved without them. We suspect that solutions in these areas will be found with the aid of early man-computer symbioses, rather than conversely.

An Intermediate Problem

A system combining an elementary form of computer speech recognition, computer recognition of carefully hand-printed characters, and simple light-pen editing techniques, would provide, we think, a very convenient and effective communication link between man and computer. The problems involved in creating such a system seem to us to be intermediate between the five and the four. They may be solved in time to permit the use of correlated voice-hand input in the earliest man-computer partnerships, but, if the required solutions are not ready, it would not be good to wait for them.

References

1. James J. Souder, Madison Brown, Weldon Clark and Jerome Elkind, Collaborative Research in Hospital Planning, United States Public Health Service, Project W-59, to be published in the spring of 1962.
2. B. O. Peirce, A Short Table of Integrals, 3rd edition, Boston: Ginn and Company, 1929.
3. H. B. Dwight, Table of Integrals and other Mathematical Data, 3rd edition, New York: The Macmillan Company, 1957.
4. H. M. Teager, Semi-Annual Progress Reports dated January 1961, June 1961 and January 1962, M.I.T. Computation Center. Also, Quarterly Progress Reports 2, 3, 4 and 5 of the Real-Time Time-Sharing Project, M.I.T. Computation Center.

```
O

Good afternoon.  This will be
your German-English Lesson No. 4.
If you are ready to start at
once, please type "s."  If you
would like to review the
procedure, please type "p."

s

reichen          to hand. +
reichen          to pass. +
   64               64   good
öffnen           to offer. - ta   n
to open          to open.
  -120             -56   poor
arbeiten         to arbitrate. - ta   y
arbeiten         to look. - ta   n
to work          to work.
  -184             -240  Dumbkopf!
kochen           to cook. - ta   y
kochen           to boil. +
    0              -240  okay
öffnen           to open. +
   64              -176  hot dog
rauchen          to smoke. +
   64              -112  admirable
arbeiten         to work. +
   64               -48  good
kochen           to boil. +
   64                16  very good
machen           to make. +
   64                80  Keep it up.
   80

That's it.  You did well.  I'll
be looking forward to the next
lesson.
```

Fig. 1 -- Typescript of a short illustrative lesson in which a computer plays the role of instructor in language-vocabulary drill. The student typed "O" to start the session, "s" to start the lesson, the English words (and terminating dots) in right-hand column, and the abbreviations of "yes" and "no" in response to the computer's "ta" ("Do you want to try again?"). The computer typed the remainder, including scores and comments. The procedure is explained in the text.

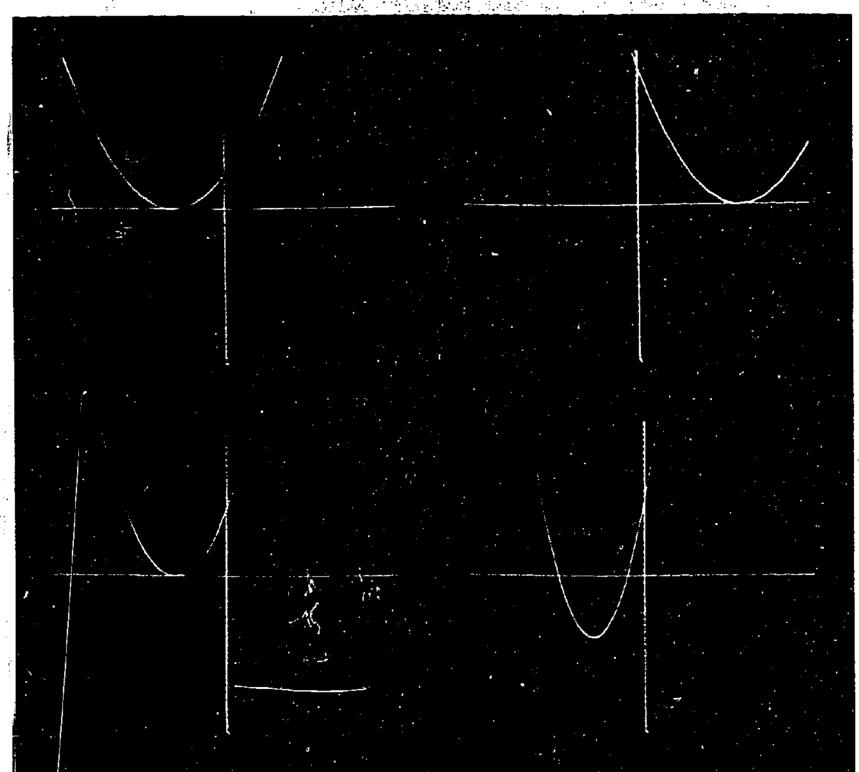


Fig. 2 -- Parabolas displayed by computer to facilitate student's exploration of relations between graphical and symbolic representations of mathematical expressions.

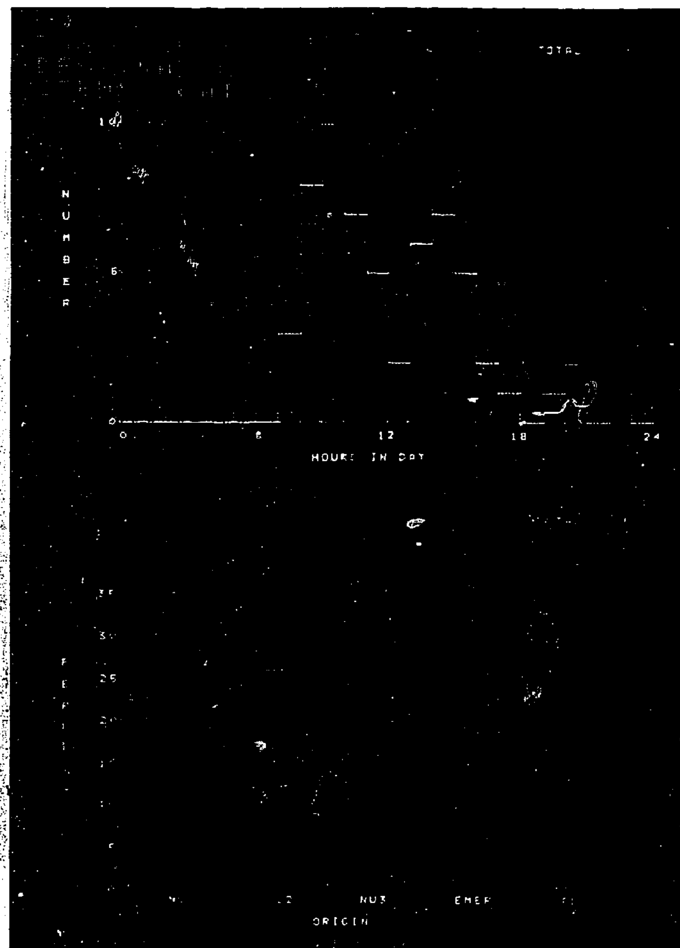


Fig. 3 -- Oscilloscope displays of several aspects of a projected inter-departmental "commerce" pattern in a hypothetical hospital. The upper graph shows the anticipated time distribution of patient transport trips to the X-Ray Department. The lower graph shows the conditional distribution of those trips among departments of origin.

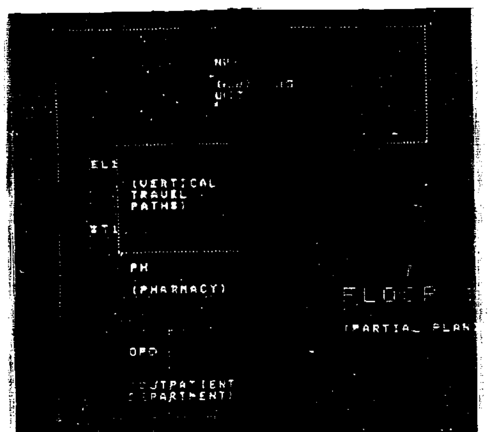


Fig. 4 — Oscilloscope display of an outline planning sketch of one floor in a hypothetical hospital.

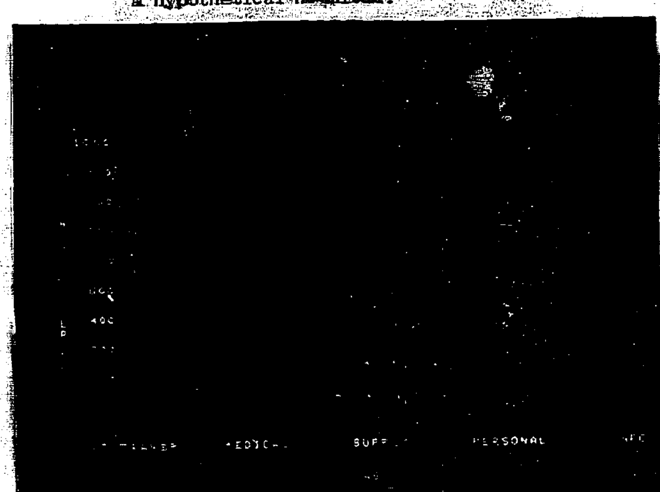


Fig. 5 — Oscilloscope display of the performance, in respect of "commerce," of a proposed hospital plan. Scale time is defined as man-minutes spent in transit. The contributions of individuals to this quantity are weighted by coefficients associated with their personnel categories.

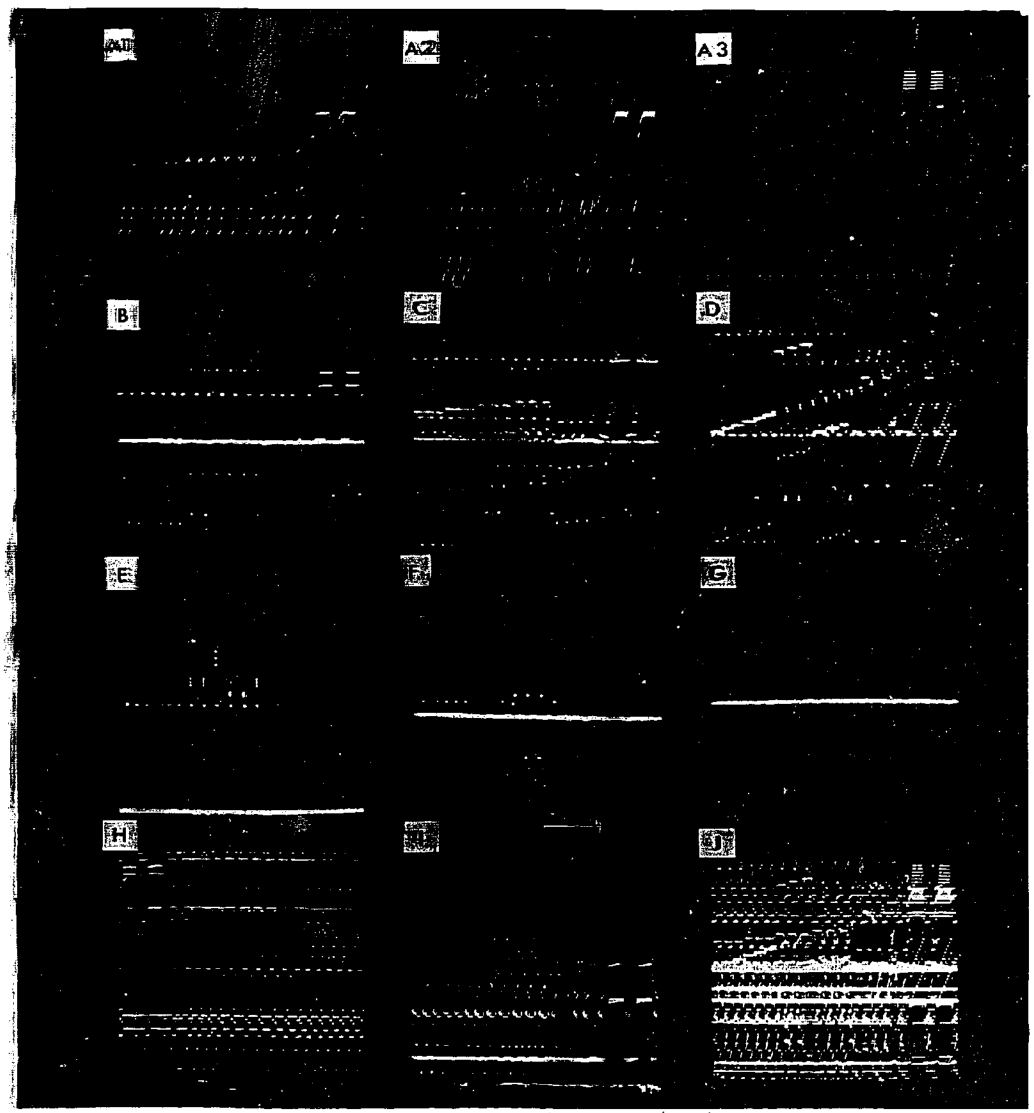


Fig. 6 — Photographs of oscilloscopic displays made by Program Graph. See text for interpretation.

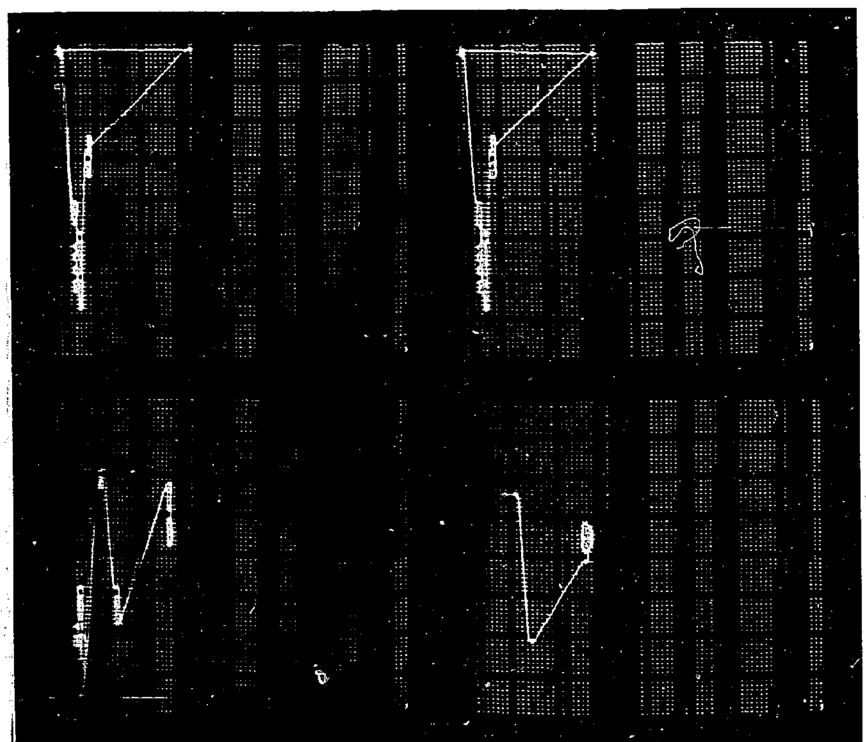


Fig. 7 — Photograph of oscilloscopic display made by Memory Course. See text for interpretation.

1968
EIGHTEENTH CONFERENCE ON SCIENCE, PHILOSOPHY AND RELIGION IN THEIR RELATION TO THE DEMOCRATIC WAY OF LIFE

EDUCATION, INSTITUTIONS, AND THE FUTURE

Section I: Sociotechnological Change and Education

A Sociotechnical Crux in the Application of Computers to Education*

J.C.R. Licklider

Massachusetts Institute of Technology

Cambridge, Massachusetts

(To be discussed at session on Wednesday, August 28, from 10:00 a.m. to noon, at The Jewish Theological Seminary of America, 3080 Broadway, New York, New York)

*The ideas described in this paper arose in part in connection with the research program of Project MAC, an M.I.T. research project sponsored by the Advanced Research Projects Agency, Department of Defense, under Office of Naval Research Contract Nonr-4102(01). Reproduction of this report, in whole or in part, is permitted for any purposes of the United States Government.

Introduction

If I understand the purpose of this Conference correctly, it is to engender discussion--and through discussion solution, or if not solution at least an intellectual climate within which solution is possible--of problems that are in part technical and in part moral or ethical. I think that within the broad intersection of computers and education there is such a problem, and I think that it needs discussion of the kind this Conference can give it.

There is, however, one difficulty. It made itself evident at the preliminary meeting at which a rough outline of this paper was examined by a small group. The difficulty is that the problem I have in mind--the problem I propose for discussion--is a real problem only if, as I believe, computers do indeed hold the potential for significant contributions to education. The members of the small previewing group to which I referred were skeptical of that premise, and the preliminary meeting was devoted, therefore, not to discussion of moral or ethical questions pertinent to realization of such a potential but to questioning what I supposed would be accepted as hypothesis: that, if developed properly for the purpose, computers can make major contributions to education.

The simplest tactic for suppressing such questioning is to reassert the premise more strongly. Even though I realize that tactic will not be effective here, I want to exercise it. I believe a stronger statement is warranted: If properly developed for the purpose, the computer can be the instrument through which the present era of despair in education is turned into a golden age.

"Properly developed," in the foregoing assertion, covers a large amount of ground. First, computers by themselves are not going to do much for education. People have to shape them for the task and apply them to it. Second, people do not know exactly what to do to develop computers properly to contribute in a major way to education. People know that much programming and a general reduction of costs are required, but few realize that it will not suffice merely to translate textbooks into computer programs and to arrange for a substantial educational discount. Third, people by and large either are not acquainted with computers at all or are acquainted with a kind of computing that does not hold much promise for educational applications. The kind of computing that does hold promise is on-line, interactive, multiple-access computing. Fourth, on-line, interactive, multiple-access computing is not, however, a magic key; much research, much programming, and much adjustment of major institutions will be required to bring about anything approaching an educational revolution.

Now, against the background of those introductory statements, let me restate the main question that I propose for discussion:

Given that a major research and engineering effort, carried out over a period of 10 to 15 years in close interaction with efforts of actual application in educational institutions, could make a fundamental and pervasive improvement in education, but given also that the efforts would involve deep changes in several fields and institutions, what should--and what can--our society do to ensure realization of the potential?

That is to say: Grant for the moment the assumption that it can be done, and note that it will not be easy and that vested interests will be affected. Then, how should we proceed to take advantage of the promise computers hold out for education?

Such a question of course requires sharpening before it can be discussed fruitfully. What are the obstacles that stand in the way of realizing the computer's potential for improvement of education? What are the dangers? What are the vested interests that will tend to contravene? In the next section, I shall try to effect the required sharpening.

Then, in the final section, I shall return to the assumption that computers do hold out a truly great promise. I shall not be able, within the constraints of this paper, to establish the assumption thoroughly or even to describe the potential fully as I see it from my point of view. But I shall do the best I can along that line, for the preliminary evidence suggests that you may be unwilling to enter wholeheartedly into an examination of the morality of social response to technological challenge until you believe that there is a technological challenge.*

Note well the word "challenge." I do not say that computer technology is offering something gratis that society may fail to lift its finger to accept. I say (a) that computer technology is challenging society to develop computer technology and educational methodology together into an advanced and effective sociotechnical process that will

*After making the commitment to prepare this paper I learned that Professor A. G. Oettinger was writing a book on the over-all sociotechnical situation of computers in education. Oettinger's effort, part of the Harvard study of Technology and Society of which Professor Mesthene is the Director, is a major one. In February, Oettinger summarized his views at a colloquium on Education and Computers at M.I.T., and in May the draft of his book was the focus of a two-day meeting at Harvard. Since making the commitment, therefore, I have had the benefit of exposure to Oettinger's thinking. Although my point of view and my assessment are not identical with his, I must say that this paper can be no more than a place holder for Oettinger's Run Computer Run.

strongly promote and support the general weal, (b) that the development will require not only great effort but also major adjustments of certain major institutions, and (c) that society--ill prepared to assess the costs and values, conservative in its response to any call for major readjustment, and on the whole poorly organized and motivated to meet the challenge--may pass it by or turn it aside with some grossly inadequate gesture of response.

Obstacles and Dangers

The main sources of difficulty in society's response to technological challenges, I think, are (a) that society as presently constituted cannot decide and act as a whole and (b) that the parts of society that are decision and action units are governed primarily not by the value-and-cost function of the commonwealth but by individual value-and-cost functions of their own. ("Payoff function" is too crass a term. It connotes a deliberateness in subversion of society's proper interests that I do not wish to ascribe to anyone or any organization.)

Among the parts of society that are playing important roles more or less well in determining the course of computers in education are, of course, the computer industry, the education profession, the government, and the many groups and individuals of the Establishment. To think in terms of such broad categories is almost not to think at all, I realize, but within the limits of this paper I cannot penetrate more deeply, for the subject explodes if one touches the stratum just below the surface.

First, the computer industry: Industry typically operates on a time scale of two to six years (i.e., seeks in each major undertaking to make a profit within such a period), whereas my estimate for the realization of the computer's promise to education was 10 to 15 years. It is simply "in the scheme of things," therefore, for industry to take too short a view and to try to move too quickly from research to "exploitation of the market." But therein lies a very great danger to the interests of the over-all society. Premature efforts at exploitation can discredit the whole undertaking and ruin the computer's chance

31-464 O—69——20

to make its major contribution.

In the case of programmed instruction,* which had its brief moment in the limelight a few years ago, a great idea was almost if not completely ruined by industry's largely insensitive and incompetent efforts to turn university and government research into quick profit. It is obvious that at least a large part of the computer industry's present effort "to penetrate the education industry" is essentially premature exploitation. I doubt that it is to the long-term advantage of the computer industry, and I am sure that it is not to the long-term advantage of education or of society as a whole.

The basic problem, as I see it, is how to introduce into the industry's decision processes, for use in such "market areas" as education, some of the fairly long perspective enjoyed by certain agencies of government and perhaps even some of the very long perspective enjoyed by religious groups and a few foundations. Government subsidy is not the solution to this problem if all the subsidy does is make premature exploitive efforts financially while not educationally successful.

The profession of education: Education is a truly vast domain, and the profession is heavy with tradition and hierarchy as well as with sheer numbers. It is said to be an elementary sociological principle that such a field tends to respond slowly to innovation of any kind. Perhaps it is an equally good principle that long resistances to change are followed by quick revolutions. But I am not as much concerned about presently working school teachers' alleged defensive reaction to the

*Programmed instruction, developed in connection with relatively simple, stand-alone "teaching machines," is of course to be distinguished from computer-aided teaching and learning, even though the latter may make use of instructional programs.

alleged threat of the computer as I am about the profession's tardiness in learning what it ought to know about the computer. If half the teachers now in training were to emerge with a basic understanding of information processing and with significant experience in interactive programming and use of computers, most of the groundwork would be prepared for effective cooperation between computer people and educators in development of the computer's potential. In short, it is an easy excuse, but not a valid argument for the long term, to blame reactionary tendencies in education upon school teachers. The turnover among primary and secondary teachers is so great that, if they had acted when the prospect was first seen, the decision-makers of the profession could have had an adequate number of working school teachers quite ready for computers now--and could be bringing the majority along in good time for any truly large-scale application.*

The government: The government--mainly the federal government, though, in the present context, certain state governments are also influential--has what is for computers in education probably the essential combination of long perspective and massive funds. Of course the government has a short perspective, too, and its short perspective has a higher priority in commanding the funds. But, as dominant as that fact is at the present time in many areas of our national life, I think it is not now the critical factor in the intersection of computers and education. The critical factor, in my assessment, is that the part of the government with the most money to spend on computers for educational

*The foregoing remarks do not apply with full force to college and university education because the turnover there is slower. But many college and university teachers have learned or are learning about computers in connection with research.

purposes--the Office of Education--seems to be supporting industry in premature exploitive efforts more than it is supporting the research and development required to make computers effective in educational applications. Other agencies, such as the National Science Foundation, the Advanced Research Projects Agency, and the Office of Naval Research, are avoiding that pitfall, but in the area under discussion they cannot make up for the Office of Education.

The failure of the Office of Education to supply what I would call wise intellectual leadership as well as funds may be traced in part to its fear of criticism for "controlling" education.* I think, however, that the Office of Education will run more risk of criticism by putting "operational" computers into schools too soon than by supporting the research and development required to make computers contribute effectively to education.

The trouble with governmental leadership in the present context, it seems to me, stems not from power hunger but from the statistics of small samples. Although the federal government is very large, insofar as decision-making is concerned its population is very small. In the parts of the federal government concerned directly with education there are not many real decision-makers, and in the parts concerned directly with computers <u>and</u> education there are only four or five. Those decision-makers are remarkably free of superimposed guidance and constraint. They are also dedicated. The result is that governmental leadership in such an area as that now under discussion is essentially personal leadership. It is based on thinking that is as wise as an individual--but not as

*I realize that it may be my assessment that is wrong but of course I do not think it is.

wise as an informed and dedicated group.

The Establishment: In each of the three preceding sections I have been critical, but critical not simply of the computer industry, the education profession, or the government. Those sectors of society seem to me to be operating reasonably or very well in relation to their motivations and their goals--in relation to their value-and-cost functions. Indeed, having spent two of the last six years in the government and three in the computer industry, I have a basis for being--and am--full of admiration for both.

In the first instance, the point of my criticism was that what is good for the computer industry in the short run will be good neither for it nor for the society as a whole in the long run--*i.e.*, that industry's value-and-cost function is not being matched well to the over-all value-and-cost function of society. In the case of the education profession, my criticism was that those who determine its value structure are neglecting a crucial value. In the case of government, my criticism was that the lack of sufficient numbers of concerned and informed individuals inside government and out leaves decision-making too much to the vagaries of small-sample statistics, *i.e.*, to the happenstances of who is in what critical position at what crucial time. All three complaints come down to one: an inadequacy of technical understanding within that weakly defined but strongly influential Borel set of organizations and individuals called "The Establishment." I consider it wholly proper to address that criticism to this Conference because almost all the participants in this Conference are members of The Establishment.

The problem is sociotechnical. The lack is of technical understanding, not social, for the understanding on the part of The Establishment of how to guide the society--of how to get some things done and how to hold others in suspense--is flawless. If most of the opinion leaders of our society had in their minds clear pictures of what computers could do for education--of education as a self-motivating, self-exciting interaction through computers with responsive knowledge--it would take only a very short time to get the computer industry, the education profession, and the government all working together along a constructive course in the over-all interest of society. The trouble is that, by and large, the right pictures are not in the right minds.

Why are they not? The question might better be put: "How could they be?" The experiences most influential people have had with computers have been (1) distant and (2) with the wrong kinds of computers and computing. The experiences and the images out of which a valid concept of computer-facilitated education can be constructed cannot yet be derived from any single source. One must put together an idea from Glenn Culler's laboratory at Santa Barbara, another from the PLANIT System at the System Development Corporation, another from Ivan Sutherland's computer-graphics laboratory at Harvard, another from Bert Sutherland's computer-graphics project at the Lincoln Laboratory, and so on--up into the dozens or hundreds. A few members of The Establishment, realizing that computers represent a revolutionary new factor in informational and intellectual life, have collected such experiences and thereby built up in themselves the ability to see the new prospects and to evaluate them. But such people are far too few. The vast majority base their judgments on the experiences that have befallen them rather than upon experiences sought out in systematic investigation--or upon what they have read in secondary or even in popular sources--or upon what they know must be true about computers from their more general knowledge of machines. I submit the foregoing for discussion as a rough scale of (increasing) social immorality.

The foregoing may sound unduly severe. One might ask, "What can be so wrong with methods or procedures that have been used for so many years, that have provided the bases for the decisions that have brought us where we are?" Resisting with difficulty the profound but facetious rejoinder, I would call his attention to the "doubling time" of the computer's advance: Populations double in 20 to 50 years. Gross national products double in 10 to 30 years. But the basic measures of computer technology--size of the largest memory, speed of the fastest processor, number of computers in operation, amount of information processing achievable per unit cost--double in two years or less. Doubling in two years means increasing thirty-fold in 10 years, a thousand-fold in 20 years. One must scale his thinking to such a rate of change. He must replenish and reorganize the base of ideas and imagery upon which his thinking stands. The old methods and procedures are too slow to keep him abreast of the rapidly advancing computer.

Our basic problem, then, is how to develop an adequate basis in experience and in imagery for sociotechnical decision making. The moral aspect of the problem concerns the responsibility of leaders to equip themselves with the technical knowledge required. The matter is of crucial importance for the future of education in our society.

The Potential of the Computer in Education

As you may have noted, my argument is both self-supporting and self-defeating. It asserts that those who influence sociotechnical decisions and actions should keep themselves technically aware and informed. It holds that, in the field of computers, technology is moving so fast that the old ways of keeping up do not suffice. It complains that The Establishment is not keeping up. It recognizes you as members of The Establishment. And it concedes that you will not take my argument seriously if you do not perceive the great potentiel for computers in education. With my argument in that plight, I can fall no farther. I shall therefore undertake in a very limited way to do what I am sure cannot be done: to convince you with words that the computer can, if properly developed, be the instrument of a great revitalization of education.

If you are already convinced, please help me, in the discussion, to convince others. If you remain unconvinced through the remainder of this paper, please seek out some personal experiences in man-computer interaction.

1. Interaction with a computer can be highly motivating: Programming in interaction with a computer is challenging; it engages one's intellectual capabilities; it provides quick feedback; it is easy enough to ensure early success, and yet it is so broad and so deep that no one can explore more than a fraction of its territory. For me, interactive programming is absorbing, compelling, frustrating, and rewarding--so much more rewarding than frustrating that I have gotten up at three AM. in the dark of winter to work at the computer--with eagerness and joy. Indeed, I have worked all night at the computer more times than a non-interactor

would believe. It is not just a personal idiosyncrasy. In the last letter from my son, who has a summer job that involves interactive computing, the last full paragraph read:

> Good morning . . . I spent the whole night at it, and wowie zowie do I ever have a beautiful program--complete with six pages of documentation, including a guided tour de luxe demonstration of the whole thing. Really snazzy, but only a beginning. I wish somebody would come so I could show it off.

Nor is it a family peculiarity. Interactive programming captures and energizes the minds and spirits of many students not reached by other intellectual activities. Sometimes it is too motivating, too attractive; the "computer bum" is not interested in or willing to do anything else.

2. A computer is not necessarily cold and impersonal: Joseph Weizenbaum's program, Eliza (Doolittle), mediates typewritten interaction between a person and a computer in fairly natural English. The person types whatever comes to mind, the computer responds, then the person responds, and so on. In experiments, many of the subjects who were not told they were conversing with a computer assumed that there was a person at the other end of the line, and some, when told, would not believe that it was a computer. It is obviously possible to make computers more polite, more pleasant, and more responsive than most people--and, although not obviously, it is surely possible to make computers more interesting.

3. Knowledge can be stored in computer programs in such a way that people can interact with it readily: Joel Moses' program, SIN (Symbolic INtegration), can solve many problems in integration in

approximately the way a mathematician solves them: not by calculating a numerical solution but by manipulating the symbols in search of a simpler form. Moses has incorporated much human and book knowledge of integration into SIN, and now he and several colleagues are incorporating SIN into a system of programs, a computerized mathematical laboratory, that lets the person at the console guide the computer whenever the latter has trouble--lets the person suggest a tactic (integrate by parts or substitute $y^3 - y$ for x) and then has the computer carry it out. In a program demonstrated by Edward Fredkin, the computer made the suggestions: when the student had trouble solving a problem, the computer suggested a pertinent theorem.

4. Computers together with computer programs constitute the most powerful and the most subtle medium for the representation of ideas: Going beyond the preceding assertion, one can say that the computer medium is the medium *par excellence* for representation and expression of ideas. If you merely want to write in English and have what you write displayed to others, the computer medium will serve--trivially and at present expensively--as a substitute for print on paper. Theodore Nelson has developed the concept of "hypertext," in which the author writes at several levels of detail and sophistication and the computer then presents to each reader the subset of what was written that best meets his needs and matches his capabilities. The computer medium includes, of course, the large assortment of formal languages used in programming and the even larger assortment used in conversing with programs. It includes facilities for constructing and manipulating models of almost unlimited variety and complexity. Not limited to visual alphanumerics and graphics, it is

capable of communicating through auditory, tactile, and in principle any other stimuli. Most important, the medium is dynamic (kinematic) and also interactive.

5. <u>The computer can retrieve information selectively while the student is studying</u>: The function of information retrieval can be integrated into the study process. For example, the program, Symbiont, which Daniel Bobrow, Bertram Raphael, Richard Kain, and I demonstrated several years ago, scanned text for segments dealing with topics specified by the student and displayed them for him to examine.* Robert F. Simmons' program, Synthex, not only finds textual material pertinent to a question but extracts it and puts it together to make an answer. Symbiont operated upon a small collection of journal articles, Synthex upon a short book. It is just a matter of time, money, and human intellectual effort, however, to combine text-processing with document-retrieval techniques and thereby make collections of significant size--eventually even libraries and the entire store of knowledge--available through interactive scanners or question-answering systems.

*The student specified the topics by constructing short lists of key words or phrases. He might ask the computer to display each 30-word segment of text that included at least one member of each of at least two of these three lists: binaural, interaural, dichotic, diotic; phase, time relation(s), timing; localization, lateralization, direction, auditory space. The computer would then quickly display the first such segment it encountered in scanning the stored text. (The student could then modify his retrieval specification.) When the student pressed a key, the computer would scan on and quickly display the next segment that met the prescription. Symbiont included other facilities for automated notetaking, comparing graphs, and so on.

6. <u>The computer makes it possible to work efficiently at progressively increasing levels of complexity and abstraction</u>. Once a procedure has been developed, it can be applied to any appropriate set of data by simply juxtaposing the name of the procedure and the name(s) of the data. And correspondingly for the data, once he has sufficiently understood them, one no longer has to deal with each one of them individually; he refers to them by name, and the computer does the rest. Moreover, one can build up complex procedures out of simple ones by concatenating their names, and then name the concatenation, and one can build up complex data sets out of simple ones in an approximately similar way. These are standard techniques, demonstrable in any advanced computer laboratory; they are to be seen in especially clear relief in the work of John McCarthy and others within the context of the programming language, LISP; in the computer-based mathematical laboratory (mentioned earlier) of Martin, Engelman, and Moses; in the simulation system, OPS, developed by Martin Greenberger, Malcolm M. Jones, James H. Morris, Jr., and David N. Ness; and in the Reckoner system under development by Douwe Yntema and his colleagues at the Lincoln Laboratory. These techniques make it possible for one to put already-mastered parts of a problem out of the focus of his attention while working on, as yet, unmastered parts -- without having to worry about remembering or remastering the side-tracked details when it comes time to attempt an integration.

7. <u>Computer-program systems permit recursive definition and use of procedures</u>: A conceptually subtle and practically important facet of the mode of organization just described is recursive definition. Most advanced programming systems permit a procedure to "call" itself -- <u>i.e.</u>, to involve itself in its own definition. An example from LOGO, Wallace

Feurzeig's seventh-grade version of LISP, illustrates recursive definition neatly. The program reverses the sequence of the letters in a "string", turning PIN, for instance, into NIP. In the following LOGO program, REVERSE is the name of the procedure being defined. The definition makes use of REVERSE. ANYTHING is any sequence of letters. FIRST OF ANYTHING is the first letter of ANYTHING, e.g., the P of PIN. BUTFIRST is the remainder, e.g., the IN. RETURN means to produce as the result. WORD is the name of an already-defined (programmed) procedure that concatenates two strings, e.g., WORD OF "N" AND "IP" IS "NIP". The definition (program) of REVERSE:

```
TO REVERSE ANYTHING
IF FIRST OF ANYTHING IS ANYTHING RETURN ANYTHING
OTHERWISE RETURN WORD OF REVERSE OF BUTFIRST OF
        ANYTHING AND FIRST OF ANYTHING
```

Recursion can have a profound effect upon one's mode of thinking.

8. Computers can keep track of each person's records. For the individual, this means that his personal files can be kept in the computer memory, where they are not only readily accessible but, what is much more important, processible by the computer. (People almost never need merely to read material retrieved from files; they almost always need to process it or have it processed.) For the computer as an educational tool, having each person's records in its memory means that the computer can adjust the level and style of its interactions to the capabilities and preferences of each individual. Use of the computer as a personal filing system is illustrated profusely within Project MAC at M.I.T. -- for example, in several professors' use of M. M. Kessler's TIP (Technical Information

Program) and the ADMINS data management system developed by McIntosh, Griffel, and Pool. Use of the computer to keep track of students' performance and to adjust its interactions accordingly is now widespread. It is clearly illustrated in computer-based teaching programs at the System Development Corporation.

9. A wide variety of educational and informational services can be integrated into one computer system: Integration is crucially important. Modeling, problem-solving, information retrieval, drill, record-keeping, programming, and all the other individual functions are mutually supporting instruments of an ensemble. For demonstrational purposes, it is not bad to bring them out one at a time and play solos, but that is not a good way to organize them in support of education. To the best of my knowledge, there is at present no comprehensive integration of the components or subsystems that promise to contribute significantly to education. The closest approach, I think, is at the System Development Corporation. At M.I.T. as well as SDC, and also under rapid development at other places, are interactive multi-access computer systems that incorporate diverse informational services, but all are oriented more toward research, development, or other applications, than to education per se.

10. Computers are for communication as well as for individual work: Although the communication aspect of computers is not yet well developed, one can project from present multi-access systems surely enough to assert that computers will be just as essential to communication of ideas as to their representation. In the Compatible Time-Sharing System at M.I.T., you receive the message of the day when you log in, and you are told whether or not you have "mail" in your "mailbox". When you create files,

you tell the system (by individual name or category) who else, if anyone, may use them. There are several kinds of use -- "read only", "read and write" (i.e., modify), "execute only", and so on -- and you specify which kinds are involved in each permission. When you write a program, you save yourself time and trouble by using parts already prepared and tested by your colleagues: you get permission, and you "link" to the subroutine in their files. Of course, their subroutines make use of subordinate parts prepared by others. You may even find yourself borrowing a subroutine that includes (i.e., links back to) one or two of your subsubroutines. Approximately the same kind of interdependency develops in some areas in the domain of data. Thus, an interdependence among users of the multi-access system arises. At present, a typical user has in force at a given time about as many links to other people's files as he has files of his own. The ratio of links to files is increasing. Linking supports communication; linking also engenders communication. People discover that they are working along similar lines, and joint projects develop. The computer facilitates teamwork. Some of my colleagues believe that effective teamwork in executing complex informational tasks is possible only through a multi-access computer system. One can see that the computer can facilitate experimentation on teamwork and in due course education in teamwork. One can go on from there, if he is idealistically inclined, to cooperation within larger groups and ultimately to altruism.

11. Interactive multi-access computers will be the foci of intellectual communities: At M.I.T., SDC, and now a few other places, one can catch a glimpse of what I think will be the intellectual community of the future -- an "on-line intellectual community" of members supported

and interconnected by a large multi-access computer and its system of storage units, satellites, and consoles.* Within such a community, education will be less isolated than it now is from the other intellectual and constructive activities. In my assessment, that is an extremely important consideration. As educators have been realizing more and more acutely as they struggle with the problem of education in the slums, people learn what they live. If school is not part of life, it is not part of learning. Interactive computing can make school part of life.

12. <u>Students can be teachers within a computer-based community:</u> "The best way to learn something is to teach it!" The computer makes it practical to apply that maxim on a wide scale. At Harvard, while Harry Lewis learned conformal mapping in a mathematics course, he programmed a computer to accept hand-drawn diagrams "in the complex plane" and to apply to the diagrams the transformations specified at the console. As the computer calculated the transform, the old diagram faded from the screen and the new one took its place. In the process of programming and experimenting with the system, Lewis learned conformal mapping as few had ever learned it before. Moreover, the system he created helps others learn conformal mapping in a fascinating -- even exciting -- way. The behavior of the diagrams on the screen affords the student a direct perceptual understanding of the transformations that supplements and supports the more abstract aspect of the concept associated with the mathematical symbols. Now, in a properly developed world of computer-

---

*See: Chapter IV of Overhage, C. F. J., and R. J. Harmon (eds.), <u>INTREX, Report of a Planning Conference on Information Transfer Experiments</u>, The M. I. T. Press, Cambridge, 1965, or J. C. R. Licklider, "The On-Line Intellectual Community," in <u>Second National Symposium on Engineering Information</u>, Engineers Joint Council, New York, 1966.

facilitated education, every student will be able to program demonstrations and explanations of things he learns -- and to learn by programming them. The art of computer-assisted explanation will be developed through creative experimentation.* As the explanations improve, the students who interact with them will learn better and will enjoy learning more. Within the computer system, interactive demonstrations, instructions, laboratories, and tests will appear like wildflowers in a field -- and all the conditions for rapid evolution on the basis of attractiveness and effectiveness will be present.

13. As geographically separated multi-access computers are connected together to form networks, all the on-line communities and their informational resources will merge into one, and the educational facilities thus made available to each individual will be almost unlimited: This is too large a topic to try to develop here. In the long term, I think, the concept of the general-purpose interactive computer network will prove to be of the greatest and most revolutionary significance to education. Informed people are not in close agreement about the degrees of difficulty and complexity involved or about probable cost and reasonable time scale. Robert Taylor and I set forth our thoughts on this topic in a recent issue of Science and Technology, to which I refer in lieu of further discussion here.

*E. Berkeley, Computer-Assisted Explanation, May, 1967, Information International, Inc. (Publisher).

Conclusion

In the foregoing sections, I scarcely mentioned computer-assisted instruction (which is the most strongly advocated approach to computer-facilitated education) and computer-operated laboratories (which also have attracted widespread interest), and I neglected entirely several other facets of the large and complex subject. As I indicated at an early point, I did not hope to do the subject full justice. In my judgment, however, the capabilities I did mention--some actual, some potential--are enough to justify a major concentration of effort in the area in which the fields of education and computers overlap.

Perhaps, now, I can state a major part of the problem very simply: If you look at what is going on in research, development, and attempts at operational application that are sponsored under such rubrics as computer-assisted instruction and computer-aided teaching and learning, you see much that is uninteresting, and nothing that would lead you to get excited about a prospect of a great boon to society. On the other hand, if you look at what is going on in the field of interactive computing, and if you consider the possibilities that obviously lie in the melding of computing and communication, and if you then reflect upon the problems and needs of education, either you see an exciting prospect and a demanding challenge--or you look with nonperceptive eyes--or I am dreaming.

I am sure I am not dreaming. In The Establishment--with some exceptions, but in effect on the whole--there is not the sense of urgency that there would be if its members sensed what I am sensing. And, largely as a result of that deficiency, the contributions of the government, the education profession, and the computer industry are not what they should be.

The broad question that I put before you, then, is simply this: How can society be reoriented and guided to sieze the golden opportunity that the computer now presents -- a golden opportunity in a field of present dire distress?

Yes, I can hear it now: "What of the cost?" "Computers are so expensive that it would destroy the economy to apply them in education on a major scale!" "The programming alone would cost billions!"

But remember the powers of two. Computers are too expensive now, but they need not be too expensive ten years from now -- and part of my argument is that it will take ten years of research, development, and exploratory use in schools to get them ready for application on a major scale. How to ensure that computers do actually become inexpensive enough for widespread educational application, may be an appropriate question for this Conference.

As for the programming: True, it will be a very great task. But the programming task itself will be small compared to the task of learning what to program, of developing effective methods and techniques. In any event: (a) most of the task can be carried out, as suggested earlier, as a part of an effective extension of the educational process, and (b) a program, once perfected on one computer, can run in a thousand others. Moreover, if the programming did cost a few billion dollars, that cost might be borne, over a period of years, by a budget that is now more than $40 billion a year, and growing.

Man-Computer Symbiosis*

J. C. R. LICKLIDER†

Summary—Man-computer symbiosis is an expected development in cooperative interaction between men and electronic computers. It will involve very close coupling between the human and the electronic members of the partnership. The main aims are 1) to let computers facilitate formulative thinking as they now facilitate the solution of formulated problems, and 2) to enable men and computers to cooperate in making decisions and controlling complex situations without inflexible dependence on predetermined programs. In the anticipated symbiotic partnership, men will set the goals, formulate the hypotheses, determine the criteria, and perform the evaluations. Computing machines will do the routinizable work that must be done to prepare the way for insights and decisions in technical and scientific thinking. Preliminary analyses indicate that the symbiotic partnership will perform intellectual operations much more effectively than man alone can perform them. Prerequisites for the achievement of the effective, cooperative association include developments in computer time sharing, in memory components, in memory organization, in programming languages, and in input and output equipment.

I. Introduction

A. Symbiosis

The fig tree is pollinated only by the insect *Blastophaga grossorum*. The larva of the insect lives in the ovary of the fig tree, and there it gets its food. The tree and the insect are thus heavily interdependent: the tree cannot reproduce without the insect; the insect cannot eat without the tree; together, they consitute not only a viable but a productive and thriving partnership. This cooperative "living together in intimate association, or even close union, of two dissimilar organisms" is called symbiosis.[1]

"Man-computer symbiosis" is a subclass of man-machine systems. There are many man-machine systems. At present, however, there are no man-computer symbioses. The purposes of this paper are to present the concept and, hopefully, to foster the development of man-computer symbiosis by analyzing some problems of interaction between men and computing machines, calling attention to applicable principles of man-machine engineering, and pointing out a few questions to which research answers are needed. The hope is that, in not too many years, human brains and computing machines will be coupled together very tightly, and that the resulting partnership will think as no human brain has ever thought and process data in a way not approached by the information-handling machines we know today.

B. Between "Mechanically Extended Man" and "Artificial Intelligence"

As a concept, man-computer symbiosis is different in an important way from what North[2] has called "mechanically extended man." In the man-machine systems of the past, the human operator supplied the initiative, the direction, the integration, and the criterion. The mechanical parts of the systems were mere extensions, first of the human arm, then of the human eye. These systems certainly did not consist of "dissimilar organisms living together . . ." There was only one kind of organism—man—and the rest was there only to help him.

In one sense of course, any man-made system is intended to help man, to help a man or men outside the system. If we focus upon the human operator(s) within the system, however, we see that, in some areas of technology, a fantastic change has taken place during the last few years. "Mechanical extension" has given way to replacement of men, to automation, and the men who remain are there more to help than to be helped. In some instances, particularly in large computer-centered information and control systems, the human operators are responsible mainly for functions that it proved infeasible to automate. Such systems ("humanly extended machines," North might call them) are not symbiotic systems. They are "semi-automatic" systems, systems that started out to be fully automatic but fell short of the goal.

Man-computer symbiosis is probably not the ultimate paradigm for complex technological systems. It seems entirely possible that, in due course, electronic or chemical "machines" will outdo the human brain in most of the functions we now consider exclusively within its province. Even now, Gelernter's IBM-704 program for proving theorems in plane geometry proceeds at about the same pace as Brooklyn high school students, and makes similar errors.[3] There are, in fact, several theorem-

* Manuscript received by the PGHFE, January 13, 1960; revised manuscript received, January 18, 1960. The background work on which this paper is based was supported largely by the Behavioral Sciences Division, Air Force Office of Scientific Research, Air Research and Development Command, through Contract No. AF-49(638)-355.

† Bolt Beranek and Newman Inc., Cambridge, Mass.

[1] "Webster's New International Dictionary," 2nd ed., G. and C. Merriam Co., Springfield, Mass., p. 2555; 1958.

[2] J. D. North, "The rational behavior of mechanically extended man," Boulton Paul Aircraft Ltd., Wolverhampton, Eng.; September, 1954.

[3] H. Gelernter, "Realization of a Geometry Theorem Proving Machine," Unesco, NS, ICIP, 1.6.6, Internatl. Conf. on Information Processing, Paris, France; June, 1959.

proving, problem-solving, chess-playing, and pattern-recognizing programs (too many for complete reference[4-15]) capable of rivaling human intellectual performance in restricted areas; and Newell, Simon, and Shaw's[16] "general problem solver" may remove some of the restrictions. In short, it seems worthwhile to avoid argument with (other) enthusiasts for artificial intelligence by conceding dominance in the distant future of cerebration to machines alone. There will nevertheless be a fairly long interim during which the main intellectual advances will be made by men and computers working together in intimate association. A multidisciplinary study group, examining future research and development problems of the Air Force, estimated that it would be 1980 before developments in artificial intelligence make it possible for machines alone to do much thinking or problem solving of military significance. That would leave, say, five years to develop man-computer symbiosis and 15 years to use it. The 15 may be 10 or 500, but those years should be intellectually the most creative and exciting in the history of mankind.

II. Aims of Man-Computer Symbiosis

Present-day computers are designed primarily to solve preformulated problems or to process data according to predetermined procedures. The course of the computation may be conditional upon results obtained during the computation, but all the alternatives must be foreseen in advance. (If an unforeseen alternative arises, the whole process comes to a halt and awaits the necessary extension of the program.) The requirement for preformulation or predetermination is sometimes no great disadvantage. It is often said that programming for a computing machine forces one to think clearly, that it disciplines the thought process. If the user can think his problem through in advance, symbiotic association with a computing machine is not necessary.

However, many problems that can be thought through in advance are very difficult to think through in advance. They would be easier to solve, and they could be solved faster, through an intuitively guided trial-and-error procedure in which the computer cooperated, turning up flaws in the reasoning or revealing unexpected turns in the solution. Other problems simply cannot be formulated without computing-machine aid. Poincare anticipated the frustration of an important group of would-be computer users when he said, "The question is not, 'What is the answer?' The question is, 'What is the question?' " One of the main aims of man-computer symbiosis is to bring the computing machine effectively into the formulative parts of technical problems.

The other main aim is closely related. It is to bring computing machines effectively into processes of thinking that must go on in "real time," time that moves too fast to permit using computers in conventional ways. Imagine trying, for example, to direct a battle with the aid of a computer on such a schedule as this. You formulate your problem today. Tomorrow you spend with a programmer. Next week the computer devotes 5 minutes to assembling your program and 47 seconds to calculating the answer to your problem. You get a sheet of paper 20 feet long, full of numbers that, instead of providing a final solution, only suggest a tactic that should be explored by simulation. Obviously, the battle would be over before the second step in its planning was begun. To think in interaction with a computer in the same way that you think with a colleague whose competence supplements your own will require much tighter coupling between man and machine than is suggested by the example and than is possible today.

III. Need for Computer Participation in Formulative and Real-Time Thinking

The preceding paragraphs tacitly made the assumption that, if they could be introduced effectively into the thought process, the functions that can be performed by data-processing machines would improve or facilitate thinking and problem solving in an important way. That assumption may require justification.

A. A Preliminary and Informal Time-and-Motion Analysis of Technical Thinking

Despite the fact that there is a voluminous literature on thinking and problem solving, including intensive

[4] A. Newell and J. C. Shaw, "Programming the logic theory machine," *Proc. WJCC*, pp. 230-240; March, 1957.

[5] P. C. Gilmore, "A Program for the Production of Proofs for Theorems Derivable Within the First Order Predicate Calculus from Axioms," Unesco, NS, ICIP, 1.6.14, Internatl. Conf. on Information Processing, Paris, France; June, 1959.

[6] B. G. Farley and W. A. Clark, "Simulation of self-organizing systems by digital computers," IRE Trans. on Information Theory, vol. IT-4, pp. 76-84; September, 1954.

[7] R. M. Friedberg, "A learning machine: Part I," *IBM J. Res. & Dev.*, vol. 2, pp. 2-13; January, 1958.

[8] O. G. Selfridge, "Pandemonium, a paradigm for learning," *Proc. Symp. Mechanisation of Thought Processes, Natl. Physical Lab.*, Teddington, Eng.; November, 1958.

[9] W. W. Bledsoe and I. Browning, "Pattern Recognition and Reading by Machine," presented at the Eastern Joint Computer Conf., Boston, Mass., December, 1959.

[10] C. E. Shannon, "Programming a computer for playing chess," *Phil. Mag.*, vol. 41, pp. 256-75; March, 1950.

[11] A. Newell, "The chess machine: an example of dealing with a complex task by adaptation," *Proc. WJCC*, pp. 101-108; March, 1955.

[12] A. Bernstein and M. deV. Roberts, "Computer versus chess-player," *Scientific American*, vol. 198, pp. 96-98; June, 1958.

[13] A. Newell, J. C. Shaw, and H. A. Simon, "Chess-playing programs and the problem of complexity," *IBM J. Res. & Dev.*, vol. 2, pp. 320-335; October, 1958.

[14] H. Sherman, "A Quasi-Topological Method for Recognition of Line Patterns," Unesco, NS, ICIP, H.L.5, Internatl. Conf. on Information Processing, Paris, France; June, 1959.

[15] G. P. Dinneen, "Programming pattern recognition," *Proc. WJCC*, pp. 94-100; March, 1955.

[16] A. Newell, H. A. Simon, and J. C. Shaw, "Report on a general problem-solving program," Unesco, NS, ICIP, 1.8.8, Internatl. Conf. on Information Processing, Paris, France; June, 1959.

case-history studies of the process of invention, I could find nothing comparable to a time-and-motion-study analysis of the mental work of a person engaged in a scientific or technical enterprise. In the spring and summer of 1957, therefore, I tried to keep track of what one moderately technical person actually did during the hours he regarded as devoted to work. Although I was aware of the inadequacy of the sampling, I served as my own subject.

It soon became apparent that the main thing I did was to keep records, and the project would have become an infinite regress if the keeping of records had been carried through in the detail envisaged in the initial plan. It was not. Nevertheless, I obtained a picture of my activities that gave me pause. Perhaps my spectrum is not typical—I hope it is not, but I fear it is.

About 85 per cent of my "thinking" time was spent getting into a position to think, to make a decision, to learn something I needed to know. Much more time went into finding or obtaining information than into digesting it. Hours went into the plotting of graphs, and other hours into instructing an assistant how to plot. When the graphs were finished, the relations were obvious at once, but the plotting had to be done in order to make them so. At one point, it was necessary to compare six experimental determinations of a function relating speech-intelligibility to speech-to-noise ratio. No two experimenters had used the same definition or measure of speech-to-noise ratio. Several hours of calculating were required to get the data into comparable form. When they were in comparable form, it took only a few seconds to determine what I needed to know.

Throughout the period I examined, in short, my "thinking" time was devoted mainly to activities that were essentially clerical or mechanical: searching, calculating, plotting, transforming, determining the logical or dynamic consequences of a set of assumptions or hypotheses, preparing the way for a decision or an insight. Moreover, my choices of what to attempt and what not to attempt were determined to an embarrassingly great extent by considerations of clerical feasibility, not intellectual capability.

The main suggestion conveyed by the findings just described is that the operations that fill most of the time allegedly devoted to technical thinking are operations that can be performed more effectively by machines than by men. Severe problems are posed by the fact that these operations have to be performed upon diverse variables and in unforeseen and continually changing sequences. If those problems can be solved in such a way as to create a symbiotic relation between a man and a fast information-retrieval and data-processing machine, however, it seems evident that the cooperative interaction would greatly improve the thinking process.

B. *Comparative Capabilities of Men and Computers*

It may be appropriate to acknowledge, at this point, that we are using the term "computer" to cover a wide class of calculating, data-processing, and information-storage-and-retrieval machines. The capabilities of machines in this class are increasing almost daily. It is therefore hazardous to make general statements about capabilities of the class. Perhaps it is equally hazardous to make general statements about the capabilities of men. Nevertheless, certain genotypic differences in capability between men and computers do stand out, and they have a bearing on the nature of possible man-computer symbiosis and the potential value of achieving it.

As has been said in various ways, men are noisy, narrow-band devices, but their nervous systems have very many parallel and simultaneously active channels. Relative to men, computing machines are very fast and very accurate, but they are constrained to perform only one or a few elementary operations at a time. Men are flexible, capable of "programming themselves contingently" on the basis of newly received information. Computing machines are single-minded, constrained by their "preprogramming." Men naturally speak redundant languages organized around unitary objects and coherent actions and employing 20 to 60 elementary symbols. Computers "naturally" speak nonredundant languages, usually with only two elementary symbols and no inherent appreciation either of unitary objects or of coherent actions.

To be rigorously correct, those characterizations would have to include many qualifiers. Nevertheless, the picture of dissimilarity (and therefore potential supplementation) that they present is essentially valid. Computing machines can do readily, well, and rapidly many things that are difficult or impossible for man, and men can do readily and well, though not rapidly, many things that are difficult or impossible for computers. That suggests that a symbiotic cooperation, if successful in integrating the positive characteristics of men and computers, would be of great value. The differences in speed and in language, of course, pose difficulties that must be overcome.

IV. Separable Functions of Men and Computers in the Anticipated Symbiotic Association

It seems likely that the contributions of human operators and equipment will blend together so completely in many operations that it will be difficult to separate them neatly in analysis. That would be the case if, in gathering data on which to base a decision, for example, both the man and the computer came up with relevant precedents from experience and if the computer then suggested a course of action that agreed with the man's intuitive judgment. (In theorem-proving programs, computers find precedents in experience, and in the SAGE

System, they suggest courses of action. The foregoing is not a far-fetched example.) In other operations, however, the contributions of men and equipment will be to some extent separable.

Men will set the goals and supply the motivations, of course, at least in the early years. They will formulate hypotheses. They will ask questions. They will think of mechanisms, procedures, and models. They will remember that such-and-such a person did some possibly relevant work on a topic of interest back in 1947, or at any rate shortly after World War II, and they will have an idea in what journals it might have been published. In general, they will make approximate and fallible, but leading, contributions, and they will define criteria and serve as evaluators, judging the contributions of the equipment and guiding the general line of thought.

In addition, men will handle the very-low-probability situations when such situations do actually arise. (In current man-machine systems, that is one of the human operator's most important functions. The sum of the probabilities of very-low-probability alternatives is often much too large to neglect.) Men will fill in the gaps, either in the problem solution or in the computer program, when the computer has no mode or routine that is applicable in a particular circumstance.

The information-processing equipment, for its part, will convert hypotheses into testable models and then test the models against data (which the human operator may designate roughly and identify as relevant when the computer presents them for his approval). The equipment will answer questions. It will simulate the mechanisms and models, carry out the procedures, and display the results to the operator. It will transform data, plot graphs ("cutting the cake" in whatever way the human operator specifies, or in several alternative ways if the human operator is not sure what he wants). The equipment will interpolate, extrapolate, and transform. It will convert static equations or logical statements into dynamic models so the human operator can examine their behavior. In general, it will carry out the routinizable, clerical operations that fill the intervals between decisions.

In addition, the computer will serve as a statistical-inference, decision-theory, or game-theory machine to make elementary evaluations of suggested courses of action whenever there is enough basis to support a formal statistical analysis. Finally, it will do as much diagnosis, pattern matching, and relevance recognizing as it profitably can, but it will accept a clearly secondary status in those areas.

V. Prerequisites for Realization of Man-Computer Symbiosis

The data-processing equipment tacitly postulated in the preceding section is not available. The computer programs have not been written. There are in fact several hurdles that stand between the nonsymbiotic present and the anticipated symbiotic future. Let us examine some of them to see more clearly what is needed and what the chances are of achieving it.

A. Speed Mismatch Between Men and Computers

Any present-day large-scale computer is too fast and too costly for real-time cooperative thinking with one man. Clearly, for the sake of efficiency and economy, the computer must divide its time among many users. Time-sharing systems are currently under active development. There are even arrangements to keep users from "clobbering" anything but their own personal programs.

It seems reasonable to envision, for a time 10 or 15 years hence, a "thinking center" that will incorporate the functions of present-day libraries together with anticipated advances in information storage and retrieval and the symbiotic functions suggested earlier in this paper. The picture readily enlarges itself into a network of such centers, connected to one another by wide-band communication lines and to individual users by leased-wire services. In such a system, the speed of the computers would be balanced, and the cost of the gigantic memories and the sophisticated programs would be divided by the number of users.

B. Memory Hardware Requirements

When we start to think of storing any appreciable fraction of a technical literature in computer memory, we run into billions of bits and, unless things change markedly, billions of dollars.

The first thing to face is that we shall not store all the technical and scientific papers in computer memory. We may store the parts that can be summarized most succinctly—the quantitative parts and the reference citations—but not the whole. Books are among the most beautifully engineered, and human-engineered, components in existence, and they will continue to be functionally important within the context of man-computer symbiosis. (Hopefully, the computer will expedite the finding, delivering, and returning of books.)

The second point is that a very important section of memory will be permanent: part *indelible memory* and part *published memory*. The computer will be able to write once into indelible memory, and then read back indefinitely, but the computer will not be able to erase indelible memory. (It may also over-write, turning all the 0's into 1's, as though marking over what was written earlier.) Published memory will be "read-only" memory. It will be introduced into the computer already structured. The computer will be able to refer to it repeatedly, but not to change it. These types of memory will become more and more important as computers grow larger. They can be made more compact than core, thin-film, or even tape memory, and they will be much less expensive. The main engineering problems will concern selection circuitry.

In so far as other aspects of memory requirement are concerned, we may count upon the continuing development of ordinary scientific and business computing machines. There is some prospect that memory elements will become as fast as processing (logic) elements. That development would have a revolutionary effect upon the design of computers.

C. Memory Organization Requirements

Implicit in the idea of man-computer symbiosis are the requirements that information be retrievable both by name and by pattern and that it be accessible through procedure much faster than serial search. At least half of the problem of memory organization appears to reside in the storage procedure. Most of the remainder seems to be wrapped up in the problem of pattern recognition within the storage mechanism or medium. Detailed discussion of these problems is beyond the present scope. However, a brief outline of one promising idea, "trie memory," may serve to indicate the general nature of anticipated developments.

Trie memory is so called by its originator, Fredkin,[17] because it is designed to facilitate re*trie*val of information and because the branching storage structure, when developed, resembles a tree. Most common memory systems store functions of arguments at locations designated by the arguments. (In one sense, they do not store the arguments at all. In another and more realistic sense, they store all the possible arguments in the framework structure of the memory.) The trie memory system, on the other hand, stores both the functions and the arguments. The argument is introduced into the memory first, one character at a time, starting at a standard initial register. Each argument register has one cell for each character of the ensemble (*e.g.*, two for information encoded in binary form) and each character cell has within it storage space for the address of the next register. The argument is stored by writing a series of addresses, each one of which tells where to find the next. At the end of the argument is a special "end-of-argument" marker. Then follow directions to the function, which is stored in one or another of several ways, either further trie structure or "list structure" often being most effective.

The trie memory scheme is inefficient for small memories, but it becomes increasingly efficient in using available storage space as memory size increases. The attractive features of the scheme are these: 1) The retrieval process is extremely simple. Given the argument, enter the standard initial register with the first character, and pick up the address of the second. Then go to the second register, and pick up the address of the third, etc. 2) If two arguments have initial characters in common, they use the same storage space for those characters. 3) The lengths of the arguments need not be the same, and need not be specified in advance. 4) No room in storage is reserved for or used by any argument until it is actually stored. The trie structure is created as the items are introduced into the memory. 5) A function can be used as an argument for another function, and that function as an argument for the next. Thus, for example, by entering with the argument, "matrix multiplication," one might retrieve the entire program for performing a matrix multiplication on the computer. 6) By examining the storage at a given level, one can determine what thus-far similar items have been stored. For example, if there is no citation for Egan, J. P., it is but a step or two backward to pick up the trail of Egan, James....

The properties just described do not include all the desired ones, but they bring computer storage into resonance with human operators and their predilection to designate things by naming or pointing.

D. The Language Problem

The basic dissimiliarity between human languages and computer languages may be the most serious obstacle to true symbiosis. It is reassuring, however, to note what great strides have already been made, through interpretive programs and particularly through assembly or compiling programs such as FORTRAN, to adapt computers to human language forms. The "Information Processing Language" of Shaw, Newell, Simon, and Ellis[18] represents another line of rapprochement. And, in ALGOL and related systems, men are proving their flexibility by adopting standard formulas of representation and expression that are readily translatable into machine language.

For the purposes of real-time cooperation between men and computers, it will be necessary, however, to make use of an additional and rather different principle of communication and control. The idea may be highlighted by comparing instructions ordinarily addressed to intelligent human beings with instructions ordinarily used with computers. The latter specify precisely the individual steps to take and the sequence in which to take them. The former present or imply something about incentive or motivation, and they supply a criterion by which the human executor of the instructions will know when he has accomplished his task. In short: instructions directed to computers specify courses; instructions directed to human beings specify goals.

Men appear to think more naturally and easily in terms of goals than in terms of courses. True, they usually know something about directions in which to travel or lines along which to work, but few start out with precisely formulated itineraries. Who, for example, would

[17] E. Fredkin, "Trie memory," in preparation.

[18] J. C. Shaw, A. Newell, H. A. Simon, and T. O. Ellis, "A command structure for complex information processing," *Proc. WJCC*, pp. 119–128; May, 1958.

depart from Boston for Los Angeles with a detailed specification of the route? Instead, to paraphrase Wiener, men bound for Los Angeles try continually to decrease the amount by which they are not yet in the smog.

Computer instruction through specification of goals is being approached along two paths. The first involves problem-solving, hill-climbing, self-organizing programs. The second involves real-time concatenation of preprogrammed segments and closed subroutines which the human operator can designate and call into action simply by name.

Along the first of these paths, there has been promising exploratory work. It is clear that, working within the loose constraints of predetermined strategies, computers will in due course be able to devise and simplify their own procedures for achieving stated goals. Thus far, the achievements have not been substantively important; they have constituted only "demonstration in principle." Nevertheless, the implications are far-reaching.

Although the second path is simpler and apparently capable of earlier realization, it has been relatively neglected. Fredkin's trie memory provides a promising paradigm. We may in due course see a serious effort to develop computer programs that can be connected together like the words and phrases of speech to do whatever computation or control is required at the moment. The consideration that holds back such an effort, apparently, is that the effort would produce nothing that would be of great value in the context of existing computers. It would be unrewarding to develop the language before there are any computing machines capable of responding meaningfully to it.

E. Input and Output Equipment

The department of data processing that seems least advanced, in so far as the requirements of man-computer symbiosis are concerned, is the one that deals with input and output equipment or, as it is seen from the human operator's point of view, displays and controls. Immediately after saying that, it is essential to make qualifying comments, because the engineering of equipment for high-speed introduction and extraction of information has been excellent, and because some very sophisticated display and control techniques have been developed in such research laboratories as the Lincoln Laboratory. By and large, in generally available computers, however, there is almost no provision for any more effective, immediate man-machine communication than can be achieved with an electric typewriter.

Displays seem to be in a somewhat better state than controls. Many computers plot graphs on oscilloscope screens, and a few take advantage of the remarkable capabilities, graphical and symbolic, of the charactron display tube. Nowhere, to my knowledge, however, is there anything approaching the flexibility and convenience of the pencil and doodle pad or the chalk and blackboard used by men in technical discussion.

1) *Desk-Surface Display and Control:* Certainly, for effective man-computer interaction, it will be necessary for the man and the computer to draw graphs and pictures and to write notes and equations to each other on the same display surface. The man should be able to present a function to the computer, in a rough but rapid fashion, by drawing a graph. The computer should read the man's writing, perhaps on the condition that it be in clear block capitals, and it should immediately post, at the location of each hand-drawn symbol, the corresponding character as interpreted and put into precise typeface. With such an input-output device, the operator would quickly learn to write or print in a manner legible to the machine. He could compose instructions and subroutines, set them into proper format, and check them over before introducing them finally into the computer's main memory. He could even define new symbols, as Gilmore and Savell[19] have done at the Lincoln Laboratory, and present them directly to the computer. He could sketch out the format of a table roughly and let the computer shape it up with precision. He could correct the computer's data, instruct the machine via flow diagrams, and in general interact with it very much as he would with another engineer, except that the "other engineer" would be a precise draftsman, a lightning calculator, a mnemonic wizard, and many other valuable partners all in one.

2) *Computer-Posted Wall Display:* In some technological systems, several men share responsibility for controlling vehicles whose behaviors interact. Some information must be presented simultaneously to all the men, preferably on a common grid, to coordinate their actions. Other information is of relevance only to one or two operators. There would be only a confusion of uninterpretable clutter if all the information were presented on one display to all of them. The information must be posted by a computer, since manual plotting is too slow to keep it up to date.

The problem just outlined is even now a critical one, and it seems certain to become more and more critical as time goes by. Several designers are convinced that displays with the desired characteristics can be constructed with the aid of flashing lights and time-sharing viewing screens based on the light-valve principle.

The large display should be supplemented, according to most of those who have thought about the problem, by individual display-control units. The latter would permit the operators to modify the wall display without leaving their locations. For some purposes, it would be desirable for the operators to be able to communicate with the computer through the supplementary displays and perhaps even through the wall display. At least one scheme for providing such communication seems feasible.

[19] J. T. Gilmore and R. E. Savell, "The Lincoln Writer," Lincoln Laboratory, M.I.T., Lexington, Mass., Rept. 51-8; October, 1959.

The large wall display and its associated system are relevant, of course, to symbiotic cooperation between a computer and a team of men. Laboratory experiments have indicated repeatedly that informal parallel arrangements of operators, coordinating their activities through reference to a large situation display, have important advantages over the arrangement, more widely used, that locates the operators at individual consoles and attempts to correlate their actions through the agency of a computer. This is one of several operator-team problems in need of careful study.

3) *Automatic Speech Production and Recognition:* How desirable and how feasible is speech communication between human operators and computing machines? That compound question is asked whenever sophisticated data-processing systems are discussed. Engineers who work and live with computers take a conservative attitude toward the desirability. Engineers who have had experience in the field of automatic speech recognition take a conservative attitude toward the feasibility. Yet there is continuing interest in the idea of talking with computing machines. In large part, the interest stems from realization that one can hardly take a military commander or a corporation president away from his work to teach him to type. If computing machines are ever to be used directly by top-level decision makers, it may be worthwhile to provide communication via the most natural means, even at considerable cost.

Preliminary analysis of his problems and time scales suggests that a corporation president would be interested in a symbiotic association with a computer only as an avocation. Business situations usually move slowly enough that there is time for briefings and conferences. It seems reasonable, therefore, for computer specialists to be the ones who interact directly with computers in business offices.

The military commander, on the other hand, faces a greater probability of having to make critical decisions in short intervals of time. It is easy to overdramatize the notion of the ten-minute war, but it would be dangerous to count on having more than ten minutes in which to make a critical decision. As military system ground environments and control centers grow in capability and complexity, therefore, a real requirement for automatic speech production and recognition in computers seems likely to develop. Certainly, if the equipment were already developed, reliable, and available, it would be used.

In so far as feasibility is concerned, speech production poses less severe problems of a technical nature than does automatic recognition of speech sounds. A commercial electronic digital voltmeter now reads aloud its indications, digit by digit. For eight or ten years, at the Bell Telephone Laboratories, the Royal Institute of Technology (Stockholm), the Signals Research and Development Establishment (Christchurch), the Haskins Laboratory, and the Massachusetts Institute of Technology, Dunn,[20] Fant,[21] Lawrence,[22] Cooper,[23] Stevens,[24] and their coworkers, have demonstrated successive generations of intelligible automatic talkers. Recent work at the Haskins Laboratory has led to the development of a digital code, suitable for use by computing machines, that makes an automatic voice utter intelligible connected discourse.[25]

The feasibility of automatic speech recognition depends heavily upon the size of the vocabulary of words to be recognized and upon the diversity of talkers and accents with which it must work. Ninety-eight per cent correct recognition of naturally spoken decimal digits was demonstrated several years ago at the Bell Telephone Laboratories and at the Lincoln Laboratory.[26, 27] To go a step up the scale of vocabulary size, we may say that an automatic recognizer of clearly spoken alphanumerical characters can almost surely be developed now on the basis of existing knowledge. Since untrained operators can read at least as rapidly as trained ones can type, such a device would be a convenient tool in almost any computer installation.

For real-time interaction on a truly symbiotic level, however, a vocabulary of about 2000 words, *e.g.*, 1000 words of something like basic English and 1000 technical terms, would probably be required. That constitutes a challenging problem. In the consensus of acousticians and linguists, construction of a recognizer of 2000 words cannot be accomplished now. However, there are several organizations that would happily undertake to develop and automatic recognizer for such a vocabulary on a five-year basis. They would stipulate that the speech be clear speech, dictation style, without unusual accent.

Although detailed discussion of techniques of automatic speech recognition is beyond the present scope, it is fitting to note that computing machines are playing a dominant role in the development of automatic speech recognizers. They have contributed the impetus that

[20] H. K. Dunn, "The calculation of vowel resonances, and an electrical vocal tract," *J. Acoust. Soc. Amer.*, vol. 22, pp. 740–753; November, 1950.

[21] G. Fant, "On the Acoustics of Speech," paper presented at the Third Internatl. Congress on Acoustics, Stuttgart, Ger.; September, 1959.

[22] W. Lawrence, *et al.*, "Methods and Purposes of Speech Synthesis," Signals Res. and Dev. Estab., Ministry of Supply, Christchurch, Hants, England, Rept. 56/1457; March, 1956.

[23] F. S. Cooper, *et al.*, "Some experiments on the perception of synthetic speech sounds," *J. Acoust. Soc. Amer.*, vol. 24, pp. 597–606; November, 1952.

[24] K. N. Stevens, S. Kasowski, and C. G. Fant, "Electric analog of the vocal tract," *J. Acoust. Soc. Amer.*, vol. 25, pp. 734–742; July, 1953.

[25] A. M. Liberman, F. Ingemann, L. Lisker, P. Delattre, and F. S. Cooper, "Minimal rules for synthesizing speech," *J. Acoust. Soc. Amer.*, vol. 31, pp. 1490–1499; November, 1959.

[26] K. H. Davis, R. Biddulph, and S. Balashek, "Automatic recognition of spoken digits," in W. Jackson, "Communication Theory," Butterworths Scientific Publications, London, Eng., pp. 433–441; 1953.

[27] J. W. Forgie and C. D. Forgie, "Results obtained from a vowel recognition computer program," *J. Acoust. Soc. Amer.*, vol. 31, pp. 1480–1489; November, 1959.

accounts for the present optimism, or rather for the optimism presently found in some quarters. Two or three years ago, it appeared that automatic recognition of sizeable vocabularies would not be achieved for ten or fifteen years; that it would have to await much further, gradual accumulation of knowledge of acoustic, phonetic, linguistic, and psychological processes in speech communication. Now, however, many see a prospect of accelerating the acquisition of that knowledge with the aid of computer processing of speech signals, and not a few workers have the feeling that sophisticated computer programs will be able to perform well as speech-pattern recognisers even without the aid of much substantive knowledge of speech signals and processes. Putting those two considerations together brings the estimate of the time required to achieve practically significant speech recognition down to perhaps five years, the five years just mentioned.

[Reprinted from AMERICAN PSYCHOLOGIST, Vol. 21, No. 11, November, 1966]

A CRUX IN SCIENTIFIC AND TECHNICAL COMMUNICATION

J. C. R. LICKLIDER

ONLY in high hyperbole does a thing "explode" that takes 10 or 15 years to double its volume. Yet most estimates place the doubling time of the size of the printed record of science and technology within that range, and most papers on scientific and technical information begin by pointing in the general direction of the library and shouting "information explosion."

The best response to a warning of explosion is usually either to duck or to run, depending upon one's distance from the center of the scene. In this case, however, I think there is time to examine the problem and to look about for a more constructive solution.

THE INUNDATION

What is happening in scientific and technical communication is more closely analogous to a flood than to an explosion. The water has been rising slowly—at a progressively increasing rate, but slowly, for a long time, and now it is overflowing the banks in several areas. Although the rise has been gradual, the overflow is sudden and dramatic. It is causing damage and alarm, but note that it involves only the water that rises above the banks—the excess beyond their capacity to contain—and not the entire volume of the water in the river. If the entire volume were to undergo so great and abrupt a relative increase, it would be an explosion indeed, and there would be no hope—but fortunately it is only the rate of getting out of hand, not the rate of overall growth, that is so high that it attracts everyone's attention.

Although science and technology are concerned, respectively, with augmentation and application of knowledge, it is not knowledge but information that is the commodity they store, retrieve, and communicate. Through subtle cognitive processing, some information is distilled and organized into knowledge. The quality of the information appears to be at least as important as the quantity in determining the value of the product. In any event, it is a flood of information and not a flood of knowledge that is causing the trouble with which we must cope.

The body of recorded scientific and technical information now has a volume of about 10 trillion alphanumeric characters (i.e., letters, numerals, and punctuation marks) and is increasing along (what for lack of precise data is usually assumed to be) an exponential curve characterized by a doubling time in the range 10–15 years as mentioned (Licklider, 1965; Senders, 1963).

To simplify back-of-the-envelope calculations, let us take the figures, 10^{13} characters and (say) 12 years, at face value; let us assume that one one-thousandth of all science and technology constitutes a field of specialization; and let us consider the plight of a scientist who reads 3,000 characters a minute, which is a rate more appropriate for novels than for journal articles. Suppose that he gathers together the literature of his field of specialization (10^{10} characters) and begins now to read it. He reads 13 hours a day, 365 days a year. At the end of the 12 years, he sets down the last volume with a great sigh of relief—only to discover that in the interim another 10^{10} characters were published in his field. He is deterred from undertaking 12 more years of reading by the realization that not only the volume but the rate of publication has doubled.

Sixty years ago, according to our simplifying (but for this purpose not oversimplifying) assumptions, the 3,000-character-per-minute reader needed only 25 minutes a day to keep up with everything in his field. Eleven years hence, he will have to read continuously, every hour of every day. Of course most of us do not read so fast and so persistently. Of course most of us make do with less than total scrutiny of less than one one-thousandth of the corpus. Give or take a small factor in speed; give or take a small factor in size. The essential point is that an exponentially increasing requirement is passing a constant capability. It is our unique experience to live and work through the period in which individual mastery of a field turns from possible to impossible—in which the depth of the water exceeds the height of the banks.

As individual mastery becomes impossible, we turn (without being sharply aware of our changing strategy) to a group approach, to individual specialization plus organization across or over individuals. But it is still essential to bring together in an individual mind the ideas relevant to a given problem. Many of the difficulties of scientific and technical communication, and much of the proliferation of scientific and technical literature, stem from that requirement. In the days of individual mastery, a man attacked a problem by drawing pertinent ideas from his memory's store, built up over the years—and his memory performed well for him even though no one understood its processes of storage, organization, and retrieval. In the group approach, however, those processes have to be externalized, and to be made to work effectively they have to be understood. Pertinent ideas have to be selected either from diverse human memories or from one or more nonneural stores, and they have to be communicated to the individual or individuals in whose mind(s) they may interact to yield solution(s).

During the present decade, the needed external arrangements for storage, organization, and retrieval of information are becoming the objects of widespread concern. Just as a flood of water hits first one area, then another, then another—not all simultaneously but all within a brief span of time—so is the flood of information hitting the various areas of science and technology. Some are still high and dry. Some are just now feeling the effects. In a few areas, inundated early, extensive arrangements for externalization of the selection, retrieval, and dissemination functions have already been made. To the old array of published abstracts and indexes, and to the traditional library services, new schemes and systems have been and are being added: published lists of titles (as given or permuted), citation indexes, referral services, clearinghouses and exchanges, information evaluation centers, automated searching systems, selective dissemination systems, and so on.

In this movement, most of the kinds of organization concerned with science and technology are involved: universities (e.g., M.I.T., with its Projects MAC and INTREX [1]), professional societies (e.g., the American Chemical Society, of which *Chemical Abstracts* Service, with its manifold of information services, is a part), nonprofit documentation services (e.g., Biosciences Information Service), privately owned documentation services (e.g., Institute for Scientific Information), publishing firms (McGraw-Hill Book Company), nonprofit research organizations (e.g., Battelle Memorial Institute, with its eight specialized technical information evaluation centers), business firms (Dupont, with its advanced technical information system), quasi-governmental bodies (e.g., the National Academy of Sciences), governments (e.g., the Government of the United States—*vide infra*), and international organizations (e.g., the United Nations).

The professional societies are indeed very active: the APA in its pioneering studies of the process of scientific communication (APA, 1965; Garvey & Griffith, 1964); the American Institute of Physics in analyzing the needs of physicists and planning a balanced array of services to meet them (Williams, Hutchisson, & Wolfe, 1966); the Engineers Joint Council, Engineering Index, and Engineering Societies Library in their joint effort toward a national system for engineering information (Cottrell, 1966; Speight, 1966); the American Society for Metals in operating a mechanized searching service for its members (Cottrell & Flanagan, 1965). The Government has recognized responsibility for fostering the use of the knowledge gained through Government-sponsored research and development and is engaged in a major effort to improve the availability and use of scientific and technical information (Knox, 1965a). This effort is guided by the President's Special Assistant for Science and Technology and the three organizations he heads: the Office of Science and Technology, the President's Scientific Advisory Committee, and the Federal Council for Science and Technology. The effort involves such operating agencies and services as the three national libraries, the National Referral Center for Science and Technology (which will tell you who knows about a given subject), the Science Information Exchange (which will tell you who is working on it under Government support), the Clearinghouse

[1] MAC—Multiple-Access Computing, Machine-Aided Cognition; INTREX—Information Transfer Experiments.

for Federal Scientific and Technical Information (which will get you a copy of the report if the work reported was supported by the Government), the National Standard Reference Data Center (which maintains validated data, as distinguished from documents), the documentation centers of the various departments and their current awareness, abstracting, indexing, and searching services (e.g., Defense Documentation Center, NASA's *STAR*, AEC's *Nuclear Science Abstracts*, and MEDLARS'[2] *Index Medicus* and computer-based searches in biomedicine), the scores of specialized technical information centers supported by the Government (which not only maintain and retrieve information but analyze, evaluate and "repackage" it), and the command, control, and intelligence organizations. In this vast and complex situation, the National Science Foundation plays a role not limited to financial support of research; NSF fosters new informational services during the initial years of their operation, and it sponsors surveys and analyses of the situation in scientific and technical communication and planning of national information systems and networks.

Thus the flood is upon us, and almost every agency in sight is building a dike or a dam or a boat or a helicopter—or making a plan. There are still quite a few individual scientists and engineers who say they think there is no problem. Some are foremost leaders of their fields for whom meetings, visits, and preprint exchanges have short-circuited the library network. (They spend so much time above the clouds they never see the flood.) Most of the others are so far removed from the main stream that they are in no danger of getting wet at all. For most of us, however, the flood of information is a major factor in our lives. It is markedly affecting what we do and how we do it. All of us have reason to be concerned, and there is need for us to be involved. Indeed, the problem is largely one of human cognition, human behavior, and human organization—with which many psychologists are familiar—and some of the proposals for solution postulate a cooperative interaction between men, machines, and information in which many psychologists may find a fascinating challenge.

[2] Medical Literature Analysis and Retrieval System of the National Library of Medicine.

Flood Control

Widespread concern is probably necessary but of course not in and of itself sufficient. Action must be taken to control the flood.

There are three possible lines of action: (*a*) reduce the rate of publication, (*b*) improve the arrangements for selecting pertinent documents, and (*c*) improve the arrangements for processing the information the documents contain.

It seems obvious to many that much of what is published is of such low quality that its publication does more harm than good. Some urge measures to preclude publication of low-grade contributions. A more constructive and practicable approach (which I advocate) is to enforce high standards of quality in selected media (e.g., the "prestige" journals) and to let the buyer beware or ignore the residue. Unfortunately, however, critical review, which is the main tool for enforcing high standards, tends to react against speed of dissemination, and the need or desire for early information is in some quarters very great. Preprints and technical reports must therefore be taken into account as parts of the apparatus of scientific and technical communication. The same conclusion applies to the derivative publications that are involved in the transfer of scientific findings into technological applications. Much may be lost in summarization and rewriting, and the derived version may sometimes seem a travesty to the man who wrote the primary article. In the judgment of many engineers and managers, however, summarization and "slanted repackaging" are necessary steps in the process of application. They should not and probably could not be eliminated. They should be kept in marked channels.

Since few psychologists would be so naive as to undertake under present circumstances to reduce the rate of scientific and technical publication, the foregoing brief consideration of the first possible line of action serves mainly to introduce the second: improvement of the arrangements for selecting pertinent documents. It suggests that one basis for selection is the reputation of the media through which documents are transmitted or, more generally, the classes to which documents are assigned. That is probably a better basis for selecting value than for selecting pertinence, but it is important.

A sharply and subtly discriminating system for selecting pertinent documents and screening out nonpertinent ones would probably bring the flood under control for most scientists—not for most engineers or managers—and keep it under control for some time to come. The critical question is, can such a system be achieved by augmenting and automating the traditional procedures of libraries and document rooms? That is the essential point of difference between the second and third lines of action. The second would seek to cut down the required amount of interaction between people and the store of information by employing the best arrangements for selection that can be achieved without radically changing the method of processing the contents of documents. The third would seek a marked improvement in the method of processing and then would employ the improved method both in the selection and in the organization and interpretation of information. The choice between the second and third lines is a fundamental and crucial decision, I think, for the next 2 or 3 decades of scientific and technical communication.

In that formulation of the crux, discriminating selection appears explicitly and rapid response does not. Rapid response is extremely important, in my assessment, because without it one cannot develop the penetrating interaction with the store of information that, I think, will be required to achieve discriminating selection. But I do not stress instant delivery of primary documents (or images thereof) for consecutive reading. If a book takes 3 days to read, it may as well take 1 day to deliver.

The second line of action would improve and augment the traditional apparatus of bibliographic control. That apparatus consists mainly of catalogues, indexes, abstracts, and bibliographies. The items catalogued, indexed, abstracted, and referred to in bibliographies are documents. Much of the inadequacy of the traditional apparatus is related to the fact that documents are too large to make good bibliographic units. A journal article deals with several topics, a book with many. Other limitations stem from the essentially hierarchical nature of the systems (e.g., Dewey Decimal System) widely used by libraries in classifying documents, from the shallowness of subject-matter indexing in most card catalogues, from the fact that authors tend not to be expert in abstracting and professional abstractors tend not to be at the forefronts of substantive fields of science and technology, and so on. Can those inadequacies and limitations be removed by more intensive effort along the same lines?

Technically, of course, there is no great obstacle to reducing the size of the bibliographic unit. With sufficient effort chapters or sections or even paragraphs could be indexed and abstracted. Each document could be assigned dozens of retrieval terms and abstracted in depth from several points of view by teams of subject-matter experts and information scientists. However, the amount of effort required to perform the deeper indexing and fuller abstracting would be great. If we estimate 3 minutes for indexing and 20 minutes for abstracting per 5,000-character page, the world's not quite 10^{12} annual characters of science and technology turn out to require about 4,500 man-years of indexing and 30,000 man-years of abstracting. From an administrator's point of view, that is obviously out of the question: at $12,000 per man-year, the cost would exceed our Government's entire budget (estimate, $380 million—Knox, 1965b) for scientific and technical information; moreover, to recruit the people would take a decade. As seen more abstractly, perhaps the scheme seems less preposterous: It must have taken more than 100,000 man-years to draft the original papers, let alone do the underlying research and engineering, and a $400 million investment might be justified if it markedly improved the usefulness of $15 billion (United States) or $30 billion (world) worth of research and development. Nevertheless, the administrator's assessment is sure to prevail; it takes into account the inescapable constraint imposed by the limited availability of competent human processing time.

The argument then comes down to this: To provide a basis for discriminative document retrieval, deep analysis of the published literature is required. At human processing speeds, deep interaction with information takes a long time. The supply of people able to understand science and technology well enough to contribute constructively to organization of its corpus for retrieval and dissemination is limited. The same people, by and large, are capable of doing more substantive scientific or technical work and prefer to do it. There is little hope, therefore, of sufficiently expanding the conventional indexing and abstracting efforts to cover all science and technology in great depth.

The argument might go on to question whether merely deeper indexes and fuller abstracts would provide the required improvement of selectivity. I think they would not. I think that new concepts are needed and that much exploration and research will be required—exploration and research that would not themselves be feasible with traditional methods. But in the interest of brevity I shall not try to support those opinions.

Where human processing of information is slow or costly, digital computers enter. They have entered the domain of scientific and technical information in six main operational roles:

1. Calculators—in solution of scientific and engineering problems
2. Simulators and modeling devices—in planning, research, and engineering design
3. Data processors—in storage and retrieval of the data of data banks
4. Message handlers—in telecommunication and intelligence systems
5. Language processors—in compilation of bibliographies and indexes and in the automation of routine library work such as control of serials and monitoring of circulation
6. Control devices—in document storage and retrieval (and dissemination) systems

In each of the six roles, computers have been successful in handling those tasks that could be reduced to definite, explicit, routine procedures—i.e., that could be programmed. In the fifth role, for example, computers have made it cheap and easy to compile permuted-title indexes ("KWIC Indexes") and citation indexes (showing who has referred to whom), and in the sixth role computers have made it practicable to search 100,000-item indexes for documents that meet complex boolean prescriptions (e.g., all the entries that deal with allergy or erythema and dryl compounds or tranquilizers other than meprobromate or with allergy and nylon) and even to pick out, copy, and deliver within seconds microform images of the prescribed documents.

There is a critical difference between the fifth-role examples and the sixth-role example. The former depend upon nothing but routine processing of strings of characters contained in the primary publications; the latter depends upon someone's having prepared the indexes and upon some means, such as a thesaurus, for relating the terms selected by the indexer to those selected by the searcher. Having noted the difficulty of providing deep indexes, and sensing even more difficulty in area of thesauri, synonyms, roles, links, and standard terms we may turn away from that approach and ask how much can be accomplished wholly within the domain of routine clerical, programmable operations. The answer to that question is: "only as much as we know in precise detail just how to accomplish, which in the present state of the art is not very much." Permuted titles and citation indexes are moderately helpful, but they are by no means containing the flood.

That answer leads into examination of the third line of action, which postulates a new approach to processing the contents of documents. "Processing" is used here in a generic sense, to include what people do when they assimilate and understand and also what computers do when they execute explicitly defined procedures. The fundamental consideration, it seems to me, is that in most of the processing that is involved in scientific and technical communication the two kinds of activity just mentioned are tightly meshed together. In reading, for example, one sees an interplay between orthographic, lexicographic, and syntactic procedures that appear to be governed by definite (though complex) rules and semantic, correlative, and interpretative processes that no one has much idea how to define explicitly. Attempts to analyze such activities as abstracting and searching for pertinent analogues reveal the same kind of organization. In the study of such processes, the parts that one can define explicitly and in detail are called "algorithmic" and the parts that defy such definition—that seem to involve the formulation of good hypotheses, the selection of promising lines of attack, the finding of the "grain" of a complex problem—are called "heuristic." In those terms, and in a metaphor of cloth instead of gearworks, the fundamental consideration is that in most of the activities with which we are concerned the algorithmic threads and the heuristic threads are woven together very closely.

Programmed computers can execute complex algorithms much more rapidly and accurately than people can. Intelligent, creative people can discover or invent and apply heuristic methods much better than presently programmed computers can. To solve problems and carry out courses of action that involve closely interwoven heuristic and algorithmic threads, therefore, close interaction between people and computers is required. The key to the third line of action is man-computer interaction.

During the last 5 years, man-computer interaction—"on-line" or "interactive" information processing—has grown from a gleam in an eye to a major sociotechnological movement. In several universities and research organizations, the way to use the computer is to sit down at one of its consoles and "converse" with the machine and its programs through a typewriter and/or a cathode-ray display and stylus arrangement. The computer divides its time among several or many users, switching from one to another very rapidly and attending to each one every few seconds.[8] Such arrangements, supported by a very large amount of programming, have made it possible for men and computers to work in close partnership in exploring and formulating as well as in "solving" complex problems. In the opinion of many, this multiple-access on-line approach will dominate the next several decades of information processing.

In distinguishing between heuristic and algorithmic methods, I was careful not to say that programmed computers cannot handle heuristics. When they work in close interaction with computers, creative people continually augment the repertoire of programs. A person who finds himself repeatedly using a method or a tactic is likely to examine carefully just what he does and then prepare a program to do it for him. If they have wide applicability, such programs tend to become "public," to find their ways into the library of programs available to all the users. Thus, as methods once regarded as heuristic are understood and programmed, they come within the growing province of the computer's capability.

In the phenomenon just described, I see the only credible promise for development of an effective system of informational flood control. The techniques of bibliographic control that have proved inadequate without the help of computers cannot be made adequate simply by introducing computers, for only the simplest of those techniques can be converted directly into computer programs. To meld the computer's speed with the working scientist's sense of relevance, for example, will require much more than a one-shot effort of planning and programming. Many ideas will have to be tried out, tested, modified, and tried out again in a context of operational use by scientists and engineers, and not only new programs but new physical arrangements (displays, controls, consoles) for man-computer interaction will be required. Within an on-line, interactive community of the kind arising in several universities, the necessary conditions exist: creative people interested in solving the problems, a way of converting ideas into operable procedures and testing them rapidly, and a context of operational use in which to test them. Never before has there been such a facility for solving problems that are at once psychological, social, technological, and informational.

With the new facility, I think it will be possible during the next few years not only to sharpen the selectivity of information retrieval but also to improve the effectiveness of our use of the retrieved information. Instead of merely reading about the result of testing three learning models with a specified set of experimental data, for example, a student will be able to apply the models (which will be stored, retrieved, and operated as computer programs) to the data and watch the processes unfold through graphical and diagrammatic displays. He will be able to experiment with the models, to modify them, to incorporate into them ideas of his own, and he will be able to test A's model with B's data, making such transformations as are necessary with the aid of programs retrieved from the program library and modified on-line to meet his immediate need. Indeed, a model will be not a set of static formulas but an active process producing visible behavior, and models will become preferred vehicles of scientific and technical communication. With tedium removed from data processing and compact outcomes rather than masses of numbers meeting the eye, data banks will also grow in popularity and usefulness.

Problems of informational flood co[illegible], are beginning to come within the grasp of on-line, interactive communities. M. M. Kessler's (1965) Technical Information Project has demonstrated the capability and convenience of a multiple-access computer system as a medium of interaction between phys-

[8] A "Time-Sharing System Scorecard" issued in the spring of 1965 by the Computer Research Corporation lists 20 on-line multiple-user computer systems. Among the pioneering system are those of Bolt Beranek and Newman, Inc., Carnegie Institute of Technology, Dartmouth College, IBM's Mohansic Laboratory and Thomas J. Watson Research Center, Massachusetts Institute of Technology, the Mitre Corporation, the RAND Corporation, Stanford University, the System Development Corporation, and the University of California.

icists and bibliographic information pertaining to journals of physics. Project INTREX is undertaking a program of experiments in information transfer that will exploit the Massachusets Institute of Technology's advanced facilities for interactive information processing (Overhage & Harmon, 1965). EDUCOM's Summer Study '66 formulated plans for a network of computer, facsimile, television, and other channels to foster coherent interaction among the people (and the other intellectual and informational resources) of universities and related organizations.[4] And several Governmental agencies, such as the Advanced Research Projects Agency, the Public Health Service, the National Institutes of Health, and the Office of Education, are seeking to develop new syntheses of brains, computers, and telecommunications for more effective accomplishment of their missions.

From a point of view only slightly different from the one we have been taking, the essential difference between the second and third lines of action is that the second is based mainly on representation of the corpus in analogue images (e.g., print on paper, microform photographs) whereas the third is based mainly on representation of the corpus in digital code. The main advantages of the former are that most of the corpus is now in analogue-image media and that people can read analogue images directly. The main advantages of the latter are that digital code can be stored more compactly, that it can be moved from one place to another by transmission instead of transportation, that computers can process digital code directly, and that conversion from digital code to analogue image is very much simpler than conversion from analogue image to digital code.

The main technological question that affects decision between the second and third courses is whether or not digital technology is ready, or will be ready in time, to handle the vast quantities of scientific and technical information and to serve the large numbers of people who use it. The main general guideline that bears upon that question compares the rate of growth in capability of digital technology with the rate of growth in size of the body of information. Most of the capacities and speeds of the computer technology have been doubling approximately every 2 years. For the doubling time of the corpus we have been using 12 years. There is more to the matter than just the two numbers, of course, but they show the trend. As for the present status:

1. *Storage*—photodigital stores capable of holding more than 10^{11} characters have been announced.

2. *Processing*—digital computers designed specifically for on-line, multiple-access processing are now entering the picture.

3. *Transmission*—the common carriers are providing an array of digital data services, and, in terms of effective bit-miles per day, digital transmission has already passed analogue transmission.

4. *Display and control (consoles)*—both typewriter and cathode-ray display-plus-stylus consoles are available and in use.

The factor of cost is of course both very important and very difficult to discuss adequately in a paper such as this. A rough rule for the period 1967–70 is that, in steady operation, storage (the storage hardware itself), transmission (the service over a few hundred miles via switchable common carrier), and display (hard copy or soft copy) will each cost about a thousandth of a cent per character. The cost of processing will depend of course upon the depth of processing, but fairly deep processing can be achieved at a thousandth of a cent per character. The total, .004 cent per character "delivered to the eyeball," corresponds approximately to 10 cents per typewritten page. In comparing that cost with the cost of information in conventional books or journals, one should estimate what fraction of the pages or paragraphs of the latter he actually consults, for in the on-line interactive mode he will use almost all of what he pays for. Another relevant consideration is that the cost per unit machine operation is continually going down as digital technology advances, whereas the cost—very significant in the overall equation—of the time of the scientist or engineer who scans, reads, or studies the retrieved record, does not.

The main immediate difficulty in the third course of action is the difficulty of converting a sufficient part of the corpus to computer-processible form. One can observe that almost every word that is published is keyed two or more times before it gets into print—and that the information should be (and

[4] "EDUCOM" is a short name for the Interuniversity Communications Council, a new organization with more than 40 major universities as members. The report of the Summer Study is scheduled to appear at about the same time as this issue of the *American Psychologist*.

increasingly is) captured in coded form as it is keyed. One can imagine a huge roomful of typists at tapewriters or keypunches, transcribing from print to digital code. It will probably turn out, however, that widespread use of digital devices in storing, processing, and transmitting the substance of the record of science and technology will wait upon the development of print-reading machines that can handle letterpress printing. Automatic readers capable of handling multifont typewritten material are now in operation, but machines are yet to come that can scan a book or journal page and convert its contents into digital code.

Which course of action will be followed, the second or the third? When will the choice be made? (Who can foretell the future, but who does not presume to try?) Although the decision will not be made all at once or by any single individual or group, the third course will in time prevail. In the interim of perhaps a decade or more, in operational as distinguished from experimental systems, bibliographic information such as titles, indexes, and abstracts will be handled digitally while the full texts of books and papers continue to be read from print on paper or from microform. This will be for many a time of frustration, for the basic difficulty will not have been solved, and the flood will not have been contained. During the same period, however, in a few experimental networks of significant size, the facilities, the methods, and the "software" required for the third course will be developed. When they have been proven and demonstrated, there will be a massive movement, encompassing all the technologically advanced countries and the operation and management of government and business as well as science and technology, to on-line interaction with stored information. Scientists and engineers will be early and key members, but not the only members, of the resulting "on-line intellectual community," and an important part of their work will be to organize the store of information into a coherent body of knowledge.

REFERENCES

AMERICAN PSYCHOLOGICAL ASSOCIATION. *Reports of the American Psychological Association's Project on Scientific Information Exchange in Psychology*. Vol. 2. Washington, D. C.: APA, 1965.

COTTRELL, N. E. The role of the engineering societies in a national information system. In, Second Annual National Colloquium on Information Retrieval, University of Pennsylvania, April 23, 1966.

COTTRELL, N. E., & FLANAGAN, C. E. Pilot studies and system components evaluation. *Proceedings of the Second National Symposium on Engineering Information*. New York: Engineers Joint Council, 1965. Pp. 37–42.

GARVEY, W. D., & GRIFFITH, B. C. Scientific information exchange in psychology. *Science*, 1964, 146, 1655–1659.

KESSLER, M. M. The M.I.T. Technical Information Project. *Physics Today*, 1965, 18, 28–36.

KNOX, W. T. Planning for national information networks. *Proceedings of the Second National Symposium on Engineering Information*. New York: Engineers Joint Council, 1965. Pp. 5–8. (a)

KNOX, W. T. *Recommendations for national document handling systems in science and technology*. Washington, D. C.: Federal Council for Science and Technology, Committee on Scientific and Technical Information, 1965. (b)

LICKLIDER, J. C. R. *Libraries of the future*. Cambridge: M.I.T. Press, 1965.

OVERHAGE, C. F. J., & HARMON, R. J. (Eds.) *INTREX: Report of a Planning Conference on Information Transfer Experiments*. Cambridge: M.I.T. Press, 1965.

SENDERS, J. W. Information storage requirements for the contents of the world's libraries. *Science*, 1963, 141, 1067–1068.

SPEIGHT, F. Y. Engineering society cooperation in improving dissemination of engineering information. Automotive Engineering Congress, Society of Automotive Engineers, Detroit, 1966. (Paper 660123)

WILLIAMS, V. Z., HUTCHESON, E., & WOLFE, H. C. Consideration of a physics information system. *Physics Today*, 1966, 19, 45–49.

A TIME-SHARING DEBUGGING SYSTEM FOR A SMALL COMPUTER

J. McCarthy
Computation Center, Stanford University, Stanford, California
S. Boilen
Bolt Beranek and Newman Inc., Cambridge, Mass.
E. Fredkin
Information International Inc., Maynard, Mass.
J. C. R. Licklider
Advanced Research Projects Agency, Department of Defense

The purpose of the BBN time-sharing system is to increase the effectiveness of the PDP-1 computer for those applications involving man-machine interaction by allowing each of the five users, each at his own typewriter to interact with the computer just as if he had a computer all to himself. The effectiveness of this interaction is further enhanced by the use of the TYC language for controlling the operation and modification of programs.

First the computer. The PDP-1* is a single address binary computer with an 18 bit word and five microsecond memory cycle; most instructions require ten microseconds to execute. The basic memory size is 4096 words, but up to 65,536 words may be addressed indirectly. The machine we used has 8192 words, 4096 of which are reserved for the time-sharing system. Each user sees a 4096 word memory. We shall describe further relevant features of the computer later.

* The PDP-1 computer is manufactured by Digital Equipment Corporation of Maynard, Massachusetts. All the equipment described in this paper was made by D.E.C. and their cooperation in developing and building the modifications and additions to the basic computer required for time-sharing was essential to the success of the project.

Attached to the computer is a high speed magnetic drum memory divided into 22 fields each of 4096 words. A basic operation of the drum system is the *memory-swap* accomplished in 33 milliseconds. In this operation 4096 words are transferred from the core memory to a drum field and simultaneously the core memory is loaded from a different drum field. This permits the following time-sharing mode of operation.

A 4096 word drum field is allocated for saving the *core image* of each user when his program is not running. A user's program in *run status* is run for 140 milliseconds, then if there is another user also in run status, the state of core memory is stored in the first user's core image on drum and simultaneously the second user's core image is loaded into core and the second user's program is started in the appropriate place. In the worst case of all five users in run status, the system makes its rounds in $5 \times (140 + 33) = 865$ milliseconds. For man-machine interaction this means that if the user types a character calling for a response from his program that requires less than 140 milliseconds (= 14,000 machine instructions), he will get the first character of the response in less than .865 seconds. This worst case is expected to be rare because when a user's program types out a multicharacter message, successive characters go into a buffer area in the system core; when the buffer is full the user's program is removed from run status until the buffer is nearly empty. Therefore, users with extensive output spend very little time in run status and the other users get correspondingly quicker service. (In fact the condition in which no users are in run status is expected to be so common that a provision for a background program to be run only when no time-sharer is in run status is contemplated.)

THE TYC CONTROL LANGUAGE

The language used to control the debugging is adapted from the DDT language devised by the TX-0 and PDP-1 group at M.I.T. directed by Jack Dennis for the TX-0 and PDP-1 computers. The use of typewriters rather than the console switches for on-line debugging has been developed at M.I.T. and M.I.T. Lincoln Laboratory since 1957, and at BBN since 1961. These languages have greatly increased the effectiveness of the TX-0, TX-2 and PDP-1 computers and are now being developed for the IBM 7090 time-sharing system by F. J. Corbato of the M.I.T. Computation Center. Unfortunately, except for a recent paper by Corbato, the work has not been published. Our only bow at history is to credit John Gilmore with the first such system for the TX-0 in 1957.

First, we shall consider the facilities for examining and changing registers. Suppose the user wants to examine register 344. He types

344/

and the computer types back the contents of this register interpreted as a computer instruction if possible. Thus it might type back "add 4072". The user then has several options.

1. He can carriage return and close the register if he is satisfied with its contents.
2. He can ask to see the next register by hitting the backspace key. The computer might then type back

345/ sub 4075.

3. He can ask to see the previous register.
4. He can ask to see register 4072 by hitting the tab key.
5. He can ask for the contents of the register as an octal or decimal number.
6. He can change the contents of the register by typing new contents such as "add 4073" and then hitting one of the delimiter characters.

The computer user who does not have experience with systems of this kind may not immediately realize the increase in effectiveness that these facilities alone give over console debugging. The advantages are that typing is easier than flipping switches, that a record is obtained of what was done, and that useful features can be added to the control language.

As a further feature the user can define symbolic names of addresses so that his typeouts can take the form

a/ add b + 3
a + 1/ sub b + 6

In order to start a program say at register 3145 the user types 3145G. This gives the typewriter up to the program, but he can get it back for control purposes by typing *center dot*. If he does so he can interrogate and change registers without stopping his program but if he wants to stop it he types H. Once it is stopped he can start it where it left off by typing G without a numerical argument. He can also interrogate the arithmetic registers either while the program is running or while it is stopped. Of course, the contents of a register interrogated when the program is interrupted at a random moment may not be significant; this depends on the program.

Except at the beginning and the end of his session the user does not ordinarily use the paper tape apparatus. Instead he designates a position on the drum for the punch and a position for the reader using TYC. An instruction in the user's program to punch a character onto paper tape actually results in entering the character into a buffer for transmission to the drum when the buffer is full or no punch instructions have been given for a while. This feature allowed us to make available in the time-sharing system symbolic assembly programs and other utility programs that were developed previously.

The TYC language is described in detail in reference 7.

RELEVANT FEATURES OF THE PDP-1 COMPUTER

In order to explain the detailed functioning of the BBN time-sharing system, it is necessary to understand the input-output system of the PDP-1 computer, the sequence break system and the restricted mode.

1. Typewriters and paper tape

Each *iot* instruction transfers a single character between the 18 bit *io* register of the computer and the external device. All *io* instructions have the same left 5 bits, the 6th bit is normally used to determine whether the wait before the next instruction is determined by the external device or whether the program keeps this responsibility. The remaining 12 bits of the instruction are used to determine the device and the direction of transfer. The characters are 8 bits on paper tape and 6 bits for typewriters. When the computer is not in sequence break mode a character typed by the user results in turning on a sense flag which can be interrogated by the program to determine when to pick up the character.

2. Drum

In transfers from the drum the number of words to be transferred and the locations in core and on the drum are specified. During the transfer the arithmetic unit of the machine is tied up.

3. The machine has other input-output devices but their operation does not have to be described in this paper.

4. The sequence-break system.

Besides the simple form of input-output described above, the machine has a sequence-break system which permits input-output and computation to be carried out simultaneously and asynchronously. The BBN time-sharing system makes full use of sequence break.

The sequence-break system has 16 channels to the outside world arranged in a priority chain with channel 0 having highest priority and channel 17, lowest priority. Associated with each channel are four registers in core 0. When a signal comes from an *io* device that the device has a character ready for the computer or is ready to receive a character from the computer, an interrupt will occur if an interrupt is presently allowed on that channel. When an interrupt occurs the contents of the *ac* (accumulator) *io* (input-output) and *pc* (program counter) registers are stored in three of the registers and control is transferred to the fourth which must therefore contain a jump to a program for dealing with the interrupt. When this program has finished its work it must execute an indirect jump through the register where the program counter was stored when the break started. This returns control to the program that was interrupted and tells the sequence break system that the break is over. Once a break is started on a channel a break cannot occur on a lower priority channel nor can another break occur on the same channel until the break is over. Each channel can store one break until it is allowed to occur.

5. Restricted Mode

This mode was devised specifically for the time-sharing system. When the computer is in this mode and if there is no break started in the sequence break system, then any of the following events lead to a sequence break on channel 16.

1. An attempt to obey an *io* instruction.

2. An instruction that would normally stop the computer such as a halt instruction or an illegal instruction.

3. An attempt to refer to core 0.

The instructions that enter and leave extend mode and restricted mode are considered *io* instructions. The time-sharing system operates only when a sequence break has occurred and hence is not subject to the restrictions.

6. The Channel 17 Clock.

Every 20 milliseconds a signal for a sequence break on channel 17 occurs. Programs can turn off channel 17 (or any other channel) by an *io* instruction if they don't want breaks to occur. Note that channel 17 is the lowest priority channel. The clock is a multivibrator whose period is controlled by a potentiometer.

HOW THE TIME-SHARING WORKS

The time-sharing executive program is not readily described by a single flow chart because its different parts act asynchronously as determined by sequence breaks. It includes the following programs:

1. The typewriter *io* program

Associated with each typewriter is an input-output program and a buffer area. These programs are entered when sequence breaks occur. Suppose a user types a character w. The program knows whether the character is addressed to the user's program or to TYC.

On the other hand, if the interrupt comes from the completion of the type-out of a character the program types the next character from the buffer if any.

After transferring the information the break is ended.

Channels 6, 7, 11, 14 and 15 are allocated to typewriters.

2. The channel 16 dispatcher.

The computer is in restricted mode during the operation of the time-sharing system. As we stated earlier, this means that io instructions and instructions that halt the machine lead to sequence breaks on channel 16. The user programs his input-output just as if there were no time-sharing system. Therefore, when a channel 16 break occurs the program first looks at the instruction that caused the break. Suppose the instruction is a type-out instruction. If the type-out buffer is not full the character that the user program wants to type is added to the buffer and if necessary a sequence break on the typewriter channel is instigated to start typing. If the type-out buffer is full the program must be dismissed from run status. If the instruction is a type-in instruction, a character is given to the user program if there is one in the buffer; otherwise the program must be dismissed from run status.

If the instruction is discovered to be one that halts the machine, the program is dismissed from run status and a note is left for TYC to tell the user what happened.

Paper tape input and output is handled in a similar way except that the dispatcher must check whether the user has the punch or reader assigned to him. If not, the user's program is dismissed, and a complaint is made to him. As soon as the reader or punch has been relinquished he can continue the program from where it left off.

The typewriter and paper tape instructions are interpreted and simulated by the channel 16 dispatcher so precisely that programs written before the time-sharing system was developed can be run without change in the system, provided they do not themselves use the sequence break system. This means that almost all the previously used symbolic assemblers, typewriter input-output routines, text editors etc. can be used without change and that the user can use the TYC language to debug routines that are to be used outside it.

3. The channel 17 clock routine.

Every 20 milliseconds or so a sequence break signal is given on channel 17. Since channel 17 is the lowest priority channel this break can take effect only when no typewriter, paper tape or channel 16 dispatcher break is in progress. Moreover, except when the channel 17 program turns off the sequence break system it can be interrupted by typewriter or paper tape sequence breaks.

The basic task of the channel 17 clock routine is to decide whether to remove the current user from core and if so to decide which user program to swap in as he goes out. A user may be removed from core for any of several reasons.

1. His quantum of time is up and he should be put on the tail of the queue.

2. He has filled an output buffer.

3. He has asked for a character and there is none in the input buffer.

4. He has tried to execute an illegal instruction or to use input-output equipment not available to him.

5. The typewriter control program has filled a buffer or has finished a request concerning his program.

If the channel 17 routine decides to remove the current user it will swap into core the next user in the round robin who is in run status. A user not in run status can become so for any of the following reasons.

1. An output buffer is almost empty.

2. A character requested by his program has arrived.

3. The typewriter control program wants him in core to interrogate registers, to change them, or to run the program.

4. The typewriter control program (TYC).

The typewriter control program is in core 0 and it interprets and obeys requests from the user to give him information about his program, to change it, to run it, and to stop it. The same program must work for all users and whenever a user is put in core TYC is modified so that it refers to the current user's program.

The user makes his requests and receives information from TYC using the same typewriter as his program uses for input and output. Therefore, it is important that no matter what program the user is attempting to debug he shall be able to regain control if it goes astray. This is accomplished as follows: When the user starts a program running he can either retain the typewriter for control purposes or else give it up to the program. If he gives the typewriter to the program, then characters it types appear on his typewriter and characters he types are given to his program if it asks for them. Suppose his bad program is taking characters from the typewriter but ignoring them. He can then type the character center dot "·" which is a non-spacing character on the PDP-1. If he follows this by a carriage return the typewriter is then in the control of TYC and subsequent characters are interpreted by TYC. If he actually wants *center dot* to be transmitted to his program, he must type it twice.

Suppose now that his program is in an output loop and refuses to stop typing. Then he turns the power off on the electric typewriter. The result of this is that the computer fails to get a "done pulse" from the next character typed within a second. Control then goes to TYC which tells the channel 17 program to dismiss the user's program from core and returns the typewriter to the control of TYC as soon as the power switch is turned on again.

APPLICATIONS

The most obvious application of the BBN Time-Sharing system is to speed up debugging by allowing each user more console time and good debugging languages. In our opinion the reduction in debugging time made possible by good typewriter debugging languages and adequate access to the machine is comparable to that provided by the use of ALGOL type languages for numerical calculation. Naturally, one would like to have both but this has not yet been accomplished on any machine.

We can now mention some other applications that our system makes possible by providing inexpensive console time.

1. *Small calculations.* At present there is a large gulf between desk calculators and computers. One can start getting results 10 seconds after sitting down at a desk calculator, but extensive calculations are very tedious. The BBN Time-Sharing System makes possible and economically reasonable providing a continuous transition from using the computer as a desk calculator at one extreme to writing ALGOL programs at the other. An intermediate step is a system that allows the user to define functions by statements like

$$f(x) = x \uparrow 2 + 3.0x \times + 4.3$$

or even

$$g(m,n) = \text{if } m>n \text{ then } g(n,m) \text{ else if } rem\ (n,m) = 0 \text{ then } m \text{ else } g(rem\ (n,m),\ m)$$

and then be able to use these functions in arithmetic calculations by writing something like

$$g(3,21) \times f(38) + 19 =$$

and have the computer print the answer by interpreting the formulas for the functions. To some extent this has been achieved by the program "Expensive Desk Calculator" written by Robert Wagner at M.I.T.

2. *Editing Texts.* Several programs have been written to use the PDP-1 computer to edit paper tape texts. The user can originate text, make insertions and deletions, display the corrected text to make sure it is correct, find all occurrences of certain strings of symbols. These editing programs are much more convenient for correcting programs than using flexowriters or than making changes in a card

One such program, Colossal Typewriter, operates as follows:

There are two modes, text mode and control mode. When the program is in text mode, each character typed by the user is added to a buffer held in the core memory of the computer. There are four exceptions to this: If the user types a backspace, the program deletes the last character from the buffer, and this operation can be repeated as many times as may be required to correct a local error. Another character causes the program to type out the last 20 characters in the buffer, and a third returns the computer to control mode. The fourth special character—the single quote ' causes the cliche whose name is the following character to be entered in the text if there is such a cliche. Thus typing ' a causes the cliche named a to be entered. In addition, the cliche Feature may be used to enter any of the four control characters into the text. The user need only type ' followed by the character in question.

In control mode the user has the following facilities: to type out the buffer, to punch (pseudo-punch) the buffer, to read (pseudo-read from the drum) into the buffer a number of lines or until the first occurrence of a given cliche, to reset the ends of the buffer, to give the current buffer a name as a cliche, to kill the buffer, and to go into text mode.

Other text-editing programs allow the use of the CRT on the computer to display lines of text.

3. *Teaching Programs.* An experimental teaching laboratory using a system based on the principles of this paper is being installed at Stanford University.

Additional applications of large time-sharing systems are described in (2), (3) and (5).

OPERATING EXPERIENCE

The BBN Time-Sharing System has been in operation at Bolt Beranek and Newman Inc. since September 1962. The computer is operated in the time-sharing mode four hours per day. Initially, the number of typewriters was two but this has been increased to five. The present system has been found to have the following weaknesses which we hope will be corrected: There is no program library on the drum so that excessive use of the paper tape reader is required. Magnetic tape files for user programs are not available in the system. Five computer operated typewriters in one room make too much noise. Versions of the utility programs especially adapted to time-sharing are desired.

EXTENSION TO LARGER COMPUTERS

It is worthwhile to ask to what extent the time-sharing technique described in this paper is of more general use. As a computer the PDP-1 is characterized by high speed and relatively small memory. Its low cost means that it will not ordinarily have to be shared by a very large number of users. Suppose we wanted a time-sharing system based on core-drum swapping on another computer. Suppose that

n = number of simultaneous users
t = time for a memory cycle
m = number of words in user's memory that have to be swapped
r = response time
f = fraction of time taken by swaps;

then we have

$r = n\,t\,m(1 + \frac{1}{f})$ under the assumption that the drum keeps up with the core memory and that the read and write halves of the core memory cycle are used separately.

In the present case if we put $f = .25$, $n = 5$, $t = 5 \times 10^{-6}$ sec $m = 4000$ we get $r = .5$ sec. The difference between this result and the actual maximum response time of .85 sec. comes mainly from the fact that the present drum system swaps a word about every 8 microseconds instead of every five microseconds which in turn comes from using a standard 1800 rpm motor on a drum on which each track has 4096 bits around.

If we were to make a similar system for the IBM 7090 computer, we could have $n = 5$, $t = 2 \times 10^{-6}$, $m = 16{,}000$ (the memory of this machine really consists of 16384 72 bit words) $f = .25$ and would get

$r = .75$ sec

Thus, on account of its much larger memory the 7090 would have about the same relation between number of users and maximum response time as the PDP-1. This is less satisfactory because the expense of the larger machine requires it to serve many more users. Nevertheless, such a system would still be useful. If we make the more optimistic but reasonable assumptions that only ⅕ of the users sitting at typewriters will be in run status at a given time and that a 3 second response time is tolerable, then the system could accommodate 100 typewriters which is economically quite reasonable. This would require a better drum system than is available connected so as to allow memory swaps at core speed.

REFERENCES

1. J. GILMORE—Lincoln Lab memo (out of print)
2. C. STRACHEY—Time-Sharing in Large Fast Computers in Proceedings of the International Conference on Information Processing, UNESCO, Paris 15-20 June 1959, UNESCO, Paris, 1960, pp. 336-341.
3. J. C. R. LICKLIDER—"Man Computer Symbiosis". *IRE Transactions on Human Factors In Electronics,* (March 1960).

4. F. J. CORBATO—1962 WJCC An Experimental Time-Sharing System, Fernando J. Corbato, Majorie Merwin-Daggett, Robert C. Daley, 1962 Spring Joint Computer Conference.

5. J. McCARTHY—Time Sharing Computer Systems in Management and the Computer of the Future edited by Martin Greenberger, M.I.T. Press, 1962.

6. PDP-1 manual—Digital Equipment Corporation, Maynard, Mass.

7. S. BOILEN—User's Manual for the BBN Time-Sharing System—Bolt Beranek and Newman, 50 Moulton St., Cambridge, Mass.

[Reprinted from MODELS FOR THE PERCEPTION OF SPEECH AND VISUAL FORM]

INVITED PAPERS I

The Perception Problem

Chairman: Weiant Wathen-Dunn
Data Sciences Laboratory
Air Force Cambridge Research Laboratories
Bedford, Massachusetts

DYNAMIC MODELING

J. C. R. Licklider
Thomas J. Watson Research Center
International Business Machines Corporation
Yorktown, New York

Introduction

It seems appropriate, at the beginning of this symposium, to discuss dynamic modeling even though dynamic modeling is only now in the process of being fashioned into a tool that can be used in research on the perception of speech and visual form. It seems appropriate because the field of research with which the symposium is concerned is in such a dynamic phase, moving forward rapidly with vigor and, indeed, force. As will be evident, I feel sure that dynamic modeling will play an important role, during the coming years, in research on speech and visual form. My purpose, therefore, is to describe the new tool and the way in which it appears to be developing and to relate the new tool to problems of perception.

By "dynamic modeling" I am referring to a meld of mathematical modeling, computer-program simulation, dynamic display, and on-line interaction between human modelers and computers. Mathematical models have been used in research and development for many years. Analogue computer models, which often combine mathematical models with dynamic display and man-machine interaction, are old, familiar friends. What is new — new within the last five or six years and only now coming into truly practical application — is the combining of dynamic display and close man-machine interaction with digital computing and digital-computer program simulation. Whereas dynamic modeling with analogue computers was restricted mainly to processes describable by integrodifferential equations, dynamic modeling with the aid of digital computers has an almost unlimited domain.

For the study of perception, dynamic modeling with the aid of digital computers is particularly significant because the method is the only one that is capable of handling problems and processes of the complexity that is encountered at every hand in the psychophysiology of cognition. I do not say that dynamic modeling makes it easy to handle complexity of that order. I say only that it makes it possible. As I shall try to elucidate, dynamic modeling in the context of on-line interactive computing offers two great promises. The first of these is a method and means of feeling one's way into and through a complex problem or process, of making trials easy and errors tolerable, of accumulating gains both large and small until a successful representation of even a very complicated, dynamic situation has been achieved. The other great promise is to facilitate cooperation among members of a research community — even though the community may be geographically dispersed — and to provide a way for their individual contributions to interact rapidly and precisely with one another and, insofar as they are compatible, to fit together into a coherent, over-all theory. Those promises are rather far from being realized — the second one, particularly — but I think they are worth discussing at this time. Without them, the prospect of making coherent sense of the perception of speech and visual form might seem discouragingly bleak.

Inadequacy of Static Models

My own interest in digital computers and dynamic modeling stemmed directly from frustration with the tools and techniques that were available a few years ago to facilitate thinking about problems of auditory perception. It will help me explain my enthusiasm for dynamic modeling if you will let me try to recall some of the problems and some of the difficulties that arose in thinking about auditory perception.

Perhaps seven years ago, we were trying to understand — as, indeed, we still are now, but we are farther along the road — how speech is generated, how it is perceived, and how the circuit through generation and perception is closed. We thought we understood fairly well how the outer ear and middle ear work. We thought we understood their functioning qualitatively, though perhaps without great quantitative precision. Actually, except for a few specialists among us, we thought that not very much of great significance to hearing and understanding speech happens to the speech signal as it passes through the outer ear and the middle ear; merely a little frequency distortion and, when the signal is too strong, a nonlinear clamping down by the muscles of the middle ear. Thus we had in our minds a picture of the speech waveform as it passed through a few small spaces and structures and as it was transformed from acoustical to mechanical vibration and flowed into the complex, dynamic, but familiar structure of the inner ear.

From Békésy (1956, 1958; Békésy and Rosenblith, 1951), Zwislocki (1946), Fletcher (1953), and a few others, we had derived dynamic images of the cochlear canals, the cochlear partition, the Organs of Corti, and so on. More importantly, we had, in varying degrees, an understanding of the transformations carried out by the cochlear dynamics. We thought of the input to the cochlea as a time function (pressure varying with time) and of the cochlear output as a manif... of activity (displacement varying with distance along the coch... partition from base to apex, as well as with time). Our think... the dynamics of the cochlea took place partly in moving images o... traveling waves, partly in terms of stationary graphs, and partly in mathematical equations. In my own assessment of the situation, Flanagan's (1960, 1962) computer-program simulation of the cochlear process was quite important because, even though not connected to a dynamic display, it did serve as a bridge between an essentially mathematical description of the structure and a graphical, visible expression of behavior. Békésy's (1956, 1958) demonstration models were important to me, also, because they provided a bridge, fairly clear even though implicit, to a mathematical description of structure and, at the same time, a bridge of very clear dynamic display to visual perception.

Trying to move on from the cochlea into the neural processes underlying perception, we ran into difficulties almost immediately. It was possible to add to our pictures of the cochlear process the stage in which the mechanical output of the cochlea is transformed into electrical or electrochemical excitation of neurons in the auditory nerve. Experiments by Békésy (1951, 1952), by Davis and his colleagues (1950), and others were providing significant information about the transformation, but many of us could not — at that time, at least — develop a much clearer picture of what happened in the transformation, from the time function of the displacement of the cochlear partition to the time function of neural excitation, than that the function was essentially nonlinear.

From the auditory nerve on into the brain, and from the auditory cortex back into the lower auditory centers, our pictures and our understanding of what went on in the auditory perception became vague and also fragmentary. We knew quite a bit about speech as a physical stimulus and something, thanks to such scientists as Jakobson, Fant, and Halle (1965), about speech as a carrier of language. We hoped to establish correlations between physical events, psychological events, and neurophysiological events. There was, however, both too much information and not enough information. There was no way to represent all the parts of the puzzle explicitly and to make them interact together so that we could see whether we had any significant fraction of the necessary data in our hands or heads.

One could set down a similar description of the situation then prevailing in the generation of speech. The articulatory movements were understood, at least to some extent, and they could be visualized dynamically. It was understood, of course, that the articulatory movements are controlled by muscles, which in turn are activated by messages from the nervous system. We could imagine processes, back there in the brain some place, that dealt with events corresponding to phonemes — or "phonoids" as some of us called them in order to avoid appropriating a term that had a more sharply defined meaning in the field of language. We were almost helpless to relate those merely imagined processes to our equally vague concepts of the brain's dynamic representation of the world.

In thinking about those things, we were trying to hold in mind and correlate extremely many and diverse elements of information. We were trying to fit them together into coherent patterns, trying to find internally consistent and contextually plausible mechanisms that would serve as testable hypotheses. The trouble was that the situation had become too complex to be handled with the available tools. Too much was known about the physical acoustics of hearing, too much about the neurophysiological processes of hearing, and too much about auditory behavior — too much for us to hold all the parts in mind at once. Even though we could not process all the information we had, it was obvious that there was much information we did not have. Many members of the research community continued, therefore, to conduct experiments and to acquire new information. Others of us, believing that new information would not help much until we had improved tools for processing and digesting it, turned from further experimentation, and from continuation of the effort to understand simply by reading and thinking. Indeed, some of us may have, in the quest for new tools, traveled so far from the substantive territory of psychoacoustics as to raise doubt about the probability of return. However, it is better not to think of returning until one has successfully completed his quest. The question with which I am concerned here is: Are any promising tools being found?

The answer to that question that I urge upon you is affirmative. The basic tool is dynamic modeling. The context within which dynamic modeling presents itself, the context of interactive computing systems, is perhaps even more important than the basic tool, itself, because the context makes it possible to employ the tool and because the context carries with it a variety of companion tools that are useful in themselves and which produce, with dynamic modeling, a mutually facilitatory effect. Of these associated tools, the ones that I shall mention are on-line information retrieval and communication, through a teleproces network, with other workers in a field of research.

Dynamic Models

Whereas a static model has only one form, the static form, a dynamic model has two forms, a static and a dynamic. Ordinary mathematical models are static models. They are representations in symbols, usually written in pencil or ink on paper. They do not behave in any way. They do not "solve themselves." For any transformation to be made, for any solution to be achieved, information contained in the model must be read out of the static form and processed in some active processor, such as a mathematician's brain or a computing machine. A dynamic model, on the other hand, exists in its static form only while it is inactive. The dynamic model can be set into action, by one means or another, and when it is active, it does exhibit behavior and does "solve itself" in the sense of exhibiting the consequences that stem from the interplay between its initial or boundary conditions and its internal structure. In the past, some of the best examples of dynamic models were flying scale models of airplanes, wind-tunnel models of airplanes, testing-basin models of ships, and analogue-computer models.

During the last few years, digital-computer models (models expressed in the form of digital-computer programs) have risen, I think it is safe to say, to the first rank of importance in dynamic modeling. If there is a distinction to be made between digital-computer simulations and digital-computer dynamic models, I should like it to be based upon the emphasis, in the dynamic models, of dynamic display and of close interaction between the model and the modeler. There is nothing about the terms, as terms, that forces that distinction, any more than there is between the terms in the distinction between multiprogramming and time sharing. It is simply that dynamic modeling has come, or is coming, to have the connotations of display and interaction. By "dynamic display" I mean the kind of display that is provided by cathode-ray oscilloscopes. By "interaction between the modeler and the model" I imply that the modeler manipulates the model, varying its parameters or its basic structure and observing the effects thus produced, either in order to understand how the behavior stems from the structure or to explore the behavior, itself, over a wide range of structures and conditions.

The main reason for the ascendance of digital-computer program model , I think, is that digital computers are capable of handling an almost unrestricted range of problems, whereas other means of dynamic modeling are constrained to narrow classes of problems. Digital computers and their programs are capable, of course, of reproducing exactly the same behavior, over and over: they do not "drift." One can build up an increasingly complex structure by concentrating his attention now on one part, now on another, without worrying lest a part perfected earlier fall out of adjustment while he is paying attention to a new subroutine. Furthermore, of course, several or many people can cooperate to produce an exceedingly complex computer program. I shall not say that team or group programming has yet been reduced to an efficient procedure, or that complex computer programs are easy or inexpensive to produce, but I shall say that some progress is being made toward mastery and efficiency, d that computer programming is the only known way of producing able representations of very complex situations or processe

Flanag 's (1960, 1962) model of the cochlea is a good example of a computer-program simulation. It accepts as input computer-processible representations of simple or compound oscillations and produces, as output, representations of the displacement of the cochlear partition at closely spaced points between the base and the apex. However, it does not permit the modeler to watch traveling waves progress along the basilar membrane in the way he would if the waves appeared on the screen of an oscilloscope and moved before his eyes. I do not know of any simulation or model program in the area of hearing that does have that characteristic. I must go outside the field of hearing, therefore, for examples of dynamic modeling with the aid of computer programs.

The first dynamic models I ever saw were, I believe, those of Farley, Frishkopf, Clark, and Gilmore (1957), computer-program and oscilloscope-display models of the dynamic behavior of assemblies of schematized neurons of the kind discussed by Donald Hebb in his Organization of Behavior (1949). Looking at the arrays of "cell bodies" on the oscilloscope screen, one could see waves of discharge propagating in what appeared to be partly regular, partly haphazard patterns. Farley and Clark systematically varied the parameters of the assembly model and catalogued the observed behaviors. Those early investigations contain the essence of what I think is most important in dynamic modeling. It is, as mentioned earlier, that the model has both static and dynamic forms. Actually, the model exists in three domains: it exists in processible form within the memory of the computer; it exists in displayed form in a dynamic presentation device; and it exists in perceived form in the mind of the modeler. The role of the display, of course, is to connect the computer-processible form and the perceived form directly together and thereby to permit exploration by the modeler of the structure and the parameters of the model.

My own first involvement in the construction of dynamic models dealt with so simple a matter that one might hesitate to use the word "model." Even in a very simple application, however, one can sense the great power of the arrangement consisting of computer program, dynamic display, and facilities for intervention and control by the modeler. Several of us then at Bolt Beranek and Newman prepared computer programs to help students understand the relations between the symbolic and the graphical forms of simple mathematical equations. The equations were straight lines, parabolas, or cubics. They were stored in the computer memory as configurations of bits representing the equations as equations. They were displayed on the oscilloscope screen, however, both symbolically, i.e., in the form of letters and numerals, and graphically, in the form of straight lines or curves against rectangular coordinates. Adjacent to the coordinate frame was a system of scales and arrows. By pointing to the scales with a light pen, the student could assign whatever values he liked to the coefficients in the equations. Whenever he changed a coefficient, both the symbolic and the graphical displays adjusted immediately to the new value. Thus the student could perceive directly "what each coefficient did" to the graph, and he could see how each change in the graph appeared in terms of the coefficients. The equations were perhaps too simple to be thought of as models, but this experience with the idea impressed me greatly, and I think that it exhibited the essence of a fundamental of dynamic modeling, as I am using that phrase.

Probably the most significant single step in the development of techniques for dynamic modeling was Ivan Sutherland's doctoral dissertation (1963), Sketchpad, worked out on the TX-2 computer of the M. I. T. Lincoln Laboratory. Since Sketchpad is doubtless familar to most of you, I shall not describe it in detail. Let me, however, describe two if its many demonstrations that illustrate what can be done with dynamic-modeling techniques in the domain of mechanical linkages and structures.

Sketching with a light pen on the screen of the TX-2 computer, Sutherland defined the structure of a mechanical linkage consisting of pivots, crank arms, and coupling linkages. The structure, idealized by the computer from Sutherland's hand-drawn sketch and displayed on the oscilloscope screen as straight, even line segments, was just a bit too complicated for the viewer to see exactly what would happen if one of the cranks were turned. Sutherland "grasped" the end of the crank with the light pen and turned the crank. The other members of the linkage moved in response, respecting the constraints imposed upon them by the structure, and at once one member collided with another -- and it was immediately clear what circumstances and what characteristics of the structure caused the difficulty. Using the light pen again, in conjunction with the erase button, Sutherland immediately repaired the linkage system and tested it again. This time it functioned flawlessly.

Calling for a new sheet of "paper," Sutherland then sketched a simple bridge structure consisting of several boxes with crossbracing. He drew a support under each end of the bridge and attached (schematically) a weight to the bottom of the bridge at its center. The bridge sagged under the load, and numbers appeared on the display — one number for each line or member in the structure — indicating the value of the tension or compression to which it was being subjected. Sutherland did not carry the demonstration to the extreme of causing the bridge to break when the strength of a member was exceeded, but he could have done that without much trouble.

During the years since the advent of Sketchpad, techniques of graphic input to computers and graphic display by computers have been developed intensively for application in the new field of computer-aided design. Most of the applications have been to design of mechanical structures, vehicles, highways, and the like. Programs have been prepared, for example by Bert Green[1], by Lawrence Roberts (1963), and by Timothy Johnson (1963), to display three-dimensional objects as oblique drawings, as perspective drawings, and/or in plan view, front view, and side view in the manner of an engineering drawing. The techniques are not essentially restricted, however, to the modeling of physical objects and structures. Indeed, their intellectual (as opposed to economic) power may be greater in dealing with abstractions, for the techniques permit abstractions -- permit the behavior of dynamic or kinematic abstractions — to register directly through perception, and people seem to grasp complex, dynamic things much more readily when they see them happen than when they have to reconstruct such processes mentally from a succession of messages that define, but do not dynamically depict, the processes. Complex, abstract processes there is no way to see directly. Dynamic modeling may have great value, therefore, in converting such abstractions to concrete form through dynamic display.

In the field of perception, advocacy of dynamic modeling at this time — or at any rate my enthusiasm in advocating it — has to be explained, or justified, by saying (as I tried to say in the Introduction) that the field so needs the new tool that one may talk about it in a hortatory tone even before it has been tested and proved in significant applications. In the field of computer-aided design, however, that is no longer the situation. Important applications were undertaken almost concurrently with the first laboratory demonstrations of the technique.

---

[1] Personal communication.

At the Fall Joint Computer Conference in San Francisco (September 1964), engineers of the General Motors Corporation (Jacks, 1964) unveiled a successful, significant application of computer-program simulation and display in the design of automobile bodies and related structures. The program was carried out with prototype equipment, and it is clear that there are many improvements in hardware and software to be made, but it is also clear that the fundamental concepts of the method are very powerful.

On-Line Modeling in a Time-Sharing Computer System

The fields with which we are concerned in this symposium are, of course, far too broad to be subsumed in any single model created by an individual, too broad to be understood by any single individual. The understanding of hearing and vision is an undertaking for a research community. It is, therefore, not enough to have techniques for the programming and display of models. It is necessary to have techniques that will support interaction among members of the research community with one another and with the models that they create, test, modify, publish, and criticize. Models of subprocesses have to be fitted together to make models of processes. Models cast in diverse forms have to be compared with one another. Models have to be brought into interaction with experimentation, with data reduction, and with processes of extrapolation and prediction. These considerations pose requirements for systems and techniques that go far beyond the present state of the art, but in the present art there are beginnings that hold out promise for the effective handling of the broader parts of the problem as well as of the focal element, dynamic modeling.

Since most of you are familiar with one or more of the recently developed computer time-sharing systems, I shall give only a brief sketch of the context within which it seems likely that dynamic modeling and interaction among research colleagues and their models will develop. The context is, essentially, a network of computer time-sharing systems. It seems likely that time-sharing systems will in due course be set up in most of the universities, government research laboratories, and other institutions within which research in our fields is conducted. It seems likely, also, that many of the time-sharing systems will be interconnected to form a network or networks. It will then be possible for most of the research workers in a field of science to communicate with one another through the computer network. That way of communicating will have marked advantages over telephone communication, mail, and publication, for two or more people with common concerns can work together with their models and with their data. They can substitute the running of a model for mere talk about it.

The way of working just described is in one sense a distant dream and in another sense a present reality. Some of our colleagues at M. I. T., Carnegie Institute of Technology, Stanford University, and perhaps a few other institutions already hold intergroup teletype conferences. However, for overpowering economic reasons, they do not transmit dynamic oscilloscope displays across the country. Indeed, [illegible] not nearly as much [illegible]ynamic display on oscilloscope screens [illegible] there is typing on paper in existing time-sharing systems. To operate a complex, dynamic display by plotting and replotting every individual point requires a large amount of calculation by a computer and a large amount of transmission from the computer to the display. One can simplify and economize by taking advantage of the spatial and temporal redundancies in the displayed configurations. If character-generating and function-generating devices are incorporated into the console, the load on the central computer and on the transmission facilities is reduced. Important steps have already been taken along that line, and the relevant technology is advancing rapidly, but dynamic display makes, at the present time, a somewhat embarrassing demand on the central processor of a time-sharing system, and the cost of long-distance transmission of the signals required to maintain dynamic displays is, at present, too great to permit widespread use. That is to say, the techniques and the technology are not precisely standing there crying for immediate application in our fields of study. On the other hand, I think they will be ready — quite ready — before our field, and others like it, will be ready to take full advantage of them.[2] It is that consideration, basically, that leads me to discuss this topic in the introduction to this symposium.

---

[2]Between the time of the symposium and the time of publication, significant technical developments occurred. Storage display tubes and small computers associated with consoles now offer promising solutions.

Field-Oriented Languages for Dynamic Modeling and Related Activities

The over-all task of preparing a complex, dynamic model is so great, so demanding of diverse skills, that dynamic modeling cannot become an effective way of working for the great majority of substantively oriented scientists and engineers until a considerable amount of tool-making has been done by computer-oriented scientists and engineers. I have mentioned briefly one or two of the things that need to be done in the display hardware area. Of greater direct concern to our group, however, are the things that have to be done in the software area — things that have to do with the preparation of the computer programs that constitute, or underlie, dynamic models. The main thing that has to be done in this area is to develop a modeling language in terms of which the substantively oriented scientist or engineer can describe what he has in mind and from which his statements can be converted automatically into an operable dynamic-model program.

Most of the work of constructing such a language, or such languages, is work for the computer programming specialist. Part of it, however, has to be the responsibility of people who understand deeply the areas of application. That is to say, the general-purpose parts of a dynamic modeling language can be constructed by computer programmers, but the part that defines the operations and vocabulary peculiar to a particular field of application has to be done by substantive experts working in close collaboration with computer programmers. Some substantively oriented scientists and engineers, therefore, are going to have to become closely acquainted and associated with computer software specialists and their field of activity before there will be truly effective and convenient tools for use in the various branches of science and engineering.

An Approach to the Development and Testing of Dynamic Modeling in Hearing and Vision

Being convinced that dynamic modeling is potentially of revolutionary significance for our fields, I should like, in closing this talk, to make a suggestion — a proposal of an approach that might accelerate the introduction of dynamic modeling in a practical way into the fields of hearing and vision. The proposal can be stated briefly as long as one does not go into detail about particulars. I shall not go into detail.

The idea is for five or six research workers in the field of hearing and/or five or six research workers in the field of vision to take two years off from their usual activities, one year in the near future and the other year somewhat later. The group would be invited, let us suppose, to work at one of the institutions at which there is, in existence now, a time-sharing computer system and a community of computer-oriented experts and also a community of substantively oriented scientists and engineers who are more or less familiar, as users, with the system. During the first year of work in that context, the project group would spend about half its time learning, as deeply as possible, the lore of on-line interactive computing. The other half of its time the group would spend in theoretical discussion of problems of mutual interest, plus perhaps some experimentation, and particularly in exploration of the problem of expressing ideas and hypotheses in computer-program form. By the end of the year, the members of the group would be creating and operating small models of various sorts, and there might even be some progress toward connecting several small models into an assembly that would present in a tangible way the problem of writing programs that are compatible with programs written by colleagues and documenting programs to facilitate communication of the ideas they embody. The first year would not, however, see the accomplishment of a theoretically significant system of dynamic models in vision or hearing. The significant product to be hoped for would be a series of working papers and a final report — or two final reports, one for vision and one for hearing — on the requirements, as seen by persons of longstanding expertness in the substantive fields and newly acquired sophistication in on-line computing, for a language to facilitate the creation, testing, and communication of dynamic models in hearing and/or vision.

The complementary part of the proposal now comes into the picture. It is that a small group of computer programming specialists design and implement a language for dynamic modeling, a language that would meet the requirements set forth by the substantive experts. That might be accomplished in one year. It might require two. In either case, it would involve a certain amount of consultation between the computer experts and the substantive experts, but the task would be mainly in the hands of the computer experts.

The proposal now goes back to the researchers in hearing and/or vision. They should work again in the context of a time-sharing computer system — or within more than one such context, if their own organizations have time-sharing systems by then — and try to prepare theoretically significant dynamic models. Their effort would test the language prepared for them. Doubtless there would have to be modifications. The computer programming experts would still be in the picture, and would make the improvements. The modelers would concentrate on small enough theoretical areas that models set up within them would be able to make contact with one another and to be organized together into a system of models. The models would be prepared in such a way that they would interact with experimental data — either being tested by confrontation with the data or adjusting automatically to come into accordance with it. The program of the second year of the vision/hearing group thus would consist of both theoretical and experimental activity, with dynamic models at the focus of it all. The scientific product of the second year might include published papers of the conventional type, but it would include, also, a new kind of scientific publication: the published dynamic model, a thoroughly tested and documented computer program designed to represent, and also to present dynamically, scientific or technical ideas too complex to be communicated effectively by static strings of characters or static graphs and diagrams.

References

Békésy, G. von. DC potentials and energy balance of the cochlear partition. J. acoust. Soc. Amer., 1951, 23, 576-582.

Békésy, G. von. DC resting potentials inside the cochlear partition. J. acoust. Soc. Amer., 1952, 24, 72-76.

Békésy, G. von. Simplified model to demonstrate the energy flow and formation of traveling waves similar to those found in the cochlea. Proc. nat. Acad. Sci., Wash., 1956, 42, 930-944.

Békésy, G. von. Pendulums, traveling waves, and the cochlea: Introduction and script for a motion picture. Laryngoscope, 1958, 68, 317-327.

Békésy, G. von, and Rosenblith, W. A. The mechanical properties of the ear. In S. S. Stevens (Ed.), Handbook of experimental psychology. New York: Wiley, 1951. Pp. 1076-1115.

Davis, H., Fernandes, C., and McAuliffe, D. R. The excitatory process in the cochlea. Proc. nat. Acad. Sci., Wash., 1950, 36, 580-587.

Farley, B. G., Frishkopf, L. S., Clark, W. A., Jr., and Gilmore, J. T., Jr. Computer techniques for the study of patterns in the electroencephalogram. M. I. T. Lincoln Lab. tech. Rep., 1957, No. 165.

Flanagan, J. L. Models for approximating basilar membrane displacement. Bell Syst. tech. J., 1960, 39, 1163-1191.

Flanagan, J. L. Models for approximating basilar membrane displacement — Part II. Effects of middle-ear transmission and some relations between subjective and physiological behavior. Bell Syst. tech. J., 1962, 41, 959-1009.

Fletcher, H. Speech and hearing in communication. New York: Van Nostrand, 1953.

Hebb, D. O. The organization of behavior. New York: Wiley, 1949.

Jacks, E. L. A laboratory for the study of graphical man-machine communication. Proc. AFIPS Fall joint Computer Conf., 1964, 26, 343-350.

Jakobson, R., Fant, C. G. M., and Halle, M. Preliminaries to speech analysis. (6th ed.) Cambridge: M. I. T. Press, 1965.

Johnson, T. E. Sketchpad III: A computer program for drawing in three dimensions. Proc. AFIPS Spring joint Computer Conf., 1963, 23, 347-353.

Roberts, L. G. Machine perception of three-dimensional solids. Lincoln Lab. tech. Rep., 1963, No. 315.

Sutherland, I. E. Sketchpad: A man-machine graphical communication system. Proc. AFIPS Spring joint Computer Conf., 1963, 23, 329-346.

Zwislocki, J. Mechanical frequency characteristics of the ear. Experientia, 1946, 2, 415-417.

[Reprinted from COMMUNICATION PROCESSES]

PROBLEMS IN MAN–COMPUTER COMMUNICATIONS

J. C. R. LICKLIDER
ARPA, Washington

BECAUSE the field of man–computer communication is burgeoning, it will be necessary to select only a few of many problems. These problems are being studied and, indeed, some of them are being solved, in a concerted program that involves—in addition to Professor Miller's university and Professor Newell's university—Massachusetts Institute of Technology, Stanford Research Institute, Stanford University, Systems Development Corporation, University of California (Berkeley and Los Angeles), and other organizations. The problems are multi-disciplinary. The effort involves mathematicians, logicians, linguists, electrical engineers, and computer scientists as well as psychologists.

THE SPEED-COST MISMATCH

From a practical point of view, one of the greatest problems in man–computer communication stems from the fact that computers are so very fast and expensive, whereas men think relatively slowly and cost relatively little. It is usually uneconomic to let one man, even a very creative man, monopolize the time of a large-scale digital computer. Yet, as I have been emphasizing, we are interested in developing the kind of interaction between man and computer in which the man sits at the console and carries on a kind of conversation with the computer.

There are two general approaches to solution of the speed-cost mismatch problem. One is to construct a large number of small, inexpensive computers. Small, inexpensive computers are extremely attractive, and this approach is active. However, at present and for some time into the future, a small, inexpensive computer is necessarily a computer with a small memory. More and more, we are finding that large memory is an essential prerequisite for effective man–computer interactions of many types. Moreover we are sensing that the truly important thing is not interaction between one man and a computer, but interaction between several or many men and a computer. The approach based on small, inexpensive machines does not lead to that goal.

The other approach is based upon the sharing of the time and the memory of a large-scale computer among several or many men. The problem of time sharing has been essentially solved in principle, and man[illegible] of it have been solved in practice. The problem of memory sharing[illegible] "space sharing", as one may call it in order to justify the [illegible] sharing of space and time"—has also been essentially solved [illegible] principle, but there is not yet much actual use of shared or "public[illegible] computer programs and files of data in a computer memory.

Comp[illegible] time sharing is actually a fairly simple matter. In the simp[illegible]m, a single-sequence computer works for a short time on one m[illegible] problem, then for a short time on another's, then for a short time [illegible] another's, etc., cycling back to the first man in such a short time [illegible]ch user thinks he is getting continuous attention. There are sever[illegible]ons of this system.

In one [illegible]sion, the computer's sequence of operation is interrupted whenev[illegible]y user takes any interactive action at all—even if he only presses [illegible] on his typewriter. In response to the interruption, the compu[illegible]es away the contents of its active registers, so that it will not los[illegible] of what it was doing, refills its active registers with the quanti[illegible] they contained when it last left the service of the presently interr[illegible] user, and then sets to work (again) on the problem posed by the in[illegible]rupting user. This very rapid service in request to interruptions [illegible] limited, of course, to actions that the computer can take very quick[illegible], for the machine must not spend so long handling one interruption that it is, in the process, usually interrupted by another and another and another. In the version of the system here being described, the computer spends the time between the "minor" interruptions (e.g. [illegible]ccept and store a typed character) rotating among the users and handling their main problems (e.g. to solve a problem stated in the form of a long sequence of typed characters). Obviously, there is room in this process for a scheduling routine to keep track of the users' needs and priorities.

At the other end of the scale is a version of the system that is based on the principle that the best thing for the computer to do is to pay attention to one user at a time, and to give that user a sufficiently long block of service that a reasonable amount of processing can be accomplished. In systems based on this approach, users sometimes have to sit and wait for attention from the computer, but they wait only a minute or two—and not the hours or days they have to wait when they take their work to a conventional digital computer center. In order to min[illegible]e waiting, systems that employ long blocks of time provide each use[illegible] with an input buffer. He enters a statement or question into the buffe[illegible] and, then, with a special key, signals the computer that he is ready to have it perform a non-trivial task for him.

Some modern digital computers have several processors that operate simultaneously. If certain promising developments in microelectronics prove to be successful, it may in due course be feasible for each user to have his own private processor. The requirement will remain, nevertheless, for several or many users to share a large computer memory, because—even if large memories should somehow become inexpensive—there is nothing on the horizon that promises to integrate effectively the activities of a team of men engaged in an intellectual task as effectively as common reference to a large computer memory.

The users of a time-shared computer need not be located near the computer, of course. They can work in their offices and let the information flow between them and the computer over wires. One of my colleagues, Edward Fredkin, used to dramatize the difference between computers as devices and information processing as a function by saying that people should ask, not for a computer, but for a wall socket. He was thinking, of course, in terms of the analogy discussed earlier—of information processing as a utility.

The remote aspect of time-shared computing was highlighted last summer when representatives of the Systems Development Corporation participated in a Summer Study conducted by Project MAC at MIT. One of the SDC men worked at one teletype console in a room at MIT, while a Project MAC colleague worked at another. One was sharing the time of the AN/FSQ-32 computer in Santa Monica, California, while the other was sharing the time of an IBM 7094 computer at MIT with the programs of seven to nineteen other people.

One of the things about time sharing that is not solved very satisfactorily is "memory protection". When one is sharing a computer with several others, he does not want their mistakes to ruin his programs. That general attitude is reciprocal. At the same time, because memory space is very expensive, and because it takes a considerable time to transfer programs or data from disks or drums or tapes to the primary core memory, there is every reason to make joint use of often-needed programs, and for many purposes it is desirable to have public records available to anyone, as well as private individual files of data. At the extreme, one can foresee needs for complex patterns of authorization and accessibility. Simple memory-protection systems are now in successful operation, but there are several problems yet to be solved—problems in system organization, component engineering, and even user psychology—before truly sophisticated arrangements for the sharing of memory space can be implemented.

In leaving this topic, I think it will be worthwhile to mention a point about the sharing of computer programs. One of the late John Von Neumann's great insights was that computer programs could be stored in a computer memory and operated upon just as though they were data. Ever since he announced that idea, programs have been written in such a way that, while they are being executed, the patterns of digits within the program that constitute the temporary "scratch-pad" records are continually changing. As soon as we start to think about sharing programs, however, we see the practice of changing programs during operation in a different light. Several users may want to employ the same program at once. Each user would like to be able to count on finding it in some definite, expected condition.

For programs that are to be shared, several of us have developed a style of programming that we call "pure procedure". A pure procedure is fixed and invariant. All the temporary records that are involved in its operation are kept, not inside the program, but outside it, in areas of memory associated with an individual user. This arrangement makes it possible for several users to execute the program simultaneously, and even for a high-priority user to pass a low-priority user as though they were both going down the same street.

PHYSICAL INTERFACE BETWEEN MAN AND COMPUTER

The physical interface between the man and the computer should be of particular interest to human engineers. In the conventional computer center, the physical interface between the man who formulates the problem and the computer that solves it is, almost literally, the plate-glass wall that lets him look at the computer but not touch it. Actually, he communicates not with the computer but with computer programmers, or coders, or keypunch operators, and with the receptionist who gives him the inch-thick sheet of "printouts" and the decks of punched cards when he returns to pick up the results of the run. In the kind of man–computer interaction about which we are talking here, however, the situation is quite different. The physical interface is the "console".

At the present time, the console is usually just a typewriter or teletypewriter. In a few instances, however, the console is truly a console: a desk with a computer-operated electric typewriter, a cathode-ray-tube screen for dynamic display, a "light pen" with which the operator can designate significant locations on the screen and (aided by the computer) write and draw, and miscellaneous buttons, switches and lights. The consoles with which I am familiar leave much room for creative invention and development. For the kind of man–computer interation to which we aspire, the cathode-ray-tube display should provide as sharp and clear an image as does the printed page, yet should retain the dynamic character and the responsiveness to the light pen that introduces wholly new dimensions into human appreciation and control of information processes. The light pen, itself, should feel like an ordinary pen or pencil. The typewriter (or teletypewriter) should be designed to take advantage of the fact that it is associated with a computer. There is no need to have a direct, one-to-one connection between the key one presses and the printing head that strikes the paper. It is enough for the pressing of a key to send a signal to the computer; the computer can then take care of the activation of the printing head. In a selected mode, the operator should be able to control the typing of his name and address by pressing a single key. In another selected mode, he should be able to build up an unusual character—an upper-case Greek omega, for example—by pressing several keys. The font of characters continually at the typist's disposal should be much larger than is provided in conventional machines.

The whole domain of keyboard devices is, indeed, a very interesting one for psychological study. If it is true (as many of us are convinced it is) that large character ensembles facilitate mathematical and other creative intellectual work, then there is reason to encourage the development of skills similar to the one familiar in stenotypy, in which several keys are pressed simultaneously to select one character from a set.

The cathode-ray-tube screen and light pen provide the basis for potentially a more flexible system of communication between man and computer than any keyboard device is likely to afford. The work of Ivan Sutherland has dramatically demonstrated the capability of screen-and-light-pen communication in two dimensions, and present work by Johnson is extending the demonstration to three-dimensional figures.

The Sutherland–Johnson system, called "Sketchpad", has a number of modes. In some modes, when the operator draws a line, the computer draws an absolutely straight line. When the operator makes two lines come almost together at a corner, the computer makes them come exactly together. Furthermore, it remembers that the lines join and, if the operator moves one of the lines, the computer moves the other one in such a way as to maintain the intersection at the corner. In other modes, the computer makes perfect arcs, straightens up figures so that nearly-horizontal lines are exactly horizontal and nearly-vertical lines are exactly vertical, etc. It remembers the shape of a figure or subfigure and produces replicates on demand. It permits the operator to make an assembly of several elementary figures, to replicate assemblies, to make assemblies of assemblies, etc.

The most advanced behavior I have seen demonstrated in two-dimensional Sketchpad involved a sketch of a bridge girder. Dr. Sutherland sketched the girder and indicated the points at which members were connected together by rivets. He then drew a support at each end of the girder and a load at its centre. The sketch of the girder then sagged under the load, and a number appeared on each member, indicating the amount of tension or compression to which the member was being subjected. Equally dramatic things are done by Johnson's three-dimensional program. When Johnson adds a line to the plan view, it appears simultaneously in the front view, the side view, and the oblique representation. When he rotates the oblique representation, the orthogonal views change appropriately, etc. Depending upon one's point of view, projective geometry becomes either comprehensible or obsolete.

As beautiful as the Sketchpad demonstrations are, it is clear that they are opening, rather than culminating, a rich development in man–computer interaction. There are concurrent systems that are making a beginning in the area of convenient manipulation of graphical representations and translation between graphical and symbolic representations. When one gets to symbolic representations, he is on the verge of a whole domain of computer "services" that promise to extend man's ability to explore the consequences of mathematical and logical procedures. The physical interface is, of course, only one aspect of such interaction. It is, nevertheless, in its own right an interesting and important focus for research and development, for it is difficult to match the highly dissimilar members of the partnership together, and it is very important that the interface be a mechanism for matching and not a barrier.

LANGUAGES FOR MAN–COMPUTER INTERACTION

The Sketchpad programs, described in the preceding section, are, of course, as closely associated with language as they are with the physical interface. Indeed, it is sometimes helpful to think of the physical interface as being merely part of the language system for man–computer communication. This language system is, in my opinion, one of the truly great modern challenges—and it is directed in considerable part to psychologists.

Almost all the languages that have thus far been developed to facilitate human use of digital computers have been programming languages. Most of the programming languages have been oriented toward the preparation of procedures—computer programs, subroutines, etc.—for the solution of problems, rather than directly toward the problems themselves. Such languages are called "procedure oriented languages". Some programming languages, on the other hand, have been directed toward problems or problem areas. They are called "problem-oriented languages". The languages that have not been aimed at programming have been developed mainly to facilitate retrieval of information from computer files. The latter are essentially the only existing languages for substantive computer users, as distinguished from computer programmers. They are called "query" languages. Now, as most of us realize full well, computer programming is a very difficult, complex, and time-consuming art. The development of languages and systems to facilitate programming is still young. Very much remains to be done in this field. Programming, indeed, should be made the object of psychological study to a much greater extent than it has been. Let us not pause, now, however, to consider programming or programming languages. Let us focus our attention upon the substantive user of computers, upon the man engaged in close man–computer interaction, and examine briefly his languages needs and prospects.

In a sense, of course, when he uses the computer, he is a programmer. And, actually, until we reach the stage at which most of the procedures that substantive users want to employ in their interaction with information have already been programmed, it will be necessary for the would-be user to prepare programs until he has completed the task of instructing the computer to do what he wants it to do. It is interesting, nevertheless, to look forward to the day when most of the elementary or component programs required to meet a substantive user's needs have already been prepared and are available. The problem will then be one of "commanding" the procedures instead of creating them. The language needed by the user will then be a language that will control the combining of component programs into program systems, and that will bring to bear upon specified data the various operations and services that are available within the over-all computer system.

Part of the language problem, then, must be concerned with the analysis of users' needs, with taxonomy of information structures, and with the technical features of computer system organization. Another has to do with implementation. Present-day programming languages are implemented by translators, assemblers, and compilers—programs that convert statements in the "source language" into sequences of instructions in the basic order code of the computing machine, and arrange the sequence of instructions, in relation to the data upon which they will operate, in such a way as to fit conveniently and economically into the memory of the computer. However, the translators, assemblers, and compilers are constructed on the assumption that the programming will be completed before the translation is begun, and that the program will not actually be run until all the assembling and compiling has been finished. For on-line man–computer interaction, on the other hand, it is necessary to pass directly from the statement of a command, or a question, immediately to the execution of the corresponding machine program. Moreover, one must be able to recover his position if he makes a mistake, to change part of a program without changing all of it, and—in general—to proceed partly by trial and error, partly by insight, and partly by exploiting contributions made by the computer and its programs.

MAN-COMPUTER INTERACTION IN INFORMATION SYSTEMS

J. C. R. LICKLIDER
Manager for Information Sciences, Systems, and Applications, Thomas J. Watson Research Center, International Business Machines Corporation

INTRODUCTION

A very few years ago, close partnership between men and computers was little more than a gleam in an eye, and quick access to voluminous data through a computer console was merely a dream.

Technology advances rapidly. Man's imagination leaps forward to exploit technological advances even more rapidly than the advances are made. Today, therefore, one can point to actual examples, to several experimental and to a few operational examples, of close partnership between men and computers, and one can visualize clearly, even if they do not actually exist, new applications of interaction among men, computers, and information that promise to improve markedly the usefulness of information and the effectiveness of men.

In the interest of brevity, 'information' does not appear explicitly, but is implicit in the term "man-computer interaction." The term is intended to denote communication and reciprocal cooperation, back and forth, between a man or men and a computer or computers. The term is intended to connote partnership or teamwork in which the best human abilities and the best abilities of information-processing devices, melded together and complementing and enchancing one another, yield a level of performance of informational tasks that neither men nor computers can achieve separately.

An important dimension of the interaction between man and computer is the frequency with which messages are transmitted back and forth. In many computer centers, that frequency is twice a day—once when the man brings his deck of cards to the computer room and once when he calls to pick up the stack of printouts. In "on-line" use of time-sharing computers, the frequency is usually about once per minute if the console is a buffered an unbuffered typewriter, and many times per second if the console includes an oscilloscope display and light pen or stylus tablet. One of the basic questions is: How valuable is high-frequency interaction to the user of an information system?

EXAMPLES OF MAN-COMPUTER INTERACTION

As background for examination of application in information systems, let us note briefly a few recent or current instances of man-computer interaction. Let us consider the instances in an order that proceeds from "conversation" through a computer typewriter to complex interaction through combined alphanumeric and graphic media, and then back to a typewriter —interaction particularly relevant to information systems.

1. At the RAND Corporation, a few scientists and engineers have JOSS typewriter consoles in their offices. "JOSS" is the "Johnnian Open-Shop System," a small, simple, and beautiful time-sharing system designed to put fairly sophisticated mathematical assistance at the fingertips of substantively oriented problem solvers. While other people were using other typewriters in other offices, Clifford Shaw demonstrated to me how convenient and helpful JOSS can be. First, he had me type "2+3=5," whereupon JOSS responded immediately with "2+3=5" (not "4.9999 . . ., "not" 5.0 • 10↑1," but "5"). Then, for four or five minutes, JOSS and Shaw led me through equations of increasing difficulty and into simplified programming. Finally, in about 10 minutes, they guided me through the procedure of getting JOSS to prepare a table of the squares and square roots of the integers from 1 through 20, 10 lines to a page, with pagination and column headings. I say "JOSS and Shaw" led and guided me, and not just "Shaw," because" most of my assumptions about what to do turned out to be all right (i.e., accepted by JOSS), and most of my errors were pointed out to me by JOSS.

2. At the System Development Corporation, the Command Systems Laboratory operates a large-scale time-sharing system. The newcomer to TSS sits down at a teletype console, and, after only 3 of the 31 15-minute lessons in TINT the computer offers, he stands up feeling himself to be the master

of all arithmetic, much algebra, and some programming. (After 31 lessons, the student is a competent programmer in JOVIAL, a high-level programming language used widely in military information systems.) The first lesson, for example, explains a few of the basic operators with which the user can work. One of them is "EQ." Another is "MO." When the student is having trouble and needs to know more about "EQ," he types "?MO ?EQ," and the computer-teacher tells him more about "EQ" and usually clears up the difficulty.* Jules Schwartz and his colleagues have incorporated dozens of such aids into the TINT trainer, and it is only one of the dozens and dozens of man-computer interactions programs that operate in TSS.

3. At several laboratories working in computer-assisted instruction (CAI) and using the instruction programming language "Coursewriter," one can prepare courses or take courses at a "1050" console with typewriter, slide projector, and audio tape recorder. He simply dials a number at Yorktown, New York, and connects his console to one of the two CAI Systems at the IBM Research Center. At one point in a lesson in German, to illustrate with a single instance of but one of several techniques, the CAI System types, "The house is large," and the student replies "Der Hous ist gros." CAI then comes back with "D— H—us ist gros—." and the student has to type again, trying to be right this time where the blanks show he was wrong before.

4. At Massachusetts General Hospital in Boston, a nurse in a ward types (experimentally, of course) a requisition for eight tablets of "chlorphenirmine molate, 2g. "plus some aspirin and caffeine. At Bolt Beranek and Newman in Cambridge, a computer programmed by Jordan Baruch, John Hughes, Shelley Boilen, and their associates scans its pharmaceutical tables and exercises its spelling-problem routines. Immediately the teletypewriter at the hospital asks the nurse whether she doesn't mean "chlorpheniramine maleate" and tells her that 2 grams is too much, that 2 milligrams is a reasonable quantity for a tablet.

5. Another computer at Bolt Beranek and Newman generates "target" signals for an experiment in manual tracking, delivers them to the display, and receives the operator's responses from the controls. Before the test run is over, the data-analysis programs are determining a whole array of transforms, transfer characteristics, and signal-to-noise ratios and testing orthonormal-function models of the operator. Before Jerome Elkind can get from the experimental room to the computer room, the results are dis-

* The question marks identify the symbols to the computer program as commands. Users may object to the mnemonic inelegance, which is due to the smallness of the teletypewriter's character set, but the computer is indifferent to such matters.

played on the oscilloscope screen for his immediate examination and photographically recorded for later reference.

6. At the M.I.T. Lincoln Laboratory, Lawrence Roberts, Timothy Johnson. and Bert Sutherland demonstrate programs that let them construct and manipulate two-dimensional block diagrams and three-dimensional object diagrams by drawing and pointing with a light pen, and using the oscilloscope screen of the TX-2 computer as a "Sketchpad." When one of the programs rotates the drawing of a solid object, edge lines disappear when they are "occluded," then reappear when further rotation brings them around to the front again. These programs are descendants of Ivan Sutherland's original Sketchpad program, which did more than any other one thing, I think, to convince the world of the great potential value of man-computer interaction.

7. Other descendants of Sketchpad operate with a special console connected to Project MAC's time-shared computer at M.I.T. John Ward touches a few keys and the skeleton of a ship's hull appears upon the screen. Rolling a "billiard-ball control," Ward rotates the hull to first one orientation and then another, and then, with a light pen and another key, he redesigns the bow. Then he re-examines the hull from every angle.

8. At General Motors in Detroit, the computer-aided design system, GEM, is used operationally in the design of automobile bodies. Among other things, GEM coordinates the artistic and engineering aspects of design, checking, for example, the strength and manufacturability of a fender as soon as the designer has sketched it on the oscilloscope screen.

9. At Bolt Beranek and Newman's Los Angeles office, Welden Clark and his associates demonstrate a system designed to facilitate interaction among doctors, architects, civic leaders, and a computer in the planning and design of hospitals. When someone wants to suggest a modification, he does more than merely talk about it. He has the computer display a floor plan on the oscilloscope screen, and he sketches his proposed changes on the screen with the light pen. Another member of the group is likely then to have the computer determine, through calculations based on information in its files and on measurements of the newly proposed plan, how much more time nurses would have to spend walking from Surgery to Supplies . . . etc.

10. With "Symbiont," an experimental system to facilitate the study of technical documents, the student has the computer help him find, in his set of working documents, the passages that are of immediate interest to him. The student types one to three sets of key words or phrases to define his retrieval prescription. The computer searches through the text in its store until it finds a segment of text that meets the prescription, displays the segment plus its context, and awaits either the student's revision

of his prescription or the student's signal to look for another passage that meets the prescription unrevised.

11. At the IBM's laboratory in Kingston, New York, Frank Skinner takes a light pen in hand and sketches an electronic circuit with a variable resistance and a variable capacitance. Then, against a coordinate grid just to the left of the circuit diagram, he draws the waveform of a signal he wishes to apply to the circuit. Thereupon, the output of the circuit appears just to the right of the circuit diagram. Touching the head (tail) of the arrow that indicates that the resistance is variable, Skinner causes the value of the resistance to increase (decrease), and the effect of the change appears at once in the output plot. When the behavior of the circuit is just right, Skinner presses a button to capture the "design" on quick-process microfilm.

12. Finally, in M. M. Kessler's Technical Information Project at M.I.T., a physicist goes to a teletypewriter or "1050 set," dials the MAC computer, logs in, asks for "TIP," and types, for example,

```
search: all new
find: author=jones
      title=germanium
output: print title author
```

The computer searches all the bibliographic material in its store that pertains to the most recent volumes of the 20 journals covered. It looks for articles of which one of the authors is named *Jones* and also for articles with titles that include the word *germanium*. It prints the title and the name of the authors of each such articles that it finds.

The foregoing is a list, not of examples, but of fragments of examples of man-computer interaction. Each part described is one of many parts, and the examples are but 22 of what now runs into the hundreds. In short, the aim has been only to illustrate, not to catalogue, man-computer interaction.

NEED FOR MAN-COMPUTER INTERACTION IN INFORMATION SYSTEMS

The spectrum of information systems runs from archive libraries through research libraries, technical information systems, management information systems, and intelligence systems, to military command and control systems. Evidently, the need for close man-computer interaction increases with the need for fast response, and the intensity of the effort to achieve and exploit man-computer interaction increases with the urgency of the work and with the feasibility of the application, as we move from left to right across the spectrum. Although it is still a matter of opinion and not of demonstrated fact, I am inclined to assert that man-computer interaction will prove worth its cost, even though that cost be considerable, in military command and intelligence systems. I think that the trend to on-line management information systems will continue, and that close interaction between management people and management information through computers will prove to be worth its cost, also. That takes us to technical information systems and research libraries. One of the most interesting frontiers of computer applications lies in those areas, and it seems appropriate to make them the focus of the present discussion of man-computer interaction. In saying that, I do not mean to imply that archive libraries and general libraries are less interesting, but only that they appear to present somewhat more difficult and less pressing problems, and that since it is essential to limit the field, it will be best not to try to examine their need for man-computer interaction here. Within technical information systems and research libraries, the main function that pose a requirement for man-computer interaction are the following:

1. "Negotiation" of retrieval specifications
2. Assimilation of retrieved information
3. Application of retrieved information
4. Organization of the body of knowledge and preparation, maintenance, and updating of the apparatus of bibliographic control
5. Maintenance and updating of the corpus

In stating those requirements, I avoided using such terms as "books," "documents," and "journals." The reason for avoiding them is simply to make the statement of requirements independent of the distinction between document retrieval and "fact" retrieval.

The idea of negotiating instead of prescribing the sepcification of the information one wishes to obtain from a technical information system or a research library is very simple, but it seems to me to be very important. In a "straw-man" version of a conventional information system, one has to write out his prescription of what he wants to retrieve, feed it into the system, and stagger home under the load of its voluminous outpouring—or else find out that nothing in the system precisely meets the requirements he set forth.

In most actual research libraries and technical information systems, of course, the prospective user discusses his problem with a librarian or retrival specialist and works out with her a reasonable prescription. What man-computer interaction can do is to bring the catalogues and indexes, and in principle, even the contents of the repository, into the negotiation process. Coupling the user closely to the system cuts down the "turnaround" time and makes it practicable to let the user know, quantitatively, how meager or voluminous the output will be at each stage of the formulation of his retrieval specification. In addition, it makes it practicable to let him see some of the information he is requesting, while he is still working on the specification, and to let him shape the specification progressively as he interacts with the material presented to him.

Close interaction with the computer can help the user to assimilate the information as well as to retrieve it. With the aid of the program called Symbiont, mentioned earlier, my colleagues, Daniel Bobrow, Richard Kain, and Bert Raphael, and I obtained some interesting experience in reading, searching, taking notes, manipulating graphs, and so on, at the console of a computer in which the contents of selected technical documents were stored. The combination of cathode-ray oscilloscope, light pen, and typewriter, made it convenient to explore the contents, to find the most relevant passages, and to compare and process the graphs and tables. One cannot help visualizing a system in which information-retrieval and instructional functions are blended.

Man-computer interaction in the application of retrieved information is of interest wherever the process to be managed or controlled requires large quantities of detailed information that can be specified by category and processed by recipe. That is the case, for example, in logistics. If the manager or commander or engineer does not know how to prescribe precisely the procedure for finding a solution, but can recognize a solution when he sees one, and if the information that has to be employed to arrive at the solution is too voluminous for a man to apprehend, then he certainly needs to interact with the information and the application process through the intermediary of a computing machine.

The body of scientific and technical knowledge is "organized," albeit perhaps only loosely, through the day-to-day thinking, talking, and writing of scientists, engineers, and information specialists. Most of the work of organizing knowledge, the work that finds its expression in oral and written publication, has little effect, and at best only an indirect effect, upon the procedure for retrieving information from information systems and libraries. That procedure is shaped mainly by the work of the information specialists concerned with preparation and maintenance of catalogue, indexes, and other parts of what Verner Clapp calls the "apparatus of bibliographic control." One of the most interesting prospects for man-computer interaction in libraries and information systems is that the work of substantively oriented users may be fed back into the system in such a way as not only to add to the corpus but also to contribute to the apparatus of bibliographic control.

Maintenance and updating of the corpus, in a document system, is mainly a matter of accessions, circulation, and inventory control. To a considerable extent, those functions can be preprogrammed. That is to say, they can be carried out according to rules and with the aid of procedures that do not have to be changed continually. However, the rules and procedures of research libraries and technical information systems do change, new publishers and new journals are always coming into existence, and some old ones occasionally go out of existence. As a practical matter, it will be very convenient for the people concerned with maintenance and updating of the corpus to be able to exercise hour-to-hour or day-to-day executive control over the computer's execution of the clerical chores.

In thinking about the five general functions just mentioned, it is helpful to distinguish among the "primary" information that is of interest to substantively oriented scientists and engineers, the apparatus of bibliographic content control that is helpful in retrieving primary information, and the apparatus of bibliographic carrier control that deals with accession, shelving, circulation, and the like. By and large, sophisticated processing of primary information poses very difficult problems for information science and computer technology, whereas the apparatus of bibliographic content control poses easier problems, and the apparatus of bibliographic carrier control poses fairly simple problems. There is under way, therefore, a progression of applications of computers beginning with the housekeeping chores of libraries and information systems, moving into information retrieval per se, and culminating in assimilation and application. The frequency and intimacy of man-computer interaction increase from the beginning to the end of that progression.

CAPABILITIES AND LIMITATIONS OF INFORMATIONAL TECHNOLOGY IN RELATION TO THE REQUIREMENTS

The most severe requirements are imposed, as just suggested, by applications that deal with the substantive content of documents or information bases. Lest it be tacitly assumed that those requirements are unreachably beyond the capabilities of the informational technology, we should examine a few estimates.

The size of the total corpus of recorded knowledge, with each book and published article being counted only once, and not as many times as there are copies, is approximately 10^{15} bits. That is to say, it would require 10^{15} binary cells to store it all, if moderate, but not elaborate, arrangements were made for storing it efficiently. Of that total, about 10 percent, or 10^{14} bits, has to do with science and technology. Of those 10^{14} bits, only about 10 percent, or 10^{13} bits, are good, solid information that clearly should be in the active store of scientific and technical information. If, in rough approximation, we think of science and technology as being divided into one thousand subfields, then the corpus of a subfield can be stored in about 10^{10} binary cells.

The size of the largest primary computer stores, which in the present technology are "core memories," is in the process of increasing, in a period of only two or three years, from about 10^6 to 10^8 bits. The size of the largest secondary stores, disk files and photographic storage systems, is increasing, at the same time, from about 10^8 to about 10^{12} bits. The rate of flow of information that can be achieved in transfers between primary and secondary stores is increasing from about 10^6 to somewhat more than 10^7 bits per second. And the number of elementary computer instructions that can be performed upon the contents of the primary memory is moving upward past 10^6 bits per second. Because the organization of computer systems is becoming more complex, it cannot be said that the foregoing are the only significant quantities, but they do provide a basis for a rough comparison between capabilities and requirements.

The comparison shows that we are approaching a time when it will be possible to store 10 percent of all solid science and technology within a single computer system. However, until the next saltus of the technology comes along, only about one percent of a subfield will be immediately processible at any particular moment. That means that in some applications there might have to be continual shuttling of information between primary and secondary stores, but it still leaves us with a fantastic basic capability. The questions are: Can we learn to make good use of it? and will the application support the cost? When I think about the magnitude of the task, I tend to become slightly discouraged, but then I think about the task of mastering the volumes of information we have been discussing without the aid of computers, and my enthusiasm for on-line interaction with the body of knowledge is fully restored.

A human being, reading at a rate of 100 words per minute (which we may translate roughly into 1,000 characters per minute and 10,000 bits per minute) would require 10^6 minutes (about 10 years) to work his way through the 10^{10} bits that we estimated earlier to constitute a subfield of science or technology. Ten years, however, is approximately the time required to double the size of the literature. I need not mention obsolescence. Because human reading is so slow, it is challenging to consider exploiting the computer's much faster rate of scanning in search of prespecified words and phrases. It is easy to program a computer to search at a rate of 10^4 words per second, at which rate it could comb through a subfield of science in a few hours. Evidently, all kinds of processing based upon key words, descriptors, thesauri, are rapidly coming within our reach, even for application to the alphanumeric content of scientific and technical literature.

One of the next distinguishable steps, beyond analysis based upon the matching of terms, is syntactic analysis of natural language text. For several years syntactic analysis has been, and continues to be, the focus of much interest on the part of computational linguists. Nevertheless, sophisticated syntactic analysis remains a nontrivial exercise. In most of the work that has been done thus far, little effort has been devoted to achievement of speed or efficiency of processing. The numbers of "memory cycles" required to parse a sentence have therefore been high and variable. For a long sentence, as many as 10^9 and as few as 10^7 memory cycles may be required. The corresponding processing times range from more than an hour to less than a minute. Just to parse a whole subfield of science or technology, in the present state of the art, might require somewhere between a month and 10 years. That requirement can be reduced by increasing processor speed, by increasing program efficiency, or by learning more about grammar, but it seems significant that the advantage of computers over people is so greatly reduced, if not entirely lost, in the few steps between scanning for specified terms and parsing.

In imagination, of course, one can project upward, beyond syntactic analysis, toward deep semantic understanding of natural language by machine. The obstacle to realization of that projection, however, is not merely the state of the computer technology. It is that semantic theory of the kind required to provide the basis for "understanding" of natural language by computers is only now showing the first signs of life. In short, it is easy to make a computer read, but no one knows how to make it comprehend what it reads in anything approaching the sense of human understanding.

DOCUMENT RETRIEVAL VS. FACT RETRIEVAL

Does the inability of present-day computer technology and methodology to grasp fully the meaning of statements in natural language limit the domain of man-computer interaction, now and in the near future, to the retrieval of documents? Does it rule out, for the time being, computer-mediated interaction between people and the contents of documents? In my view, the answer to both questions is, "No, but . . ." I think the present technology is adequate to help people interact with content in a significant way, and I am greatly impressed by the armamentarium of computer programs for processing natural-language text that has been developed in the course of work on military information systems. What are missing at the present time, it seems to me, are available facilities within which people can interact with scientific and technical information, and a man-computer interaction language through which substantively oriented users can command or guide, and be informed by, the computer and its programs. Thus, in respect of interaction with content, the time is ripe for research and for the development of methodology, and there is a good chance that research and development will lead to significant practical applications in a few years. In these applications, the role of the computer will be to search, compare, present for inspection, and to carry out whatever clerical operations the user commands.

Whereas it will be very difficult to develop computer programs capable of finding relevant facts and precise answers to queries by examining natural-language text, it will be fairly easy to achieve a sharper, more discriminating kind of retrieval than retrieval of entire documents. We might use the term, "passage retrieval," to refer to the computer's service (mentioned earlier in connection with Symbiont) of locating and displaying short segments of text that meet retrieval specifications defined by the user at the console. In my opinion, passage retrieval will be an invaluable aid to anyone who is faced with a fairly definite problem and a mountain of information.

Much of the content of science and technology is stored in forms more amenable to computer processing than is natural language. Man-computer partnership will be particularly helpful, and particularly easy to achieve, in working with information that can be stored in lists, tables, dictionaries, and the like.

Information structures more complex than lists, tables, and dictionaries, yet simpler and better understood by computers than natural language, afford interesting possibilities for storage and processing of scientific and technical information. The predicate calculus, for example, is capable of expressing a wide range of facts and ideas. Fisher Black at Bolt Beranek and Newman, John McCarthy at Stanford, and Herbert Bohnert at IBM have explored the use of predicate calculus as an approach to automation of the deduction of conclusions from collections of information. Their studies were not concerned directly with man-computer interaction, but it is evident that the logico-deductive assistant toward which their studies were aimed would be very helpful to the scientist or engineer at the information-system console.

Fisher Black's "Question-Answering System V" exemplifies the approach and also reveals the fundamental difficulty. Black expressed, in predicate calculus, and fed into a computer's store the essentials of McCarthy's "Airport Problem.":

I am at my desk. My desk is in my home. My car is in my garage. My

> garage is also at my home. I can walk from any place that is "at my home" to any other place that is "at my home." The airport is in the same county as my home. I can drive my car from any place in the county to any other place in the county. I want to go to the airport. What shall I do?

Black's program solved McCarthy's problem about three years ago. It deduced, in predicate calculus, the equivalent of: Walk to the garage. Then drive to the airport.

The performance of "Question-Answering System V" demonstrates two important things. First, a suitably programmed computer can indeed derive answers to questions from collections of statements. In principle, it can do that for complex questions and very large collections of statements, and it can do it in a logically perfect way. Second, however, the time required to effect the deduction increases rapidly with the complexity of the question and with the size of the information base. Black's program, operating in a large computer, required more than half an hour to solve the "Airport Problem."

Thus we see, again, a suggestion that we should be content, as a practical matter in the next few years, with relatively unsophisticated, clerical assistance from computers in our interaction with the content or substance of science and technology. That limitation emphasizes the importance of our having close control over the computer's procedures, for we will have to use our own heuristic capabilities at every step to select and guide the procedures executed by the computer.

AVAILABILITY AND COSTS OF INTERACTIVE COMPUTING

For many years the main obstacle to man-computer interaction has been an economic one. Computers are expensive, and there are few situations in which it is reasonable to devote a large, fast computer, a computer capable of providing significant assistance to the user of an information system, to interaction with an individual human being. The individual human being would not make full or effective use of the computer.

The economic obstacle appears to have been largely overcome by the advent of time-sharing computer systems. In a time-sharing system, as is now well known, the computer serves one user, and then another, and then another, jumping from one to another according to a schedule that takes into account their priorities and their needs for service, and manages, because of its high speed, to meet all their requests expeditiously. Thus time sharing, combined with "multiprocessing" and with what is coming to be called "memory sharing" or "space sharing," promises to make interactive computing available in a practical and economically feasible way to substantive users in diverse areas, and one of the areas is the retrieval and use of information.

Many problems remain to be solved, and I do not mean to offer the prospect of cheap computing available through a wall socket in the research library within the next year or two. One problem is that each console, with its control and display equipment, can be assigned to only one user at a time. That is to say that the cost of consoles cannot be "time shared" the way the cost of the central computer can be. Nevertheless, the stage is now set for exploration of man-computer interaction in research libraries and technical information centers. The next few years will tell whether or not some of the promises I have tried to describe can be realized and be worthwhile.

This committee will adjourn until quarter of 2, whereupon we will hear two more witnesses.

(Whereupon at 1:05 p.m. the subcommittee recessed until 1:45 p.m. the same day.)

AFTER RECESS

(The subcommittee reconvened at 2 p.m., Representative Roman C. Pucinski, chairman of the subcommittee, presiding.)

Mr. PUCINSKI. The committee will come to order.

I think we will proceed with our witnesses this afternoon. The other members of the committee are on their way here, but we have two witnesses this afternoon. If Dr. Cairns will be good enough to step forward, we will get started. By the time we get into the testimony, the other members I am sure, will be joining us.

Dr. Cairns has served as chairman of the Committee on Scientific and Technical Communication for the National Academy of Sciences and the National Academy of Engineering. He is an outstanding scientist and has been awarded the Perkin Medal for 1969. He was selected for this high honor by representatives of the American section of the Society of Chemical Industry, the American Chemical Society, the American Institute of Chemical Engineers, the Electrochemical Society and the American Institute of Chemists.

In 1954 he served as Deputy Assistant Secretary of Defense for Research and Development. He was a member of the Defense Science Board, 1956–62 and 1965–69. He was formerly chairman of the Division of Chemistry and Chemical Technology at the National Research Council.

Dr. Cairns has received numerous awards and citations for his distinguished work throughout his career and is widely acclaimed as one of the foremost exponents and proponents of information retrieval systems.

Dr. Cairns, I would like you to know the other members of the committee have told me they are anxious to hear your testimony, so I am sure they will be here very shortly.

We are privileged to have you here. I notice that Chemical & Engineering News has a cover story on your award of the Perkin Medal for 1969, and I consider it a distinct privilege that you would find time in your very busy schedule to join with us today in this discussion of the need for some better way of disseminating the science information that is being generated in this country.

I believe you were here this morning and you might have heard some of the testimony. I think you know what the committee's attitude is. With that in mind, why don't you proceed as you wish, sir, and I would like to welcome you before the committee.

STATEMENT OF R. W. CAIRNS, VICE PRESIDENT, HERCULES, INC., WILMINGTON, DEL.; CHAIRMAN, SATCOM NATIONAL ACADEMY OF SCIENCE AND NATIONAL ACADEMY OF ENGINEERING

Mr. CAIRNS. Thank you. It is a privilege to appear before your committee and particularly to speak for Satcom, which is the acronym for Committee on Scientific and Technical Communication. I will give a little background later on that particular committee.

I might add that I am also vice president of Hercules, Inc., a major chemical manufacturer, which gives me a background in appraising the importance of the utilization of scientific and technical information. As you pointed out, I have had some background as a director of the American Chemical Society, and you will hear from Byron Riegel, who follows me, about the leadership of the chemical society in the information field.

I am not an information expert and I don't presume to qualify as such, but I am very concerned about the organization of information transfer relating to the very important programs of scientific and technological work that are going on in this country.

Speaking now for Satcom and a summary, a very quick summary of the views of this committee, our 3-year intensive look at the scientific and technical communication picture shows a diverse and pluralistic network of communication activities which, though often criticized, should function reasonably well.

I might add I am quoting liberally from a synoptic report of our committee which will be out of the printers about May 21, and I have already promised to give your staff a copy of this synopsis early this coming week, but I am still working from a draft.

If this complex network is to meet more effectively the demands that are being placed on it, certain courses of action are essential, and we have portrayed in our report several such courses of action that we recommend:

First, the scientific and technical societies must appreciate their crucial role and take immediate steps to fulfill it. The capabilities of the for-profit information handling organizations should also be recognized and fully utilized. In saying that, I point out the essential assignment which was given to Satcom: to examine the role of what we call the private sector, its interrelationships, and its relationship with the Government.

The second point: The sponsors of research and development work, those who pay for and motivate the actual performance of R. & D., must realize that making results accessible and adapting them to the context in which they can be applied are integral parts of such work.

This would seem to be axiomatic, that one would make the most of the results that come forth, but unfortunately too often in haste to publish, one does not think about how accessible the results are after publication, and I will speak more to that point later.

The third point is that increasingly numerous special user groups, having common information needs, must be served more efficiently. Efforts to sift, evaluate, compile, and consolidate the rapidly expanding store of information require increased emphasis and support.

In other words, as the pile of information gets greater, one must be very careful to sort out the information that is or can be useful to smaller groups.

Lastly and most crucial, new mechanisms and policies are necessary in order to coordinate and focus the scientific and technical communication efforts of the private for-profit and not-for-profit organizations and the Government during this era of burgeoning activity and rapid change.

These all may be very evident points, but they are basic and they are certainly worth repeating.

What is the reason why we think at this time that so much attention should be paid to the process of information transfer? Well, scientific and technical information, certainly that portion which is available to the public, is the main product of research for which the annual expenditure in the United States is more than $5 billion a year and of certain areas of development.

In fact, the national expenditure on research and development, private and public, is now above $27 billion a year in the United States alone.

The information that is generated is an essential input to all new research, to all new development, and to most of the practical applications of research and development new or already at hand to meet our manifold needs.

This information, very diverse in kind and addressed to widely different audiences, is the basis for further steps ahead. We can say it is really the lifeblood of progress.

The effectiveness of future work in universities, government laboratories, and industry depends upon maintaining a vital flow of scientific and technical information, a task for which increasingly efficient means of information transfer are needed.

Well, that is the reason behind the push.

Information costs are usually no more than a few percent at most of the cost of doing scientific and technical work. Such work must build upon both past and current information, but much evidence indicates that the use of this information is far from optimally efficient.

Therefore, it is clear that if measures can be found that will significantly improve the handling and application of information, these measures will pay for themselves many times over, even though they may involve costs substantially greater than present information-related expenditures.

Today we are experiencing rapid changes that affect the vital flow of scientific and technical information: First, the tremendous growth in scientific and technological effort and the resulting greatly expanding volume of useful information; second, the increasing complexity of concepts and the resulting new links and interdependencies among established and emerging disciplines; and third, new and intensifying demands for the rapid and efficient application of scientific knowledge to useful ends.

Since all these factors create and heighten the problems of communication, there is pressing need here, as in so many other areas, for the proper mixture of research, development, planning, and management of information systems.

As always, it would be too easy to emphasize any one of these aspects to the exclusion of others.

Computers, mainly, in due course, will have a major impact on the transfer of scientific and technical information, but they will begin as they already have by doing things we have long done by hand. Here, as elsewhere, their uses will be limited by costs. Today their importance is greatest for research.

Cheap photoduplication is with us today in many forms, yet its impact on the transfer of information has hardly begun. Its current importance is greatest for development and planning. The diversity of people's needs and the changes that simultaneously force specialization and a broader horizon upon scientists, engineers, and practitioners have been too little recognized and implications too little appreciated. Their importance is greatest for current planning and future management.

Problems of growth, of overlap, of coordination of economic choice challenge information management today. There are no shortcuts that will eliminate any of these major problems or take full advantage of any of these opportunities.

A reasonably effective increasingly challenged, pluralistic system exists today and continues to evolve. The need is for guidance of its evolution, for increasing responsibilities for all of the organizations—governmental, scientific, technical, and for profit—involved, for more effective coordination, and for broader understanding of problems and opportunities.

In scientific and technical information the days of the computer, the photoduplicator and printing press will seem different to both users and spectators, but the importance of economics, the vital roles of organizations, and the need for increasing coordination of effort will characterize all of them.

That, in a thumbnail sketch, represents our views, and I would like to speak in more detail on the nature of the problem and on how we propose to face some of these problems.

Mr. Pucinski. Doctor, I wonder if I may at this point recall a quote that is attributed to you. You said: "Today, you need a major investment to make progress. Accordingly, I would say that information costs are not out of line with the costs of doing high-grade technical work. Furthermore, I think it is much more important in the future that we have excellent tools for getting information so that research scientists don't spend an exorbitant amount of time in the library, which actually is the greatest drain on the researcher's time, or repeat work that has been done already."

Mr. Cairns. I agree with myself, sir. In most research organizations, somehow the value of the time of the investigator in the library is not counted as a tangible cost, so library budgets are notoriously low.

If you therefore find that the information systems costs mount, you hear all kinds of complaints.

If you have a man who works at the desk, at the bench, in the laboratory, if he is fully trained, fully supported, the costs might be $50,000 a year, a thousand dollars a week. Suppose that out of the year he spend, say, 4 weeks in the laboratory or in the library; you have to count that as a $4,000 cost. Yet if you wanted to buy an information unit, a service of some kind, that costs, say, $10,000 a year, that could serve not only this one man but a dozen or 50 men in that laboratory and save even 10 percent of his time; you would hear all kinds of complaints, complaints that this is too high.

The reason or what I am getting at here, one must look at the total cost of acquiring information from the source into the head of the investigator, where it counts.

Mr. Pucinski. I am told we are now spending in this country in both the Government and private sector $27 billion on research.

Mr. Cairns. That was the figure I have seen recently.

31-464—69——25

Mr. PUCINSKI. I was under the impression we were spending only $17 billion. This later figure has brought this amount up to date. If we are spending $27 billion on research, then surely the tremendous amount of very impressive information that is being generated is now largely being lost simply because there are not sufficient methods to circulate this material. Is that a fair conclusion?

Mr. CAIRNS. I think so. If you look behind the scenes in industry, you will find that all of those who are dealing with sophisticated areas of science and technology have their own private information systems which make use of all of the techniques they can possibly apply in order to result in an internal efficiency, a saving of time, a prevention of unnecessary repetition of certain types of work which otherwise might be done over after a few years.

I think that in all cases we can say that where you have a strong organization, as in industry, they will provide information services integral with that operation which are perhaps optimal because they will take account of all of these factors.

You will find other areas, though, in the broader context, where one organization cannot do the job, where there can be some fairly gross inefficiencies because of these more or less superficial economic factors which no one thinks through very deeply.

There is an ingrained feeling in universities that libraries should be operated on a shoestring. Also that the study time involved is not really that important. I think this must change very much.

Well, I have covered in this discussion several pages of the introductory material, and I will plunge right into the middle of this part of the report.

Efforts to cope with these various aspects of the information problem have resulted in a variety of organizational, economic, and technological arrangements and methods. As a result, scientific and technical communication constitutes a heterogeneous complex of activities that have developed in response to locally perceived needs and opportunities rather than in an orderly and carefully planned manner. Opportunities for cooperation often are missed; at the same time, many needed services are not performed because they "fall in the cracks" between the domains of existing organizations.

This is a problem that has faced many people and about which they have expressed great concern for the last two decades. In the Federal Government, awareness and concern developed more rapidly and recently. Although the stewardship of information was specifically mentioned in several legislative acts in the early postwar years, it was not until 10 years ago with the reappraisal of our country's efforts that a series of major studies of scientific and technical information problems were sponsored by the legislative and executive branches of the Government.

I refer in particular to the creation of the Office of Science Information Service of the National Science Foundation to foster the development of more effective services in the not-for-profit private organizations and the creation of COSATI, the Federal Council for Science and Technology, to effect greater coordination among the diverse information-handling activities of Federal agencies.

While COSATI seems to make considerable strides toward coordination, standardization, and fitting together of the many Government-sponsored, Government-agency-operated information services, there has been no specific designation of Federal agencies to coordinate the private groups although the need for a non-Federal coordinating body was recognized by the National Science Foundation in its context and in its support of private group services.

As a consequence, the NSF requested the National Academy of Sciences, in cooperation with the National Academy of Engineering, to establish a committee to make an intensive survey of the present status and future requirements of the scientific and engineering community with respect to the organization, flow, and transfer of scientific and technical information and to recommend needed policies and courses of action based on its findings.

This committee, the one which I head, was established early in 1966 and we are about to issue our final report and we will continue in business, in interaction with the private sector and Government agencies for the rest of this year.

Mr. PUCINSKI. You say this report will be out?

Mr. CAIRNS. It will be off the press in June. Our synopsis report will be available May 21. This is the synopsis which I said I could give you the first of the week.

Satcom's creation was a move toward specific implementation of general policies recommended by previous study groups. Ample time was available in Satcom's nongovernmental location to enable it to consult the scientific and technical community broadly.

We begin our work by surveying in depth each of a number of private and governmental information-handling activities, often by visiting their headquarters. To assist in the resolution of some currently acute issues as well as to develop perspectives on possible coordination procedures in certain special fields, we organized four ad hoc task groups.

Finally, to sound out the opinions of the scientific, technical, and information-handling communities, and to secure their broad participation in the formulation and resolution of policy questions, we selected and maintained contact with a group of about 200 key individuals from diverse institutions and disciplines, called Satcom's consulting correspondents.

I can refer briefly to the major conclusions and recommendations that will evolve from this background. I don't know just how much time you want to allot, but another 20 minutes——

Mr. PUCINSKI. Please go ahead.

Mr. CAIRNS. The principal impression we received was that of diversity in information-handling activities, in the economics and techniques of operations, in functions, and in users. We concluded that such diversity was not only characteristic but essential.

Mr. PUCINSKI. It is interesting that you should make that point. I believe we need forward movement simply because great sums of money are being spent on information systems as was illustrated in the New York Times' testimony this morning. Yet as far as I can see, no guidance is now being given toward compatibility.

It is very interesting to hear you say that one of your observations was the diversity in handling.

Mr. CAIRNS. Well, you have touched on about three or four elements.

Mr. PUCINSKI. Why don't you first finish your statement?

Mr. CAIRNS. I will pick these up, I think, in order. First of all, as to diversity: Why should it be diverse? Diversity facilitates the flexibility, the sensitivity and responsiveness to user needs, and the innovative forward-looking approaches required for effective scientific and technical communication. Further, though our country's heterogeneous complex of communication activities has been criticized frequently and on many counts, there is no evidence of critically inefficient operation.

Therefore, we accepted this diversity and concentrated our efforts not on reducing or eliminating it but on maximizing its strengths and overcoming its weaknesses. We have attempted to do this by indicating areas in which greater effort is necessary for adequate performance, by defining roles and responsibilities, by challenging acceptance of them, by advocating certain broad policies in management and planning, and by proposing a way of effecting greater coordination.

Now, I notice in referring to the act or the amendment which is underlying these hearings, that you speak about "close voluntary cooperation" in one part, and this is certainly in harmony with our view of accepting diversity as a first principle.

The reason for the diversity is because there are so many different needs and so many different specializations that if you are going to involve the people who are really generating and using information, you have to have diversity. So then the question is: Where do you go from there?

A crucial area in which present efforts are inadequate to meet current, much less future demands, is that of providing what we call need group services. As we have mentioned, effective service to professional groups which, for practical reasons, we would have to say, must number 1,000 or more, having common information requirements, is a first approach to the future goal of individual service geared to each user's specific needs.

Such need groups are especially prevalent among engineers and practitioners, and the tailoring of information to facilitate prompt access and rapid application in such groups must receive top priority.

The provision of specialized services to foster the application of scientific and technical information in particular contexts depends, on the one hand, on sifting, evaluating, simplifying, and consolidating the ever-expanding store of primary information, and on the other, on reprocessing and repackaging the products of secondary—abstracting and indexing—services.

Reprocessing and repackaging the products of secondary access services are equally important. Sorting abstracts—available in machine-readable form—rearranging and merging selected ones, and providing copies of the results in readable form are basic steps in serving specialized areas of need.

Therefore, the immediate task in developing diverse need group services is to stimulate the reprocessing of abstracts and associated indexing information prepared by basic abstracting and indexing services. To do so will necessitate restructuring the support of these basic services in ways that will enable them to make their products available for reprocessing at roughly runoff costs without endangering their solvency.

I note in your bill "appropriate payment for data from private sources" as something that has reference to this particular recommendation. Now, this is a fairly radical suggestion. As it stands today, the accumulation of basic files—you will hear a bit about it in a specific illustration from Byron Riegel—is a very expensive proposition. It is being carried on partly by private sources and partly by Government sources.

The cost to the user must be increasing every year in order to encompass the increasing complexity of the inputs. But yet at the same time, we want to have these inputs as freely available as possible so that all kinds of special secondary or tertiary services can repackage and reprocess the information from the basic files, so it will in some ways be desirable to have all input costs to the basic files handled through the primary supporters of the research and development work and thereby have the filed information available at very minimal cost so it will stimulate the maximum handling, reprocessing and repackaging for need-group services, and there is where Satcom's thoughts fit in with this particular aspect of the present legislation.

For the near future, we regard the expansion of consolidation and reprocessing activities as the most vital thrust in fostering the prompt and effective application of scientific and technical information.

The next broad point is on roles and responsibilities. Here again we reemphasize the importance of the scientific and technical societies which originally were called into being to provide more effective channels of communication among scientists and engineers. Because their membership includes the principal generators and users of scientific and technical information, they are or should be uniquely able to collect, organize, and assure the quality of the information that they distribute throughout their meetings, through their primary publication programs, and through their basic abstracting and indexing services.

They are also responsible for fostering continuity and progress in the various domains of science and technology they serve. We have tried to challenge these societies to explore to the fullest their role in scientific and technical communication and to accept their responsibilities, a few of which are: (*a*) improving the quality, timeliness, and techniques of producing and distributing primary literature; (*b*) assuring adequate basic abstracting and indexing of this primary information; (*c*) stimulating reprocessing and repacking of primary and secondary information for special user groups; (*d*) conducting performance and evaluation studies of the information services they sponsor and (*e*) assuring the participation of qualified scientists, engineers, and practitioners in these and other exploratory and innovative studies.

So much for the technical society; I think they have demonstrated a profound interest in information and in information transfer; it is their "raison d'etre," and I think the proposed legislation recognizes that and it is in harmony with our views in that respect.

Equally vital is the role of the for-profit organizations. Because their survival and growth depend upon their ability to recognize, understand, and adequately serve users, and because of the management and marketing capabilities they have developed, they can assist both scientific and technical societies and the Federal Government in the development and provision of needed information services. Traditionally, they have been especially effective in developing various specialized highly user-oriented services needed not only by researchers but also, and especially, by practitioners; that is, by people who are using these results for practical purposes.

They—that is, the for-profit organizations—are well qualified to fulfill a major role in reprocessing and repackaging information to speed its application in specific contexts, and their ability should be recognized and fully utilized.

The Federal Government clearly has a responsibility to support the scientific and technical information activities that are required in the accomplishment of its various missions. Some of these present specialized information handling problems, the magnitude of which requires highly structured and centrally managed information programs.

Therefore, a number of Federal agencies—for example, the Atomic Energy Commission and the National Aeronautics and Space Administration—have statutorily assigned information functions relating to their missions. Others, such as the Department of Defense, require broad and diverse information programs in support of the numerous teams and organizations with which they work.

Of particular importance at the present time are the slowly knitting, massive programs of recent years that deal with such major social concerns as natural resources, education, transportation, pollution, and urban problems. In these areas, the role that science and technology will play still is evolving, and so, too, are the information programs that will be required.

However, it is already apparent that data bases and information systems that are substantially more extensive than those previously supporting our major scientific and engineering ventures will be necessary in such programs.

In addition to the fulfillment of mission requirements, the Federal Government inevitably must provide substantial support through various agencies to scientific and technical information efforts in the public interest. Obviously, such support cannot be extended without the exercise of responsible management and at least limited control.

Minimizing the danger of interference of such control with a ready and adequate response to the needs and views of the scientific and technical communities served is a difficult task. We believe that such interference can be minimized if the support of discipline-oriented scientific and technical services does not become more narrowly concentrated within the Federal Government than is support of a discipline's overall research and development effort.

For example, in physics, we see support programs form AEC, DOD, NASA, and the Science Foundation. We would think, therefore, that the support of the information transfer related to physics generated by such R. & D. support would naturally also rely on equally broad support from the Government.

We further urge the reliance of Federal agencies upon existing capabilities in private organizations and the upgrading of relevant activities when necessary rather than a duplication of such services. Again, I would look with pleasure on this current proposal, which seems to point in that direction.

In short, both governmental and private organizations have the common objective of providing information services that are increasingly responsive to the needs of users of scientific and technical information. We urge recognition of this common objective and acceptance of a philosophy of shared responsibility between private organizations—both for-profit and not-for-profit—and Federal agencies in the management of scientific and technical information activities.

I note also, with approval, the fact that, as I understand it, the amendment would leave in the hands of the Science Foundation the responsibilities, the broadened responsibilities, that are outlined by the amendment, that the point of attachment with the Government is the Science Foundation, which, I believe, has done an admirable job under Dr. Atkinson's leadership in supporting the private sector, in guiding them in research and development and evolution of new systems.

Not only have we considered the responsibilities of governmental and private organizations in the operation of information services; we also have pointed to the responsibilities of all who sponsor research and development work. We have emphasized, as did the Weinberg Panel 6 years ago, that such work is of value only when the results are readily accessible and capable of being adapted to the contexts in which they can be applied. In other words, the sponsor's responsibility for such work includes whatever steps are appropriate and necessary to assure its availability.

This certainly offers a major challenge to the Government which is the major sponsor of research and development.

Users of scientific and technical information were trained and work today under conditions which offer far larger rewards for doing "new" work than for finding, through careful literature search, the results of work already done.

Opportunities for management to balance the costs of better information services against the costs of doing more "new" work are few and far between. Therefore, it is inevitable that information that seems costly to get will not be sought, regardless of its value, and that, when prices are lowered, making the acquisition of greater amounts of information economically desirable, these greater amounts will not be acquired.

Some rediscovery of what is already known is economically sound, but, as the amount of obvious rediscovery increases, a slow readjustment in the habits of the scientific and technical community and in its allocation of resources is to be expected.

Users of scientific and technical information are slow to change their habits of information use, usually learned in their formative years. As a consequence, there are strong tendencies toward "in a rut" behavior and toward apathetic responses to new and more effective services. Users find it natural to rely on the most accessible and familiar sources rather than to experiment with new ones that may require a greater initial investment of effort. An intensive and concentrated reeducational or marketing effort is often necessary to gain acceptance for worthwhile innovations.

I might remark parenthetically there are those who say we should rely on the marketplace to decide what services should be made available and what should not. In other words, you charge what it cost for a service, for a new service, and wait for the users to come and use them.

Well, in the time of very, very slow change, I think this sort of a cause and effect can take place, but if you want to really upgrade the quality of information services, I think we have to look a bit beyond the marketplace and not regard it wholly as we determine it.

One effort to provide a logical distribution of responsibility between generators and users and afford financial stability to journals in spite of fluctuations in amount of input and numbers of subscribers is the page charge. Now, there has been a lot said on this subject for and against. It has never been universally employed, and as a result of current budget constraints, opposition has increased.

I think it is still essential to have something in the nature of page charges. There is need for the development and trial of other feasible arrangements to support the dissemination of information and for recognition of initial publication as but one step in the process of making results available and fostering their application.

Suitable procedures for funding secondary services, an area in which no single clear-cut policy of support has yet emerged, and for support of the essential consolidation and reprocessing activities also must be explored. Otherwise, the precious resources of our scientific and technical knowledge will be poorly utilized—a waste that we must not tolerate.

The entire area of the economics of information transfer and the allocation of financial responsibility for effective scientific and technical communication requires far more careful study and analysis than it has received heretofore. It is essential that operators of information programs would continuously explore the possibility of establishing a closer relationship between the costs and the effectiveness of services.

In closing, I want to point out two major points which impinge on the act and its potential operation of broader information systems. First is our philosophy of management. Our first principle in this respect: The management of all scientific and technical communication activities must be as responsive as possible to the needs, desires, and innovative ideas of the scientific and technical groups that they serve. These activities must be sufficiently flexible to adapt rapidly to changes in user needs and communication techniques. That is the first.

Now, the next principle: Further, the administrative entities responsible for scientific and technical information programs must be so organized and coordinated that they represent a logical and efficient division of functions, but authority over them must be sufficiently widely distributed to achieve the responsiveness we deem essential.

This again points to a plurality of responsibilities in the management of information transfer. I am not quite sure, from reading the act, whether the act is designed to foster maximum participation in the management of information systems or whether it might eventually result in a stultification of the management participation of, say, the technical societies and the other factors involved through undue influence and control through the budgetary function. This is not quite clear, and I think that one gets different responses, depending on what the interpretation might be in that respect.

Mr. PUCINSKI. Yes; there is no question it certainly is the author's view that we do not want to interfere with management of individual systems. I don't anticipate any Federal criteria being set up or management enforced. I am sure that a system such as this would require a method of standard acceptance.

To that extent, I am sure the scientific community would want to work out criteria and guidelines. I do not anticipate, nor is it my desire, to see the Federal Government managing these private systems that would become part of the network.

Mr. CAIRNS. I am pleased to hear you say that.

The last principal was that the planning and management of our information activities must involve constant attention to the simplification and consolidation of existing knowledge and its frequent reprocessing to adapt it to the needs of diverse users, especially those primarily engaged in the practical application of scientific and technical information.

The last principle related to fostering coordination among private organizations.

To build upon and strengthen the present pluralistic and decentralized scientific and technical communication complex, it is essential to foster greater coordination and cooperation among its diverse components. COSATI has contributed greatly to developing standard procedures and increasing coordination among the information-handling programs of Federal agencies.

We see the need for a broadly representative and high-prestige nongovernmental body to lead the private for-profit and not-for-profit organizations in the coordination of their interests and programs and to facilitate their interaction with appropriate governmental policymaking organizations. We believe that the private organizations can be led into their own patterns of coordination once a focal point is clearly designated.

Therefore, we propose the creation of a Joint Commission on Scientific and Technical Communication, responsible to the Councils of the National Academy of Sciences and the National Academy of Engineering. The Commission's membership of about 20 should be broadly representative of the major scientific and technical communities and of the principal kinds of information-handling organizations. It should be supported by an adequately staffed professional secretariat.

A major responsibility of the Commission would be to maintain close and continuing contact with the communities it serves by establishing ad hoc committees and task groups for major problem areas and by interacting with a large number of consulting correspondents such as those who have assisted the work of SATCOM.

The Academies were selected as the optimum location of such a Commission for four major reasons: (*a*) They would afford ready access to maximum knowledge and expertise in science and technology; (*b*) they would insure broad representation of the organizations, groups, and individuals whose efforts depend upon and influence scientific and technical communication; (*c*) they would facilitate the desired type of interaction with the Federal Government; and (*d*) they represent a longstanding tradition of diversified and intensive involvement in scientific and technical communication activities.

The proposed Commission would be conversant with scientific and technical information activities and would provide guidance useful to public and private organizations in the development of more effective scientific and technical communication programs.

It would interact with (*a*) the membership and leaders of the scientific and technical community; (*b*) scientific, technical, and educational societies and institutions; (*c*) for-profit organizations; (*d*) relevant foci for scientific and technical communication activities in the Government, especially the Office of Science and Technology, COSATI, and the NSF's Office of Science Information Service; and (*e*) other supporters of science, technology, and information services.

Its mission would be:

(1) To serve the scientific and technical community by fostering coordination and consolidation of its interests in the handling of scientific and technical information;

(2) To serve the Government by providing representatively comprehensive and authoritative information and advice on the activities, needs, and ideas of the scientific and technical community in this field.

To be pluralistic, user-oriented, rapidly evolving under strong Federal support—but with strong self-coordination to match the growing responsibilities of the private organizations—is, in broad outline, the pattern we advocate for the vigorous growth of future scientific and technical communication.

If the National Science Foundation is to play a major role in support of broad systems as visualized in the proposed amendment, the joint commission I have described would certainly be an essential factor in optimizing the contributions from the private sector.

Mr. PUCINSKI. Dr. Cairns, your recommendation of a Joint Commission on Scientific and Technical Communication is certainly something this committee will want to look at. I am not sure that the National Science Foundation is the vehicle for carrying this out. I thought they were. In view of their testimony, however, perhaps they don't seek this challenge. Therefore, we may have to start thinking of other alternatives.

It is obvious to me you didn't have to clear your statement with the Bureau of the Budget.

Mr. CAIRNS. That is right. I am speaking from the experience that I have seen over a number of years in the way they have gone about supporting the private sector.

Now, this admittedly has been limited, at least in my knowledge, largely to the so-called not-for-profit area, the scientific and technical societies, both in science and engineering. I think there have been some regulatory limitations which may not be absolute and that they could very easily extend this in certain pertinent areas to the for-profit segment of the private sector.

Mr. PUCINSKI. Dr. Carter brought this point up yesterday, and I would like your reaction to it: The National Science Foundation is to a great extent a kind of coequal agency with the other agencies that it would be working with, such as NASA, Defense, and various others that generate scientific knowledge.

He raised the question yesterday whether, in order to get this system into operation, we should create a Presidential commission that would offer some direction to the other agencies.

I was impressed with your suggestion for a Joint Committee on Scientific and Technical Communications. We may want to take a look at that proposal and perhaps study the possibility of making that a permanent committee. Perhaps we ought to think of making Satcom permanent.

Mr. CAIRNS. We are a survey group and are phasing out at the end of this year. There is no question we had a temporary assignment to have a look and come up with recommendations.

Mr. PUCINSKI. As you know, the National Library Commission played a similar role. We set it up on a temporary basis. It surveyed the needs of the country in terms of library needs and determined the magnitude of the problem. There is a bill before this committee now, H.R. 8839, which will make that Commission a permanent body. I am a cosponsor of that bill. This is a case where a commission performed admirably.

We might find our answer in encouraging such distinguished people as yourself and offering you some sort of permanent structure to provide ongoing guidance and leadership and direction for this program.

Mr. CAIRNS. We debated in Satcom at great length the placement for this proposed Joint Commission, and we, for good reasons of our own, decided to recommend that it be a nongovernmental body but placed in a spot where advice to the Government is a part of the natural function, mainly in a structure of the Academies, and at the same time to be broadly representative of the private sector.

I still feel that for an advisory body, for a group that exercises, as we said, leadership and coordination in the private sector, this would be a very good and useful influence.

Mr. PUCINSKI. Dr. Cairns, I wonder if it is agreeable to you, sir, since Mr. Bell is here, that I invite Dr. Riegel to join you. Perhaps we can hear from him briefly, I think we would then like to hear both of you comment on the questions we are discussing if you have no objection.

Mr. CAIRNS. I will be glad to wait until he completes all of his testimony, and I will remain here.

Mr. PUCINSKI. I don't think it will take long, and I think the committee will benefit from your jointly assisting us.

Mr. CAIRNS. Byron, like Dr. Lichlider, has been a valiant member of Satcom for the last 3 years, so we would, I am sure, stimulate each other in the discussions.

Mr. PUCINSKI. Dr. Riegel, will you join us, and perhaps we can make this a panel discussion. I have a lot of questions to ask Dr. Cairns, and I am sure you will want to comment on them and perhaps Dr. Cairns may want to comment on questions we have to ask of you.

Proceed, Dr. Riegel.

STATEMENT OF BYRON RIEGEL, PRESIDENT-ELECT, AMERICAN CHEMICAL SOCIETY

Mr. RIEGEL. Thank you, Mr. Chairman.

I wrote out a very short statement that I would like to make and also leave a copy, if I may, with your staff.

The American Chemical Society was given a national charter by the

75th Congress in 1937. It established the American Chemical Society as an educational and scientific society.

And if I may stop there just for a second to say something about the American Chemical Society, it is not a professional society as the American Bar Association or the American Medical Association or the American Dental Association, of this order; it is a scientific and educational society.

Mr. PUCINSKI. Off the record.

(Discussion off the record.)

Mr. RIEGEL. This was national recognition of the society which was originally incorporated in the State of New York in 1877. One of the objects of the incorporation of the society was to increase and help in the diffusion of chemical knowledge and the promotion of high standards of professional ethics, education, and attainments.

The society was dedicated in the beginning to the dissemination of chemical and chemical-engineering information. At the present time, the society publishes 20 primary journals and offers an abstracting and retrieval services known as Chemical Abstracts Service. There are about 15 services, which include printed, microimages, and magnetic tapes. Chemical abstracts is the most comprehensive abstracting service in the field of chemistry in the world. In fact, 60 percent of the sales are to foreign countries.

I might add again off the record we have considerable dealings with the Russians and their huge abstracting setup known as Viniti, I notice referred to in the minutes on several occasions. It is a monolithic structure, an enormous business.

Mr. PUCINSKI. If I may make this observation as long as you referred to the meeting: I said earlier, I personally do not believe that a monolithic Viniti system is the way to do it. It is a big warehouse. Doctor, you mentioned abstracting. As I understand Viniti, it places great value on the types of abstracting facilities we have in this country.

Viniti is essentially a cataloging agency. It obtains a great deal of information from all over the world. This information is catalogued, and stored.

Our technical people in this country can take a scientific paper and, because of their knowledge and their experience, can give the scientific community an excellent abstract of the document.

Viniti, to a great extent, is just a warehouse. Am I correct in that assumption? Perhaps Dr. Cairns or you may answer.

Mr. RIEGEL. They have separate journals that cover separate disciplines. I think there are 170 of them that they produce out of this tremendous group. The one I am particularly familiar with involved chemistry and chemistry engineering called Referativnyi Zhurnal. This journal actually tries to do almost the same things that we do with chemical abstracts except they are hopelessly bogged down in their bureaucracy.

Mr. CAIRNS. I think there is a difference in another respect. It is a monolithic organization, and there is no other word to describe it. It has at the top a group of people who are more concerned with language problems than with the scientific content in order to try to subdivide where they put the different journals for abstracts—nonscientific linguistics. They have a linguistic department to divide up the subjects by scientific departments. It just does not work. Each subject group seems to vie with each other in the amount of stuff they can turn out.

I could not find—and I was there for a couple of days—I could not find how they determined the usefulness of the information. They sold it at a very nominal price that anyone could afford, and there was no feedback at all that I could see that would tell them if this particular piece of the information or part of the service was useful. So everything was all the same.

Mr. PUCINSKI. It is my hope to take the committee to Russia and let them visit Viniti.

Mr. CAIRNS. It was a little impressive in those 2 days. Of course, in November, it was pretty cold.

Mr. RIEGEL. I might add—and I am afraid this ought not go into any permanent record particularly in Congress—that is, that the Russians take our chemical abstracts, photocopy and merely put across the front page "Photocopy produced by Viniti" and sold at about one-half of our prices behind the Iron Curtain, depriving us of $2 million in revenue.

Mr. PUCINSKI. As I understand it, Viniti takes these American abstracts of ours and translates them into Russian. Our own Science Information Services office pays our translators to translate them back into English.

Mr. RIEGEL. May I just finish and it won't take but a second here.

The total budget for the publication program for 1969 is about $25 million. Of this amount, about $2 million has been furnished by the Federal Government through the National Science Foundation. This is to enable the society—and I am talking about $2 million—to develop computer capability for the handling of chemical information.

In 1963, the American Chemical Society initiated a feasibility study for establishing a national chemical information system. Again, we had the expert help of Dr. Licklider on this, which I would like to recognize.

This has drawn so much attention that it has now been expanded to an international system. I would particularly like to call attention to the last Chemical & Engineering News—and I notice you have one there with Dr. Cairn's picture, and this happens to be the one that came out Monday; it is the April 28, 1969, issue, page 15—announcing the formation of an American Chemical Society-British linked chemical information system. Negotiations are now going forward—and I also noticed in your notes, and this has been said before—with other countries, particularly the Germans.

Mr. PUCINSKI. Is this the first time we have linked an international hookup?

Mr. RIEGEL. As far as I know.

Mr. CAIRNS. There have been attempts, I am not sure how far they have gone, between AEC and certain others.

Mr. RIEGEL. Medlars.

Mr. CAIRNS. Yes, Overseas Systems and Medlars; I am not sure how far they have gone in actual operation, but they are taking steps. This is the first one in the private sector I am aware of.

There has been for many years an international cooperation in the field of physics. We have relied on the British to provide abstracts in the physics field. So there was in that case a specific limited operation where they were doing the work and providing us with service.

Mr. RIEGEL. It would have been impossible for the American Chemical Society to afford the cost of developing computer capability without the assistance of Federal funds. It is extremely expensive to continue the printed copy as we go along and at the same time develop machine capability.

Furthermore, we are trying to do this, as was very well described by Dr. Licklider, so it could be almost instantaneously searched by many people. The American Chemical Society is also experimenting with computer-driven photocomposition of some of our primary journals.

The documentation unit for each paper that is published—and a documentation unit is a scientific word that is used to give all of the bibliographic descriptive material, authors, journals, dates, pages, titles and so forth—this so-called documentation unit, plus the abstract and index terms, will be computer recorded and transferred by computer to the Chemical Abstracts Service.

These are some of the early steps in systems designed to coordinate the handling of chemical information.

If again I might stop here in my prepared statement, I would like to say a word about informal communication. I think all of us, including Dr. Cairns and his group in Satcom, were quite surprised at seeing some of the recent surveys of how much information is now transferred between people just orally, just in the so-called informal mode.

Furthermore, this turns out to be highly effective. The interesting thing about it is that apparently the speed of transportation plus speeds of communicaion, particularly Bell telephone and so forth, make this such a convenient way to do this. Some of the surveys that were run in DOD and which have recently been substantiated in some of the other research and development organizations, has shown that as high as some 60 to 70 percent of information may be transferred in this form.

These are rather startling terms. We don't realize the importance of the meeting, just as we are meeting here today. Much of this is due to our excellent methods of transportation.

We are trying to make a real survey of the importance of the so-called informal communication to see that it, too, is incorporated into the data banks. It is hoped that this chemical information system can be developed and interlocked with other scientific and engineering disciplines.

Although the American Chemical Society has a rather large and dedicated staff, much of the management responsibilities, policy decision and financial control of these operations are done by chemists and chemical engineers on a voluntary basis without compensation.

We have over 3,000 abstractors all over the world who are paid a fee that barely covers their typing and mailing expenses.

The American Chemical Society is the largest scientific society in the world devoted to a single discipline. At the present time, there are 115,000 members that are scattered through education, government, and industrial laboratories. The American Chemical Society enjoys the support of a very healthy chemical industry. Two of us represent industry on the board of directors of the ACS.

Chemistry is a very basic science and is used by many other sister sciences, particularly the medical sciences. Likewise, the chemical industry is a basic industry supplying the essential needs of many other industries.

One might refer to the use of chemistry in the atomic energy program, space program, health sciences, petroleum, textile, food, housing industries, and others.

Therefore, in conclusion, the American Chemical Society is dedicated to be of maximum service to humanity through educational institutions, the Government, nonprofit research organizations and industries.

It is my pleasure to express our deep interest in H.R. 8809, a bill to provide for the establishment of a National Science Research Data Processing and Information Retrieval System.

That is the end of my formal comments.

Mr. PUCINSKI. Thank you very much.

I have said many times that the decade of the 1950's was the decade of nuclear development and the decade of the 1960's was the decade of space development. I believe that the decade of the 1970's is going to be the decade of information retrieval—finding better ways to deal with the huge outpouring of information that is streaming from our laboratories.

As we said, with $27 billion, scientific research now ranks among the biggest industries in the country.

Mr. RIEGEL. I was wondering if I might add a few personal comments on some of these statements. I feel this way, that many of our social problems today are the result of what America has particularly given the world, that is, expert science and technology.

This is the one thing that I think has really distinguished us in these decades we are talking about, and as such, I wish to talk about these social problems that arise from advance science and technology.

This is probably out of order, but I would like to put in a commercial plug. I think one of these is overpopulation, and my company has been very much interested in that. We are the inventors of "the pill."

What I am trying to talk about are social problems, and many of these problems can be approached by excellent science and technology. Here is an area where I feel we have not used as much of the information and technology we have at our fingertips; if there were some way this could be focused and used, it would be a fine example of good communication.

Mr. PUCINSKI. An effective information retrieval network or system, which ultimately could be tied in to Telstar or a similar facility, could become one of the most important ingredients in American foreign policy.

We are locked in a struggle, seeking ways to resolve the world struggle without losing men on endless battlefields. There was a convention in Geneva recently; 2,300 delegates adopted a resolution urging a better system of communication for scientific research so that the emerging nations, with their limited resources, could participate more effectively in scientific research.

That is what brings me to this question which I would like to ask each of you gentlemen.

How do you go about linking all of these systems without destroying them, without in any way impeding them in their own progress? What would be your thinking, if, instead of trying to achieve more effective communication through a Government agency, we were to think in terms of a communications Comsat, a quasi-Government public corporation, that would have the basic responsibility for this project? The Government would provide some of the impetus and some of the financial input, but let the scientific community itself run the show.

You would then set the standards and decide the method of establishing such a system. What is your reaction to that?

Mr. RIEGEL. I might say we discussed it, and it is an excellent idea. I might add that I almost said exactly the same thing on Tuesday to the Satcom Committee and we discussed it at some length. I guess our big problem on it was to find out how to get it started.

Mr. PUCINSKI. That was the same problem with Telstar.

Mr. RIEGEL. That is right.

Mr. PUCINSKI. We found the answer within the Comsat concept.

As far as I know, Comsat is working out very effectively. What would be your comment, Dr. Cairns?

Dr. CAIRNS. I think we have to distinguish between the broad subject of communication and what Satcom initially referred to in its own contemplation of "brain to brain" communication—in other words, the transfer of concepts or ideas and technical information from one thinking person to another thinking person in what one might call a physical network.

I can see every reason to connect physical networks so that they flow one into another. Certainly, this is the common denominator of the telephone system and Telstar and the rest of the network communications; that is, speaking in this vein, only in the electronic communications sense.

However, when we include the intellectual components, we have an additional problem, then we must admit, as Dr. Atkinson said in testimony, that the aggregate of several systems presently in the course of development, and that may be expected to emerge as a result of efforts still to be undertaken, constitutes the national information system.

The participants in this network will be drawn from all sectors of our society and we will all need a voice in its operation and management. In other words, you bring in the intellectual content and you have to diversify the input, control, and management functions.

W discussed it earlier and seem to be somewhat in agreement on this point. In that light, therefore, I would say that too strong a focus on a centric management organization would be questionable in my mind. I don't believe, in other words, that a national commission operating its entire budget and controlling the Government and private sectors would be the thing to have at this point.

I would like to say that I like what you suggested here, which is more an aggregation of numerous systems already in being. Maybe the word "system" here should be "systems," because you are presumably talking about an aggregate of systems rather than a monolithic organization which says, "This is what we are going to do."

Mr. PUCINSKI. Dr. Cairns, I am very grateful to you for bringing this point up. This has been one of the points that has plagued our hearings for years. Perhaps it is because we have a little problem of communicating ourselves.

Dr. CAIRNS. You certainly do.

Mr. PUCINSKI. Throughout all of these discussions there has been a fear (and quite properly so) that someone is thinking of setting up a huge monitor which will try to direct all of these activities and ultimately direct the scientists themselves.

When we talk about a national network of systems, we are merely talking about establishing a communications network. It has never been the intention of this legislation or our discussions that we should have a scientific czar or superpanel that will direct individual activities.

This is, of course, what we have been talking about all along. Your suggestion as to a national information systems approach has given us a chance to clarify it.

But the one common thread that we would want in this network of systems is that at least some dialog on compatability be there. We are moving today in all sorts of directions and everybody is doing a good job.

Dr. Rothman of the New York Times said he is trying to work out plans to make sure their system is compatible and that if, at some future date, there is a network of systems, the New York Times will be able to tie into this network without a complete overhaul of its system.

This is an area where we cannot afford to lose any further time. I think that is why I like Dr. Cairns' suggestion about a joint commission on scientific and technical communications. Somebody is going to have to start producing some leadership in compatibility. What do you think, Dr. Licklider?

Mr. LICKLIDER. I think you are setting the record straight beautifully. I like what you say so much, I hesitate to add a comment, but of course I shall.

I think that it is absolutely right that you emphasize the pluralism of the system, the collection of organizations that are going to implement various parts of the network of systems. I like that term, "network of systems."

I think it is right that you emphasize coherence. The one other ingredient I want to put into it, which I think you may soft pedal a little bit, possibly because if misinterpreted it might sound like too much of a centralist component, is a clear set of goals and enough central leadership with enough funds, and the responsibility to make the thing move forward.

I agree so wholeheartedly with your urge to get moving, I don't want to leave out the motivating force that will make it move. I am just afraid if it were left wholly pluralistic, with only good intentions about cooperation and coherence and standards and compatibility, it might go into too many different directions and not really get us the desired network of systems.

Mr. CAIRNS. What the Science Foundation did for the Chemical Society, besides providing several millions over a period of years for research and development in systems development, was to insist on a 5-year plan.

They really put it on us hard to work out a plan that would justify the type of expenditure and type of evolution with time scales on accomplishment, which I think have been fulfilled or even surpassed. This did a great deal to really energize the people that we had available in this area.

I could certainly agree that goal-setting is one very important element. There tends to be too much talk and not enough action in this broad area of information handling.

Mr. PUCINSKI. That is what we are trying to do with this legislation. That is why I must tell you I was really very disheartened when Dr. Adkinson came here yesterday and told us not only does he think we don't need the legislation but told us that to pass it would impede the program.

Mr. CAIRNS. I think, from what I read of the closing testimony, and I have not talked to Burt, but it appears he may have been talking about the monolithic concept and not against an aggregate of systems of which he spoke in the last page

Mr. PUCINSKI. He says:

> Nor does it appear desirable at present to establish by legislation a formal national system. Constraints imposed by such a formal system might well inhibit rather than assist the productive evolution of these services. I therefore believe that the enactment of the proposed legislation is not advisable at this time.

Mr. CAIRNS. The first sentence says:

> Aggregate of several systems presently in course of development constitutes the national information system.

It is a question of wording.

Mr. PUCINSKI. Dr. Adkinson said in answer to a question that he didn't think that we ought to be moving now, because the things that we might be doing now will be obsolete tomorrow. That has been the story of American technology for a hundred years.

Many of the things that we buy today are obsolete by the time we get delivery. That is nothing new.

Mr. CAIRNS. If you are going to put more responsibility on the National Science Foundation in this general area without trying to create a monolithic structure, but trying rather to utilize and give greater support and guidance to the private sector existing organizations, I don't see this is a bad step to take.

I think it is much better to do this in an evolutionary sense, take it one step at a time, as this appears to do, rather than to create a national commission that tries somehow to command the entire information structure of the Nation, which I don't believe is possible physically or financially or any other way.

I think this bill represents a rather simple step of giving greater responsibility to the National Science Foundation.

Mr. PUCINSKI. This bill was written in a way to augment and strengen existing agencies.

We thought at this point in time we ought to give those agencies a further impetus from the Congress to move them along further toward establishing what you have quite properly renamed, Dr. Cairns, the network of systems.

Surely, this takes imagination, it is going to take a lot of work, and it is going to take some money. I envision information retrieval within the next 5 years as one of the greatest job producers in this country.

I am talking about an industry that is going to be one of the keystones of the American economy and ultimately is going to be a worldwide activity.

Mr. RIEGEL. I hope you don't become discouraged. The bill is to correct section 902, and only that.

Mr. PUCINSKI. I missed what you said.

Mr. RIEGEL. Your bill is to modify the original act, section 902(a), where the Science Information Council is described. I might add that Dr. Lichlider and I are both on that Council.

We might have some influence in helping in the guidance of where we feel this would give the type of thing that we all need. I want to add just one other piece of personal philosophy, which I think is really important when we start talking about science and technology.

That is, and this is the one area where I can speak with some degree of authority, in chemical and chemical engineering information, of the world information we cover in chemical abstracts, we only generate 28 percent of it in the United States.

Let me say this in reverse. We depend on the rest of the world for most of the information, 72 percent to be exact, and we build on that and we use it.

The point I am trying to make is that science and technology is not divided up in the State of Wyoming or something of that order, nor is it German mathematics, but it is something that belongs to all of humanity, and any type of organization must have the systems interlocked so that we hear from Russia as well as we do from the rest of the world. The point is, it cannot be nationalistic.

Mr. PUCINSKI. I agree with you, Dr. Riegel. This committee is amenable to any suggestion from the scientific community. Even if you want to restructure this legislation, we welcome your suggestions. That is why we are holding the hearings.

When I foresee the fantastic challenge to the American scientists, and their colleagues around the globe, I don't believe that we can wait another day. I think we ought to start moving in the directions of helping these men.

As Dr. Cairns so beautifully pointed out in his statement, and I quote, "Scientists don't spend exorbitant amounts of time in the library, which after all is a tremendous drain on a researcher's time, or repeat work that has been done already."

Dr. Riegal said that a recent edition of "Reader's Digest" said, "If a chemist or a physicist sat down and read the scientific journals in his field as his full time job, at the end of a year he would be 3 months behind in his reading."

I think that Dr. Cairns made an excellent suggestion. Dr. Licklider made a series of excellent suggestions. We have to get moving forward. This is why I must say that I was disheartened with the testimony of Dr. Adkinson, for it seems to be that the Office of Science Information Service or perhaps it is the Bureau of the Budget, is putting a veto on this program.

What is your reaction to that?

Mr. CAIRNS. I feel that the problem that is being immediately faced here, of acceptance by NSF of an enhanced plan, an intensified responsibility, is something that could be easily worked out in terms of the language you use in the bill.

Quoting from Dr. Adkinson, when he says, "The aggregate of the several systems that are presently in course of development constitutes the national information system; the participants in this network will be drawn from all sectors of our society, and we will all need a voice in its operation and management,"—if you buy that, you are together.

What you are saying is, all right, let's call it by a name, let's give it some force and some backing—and presumably also some greater degree of support.

Mr. PUCINSKI. What I am saying is, the time has come for national commitment.

Mr. CAIRNS. I think so.

Mr. PUCINSKI. We tried to express that national commitment in H.R. 8809. If the words are wrong, if the structure is wrong, we want you people in the scientific community to tell us how you want it.

Mr. CAIRNS. It is not wrong. There is one element, though, that is different, basically, and that is—your amendment does propose something that one might describe as operational, whereas what they have been doing in the past is research and development on the design of systems.

Now, if they object, as they may very well do inherently to operating, or to any operational responsibility, this may affect their basic charter and this may be another element that accounts for the response.

I think with you that someone has to stand back and see how this thing is going to work.

Mr. PUCINSKI. I believe we are now at a point in time when the huge thrust in this whole field of information retrieval can no longer be ignored or left to the limited budgets of multiple organizations. If we don't have an agency such as the National Science Foundation providing the leadership in encouraging dialog between the information system, we are going to lose compatibility. Five years from today we are going to have to face the fact of multiple systems that can't communicate among themselves.

I am grateful for your testimony today. All three of you gentlemen have helped us to get this discussion underway.

Mr. CAIRNS. As long as you follow the general organizational line set up in the original act that set up the Office of Science Information Service, the Science Information Council and the activities that they have sponsored for the last 10 years as long as you have worked from that base toward an enhancement aiming toward something that is more operational, I think you are on the right track.

I would hesitate to see a new Government agency formed.

Mr. PUCINSKI. That is right. That is why, you see, we started with the National Science Foundation, because we felt they have the capability to do this job and above all, the respect of the scientific community. That is very important.

Mr. CAIRNS. I think they have done an excellent job, not only in science but in engineering. This bill speaks about a science system, but I would broaden it to include technology.

Mr. Pucinski. In the light of your testimony, perhaps we can ask the NSF take another look at this proposal. Perhaps they will reconsider their testimony of yesterday.

Mr. Riegel. There is finally one other statement I would like to make and that involves libraries. They will undoubtedly be an integral part of the network of information systems that would be generated in the United States.

I think we have to divide libraries—at least, just for convenience—into two types: those that serve as sort of a public library, where they furnish books to the general public, and the so-called research library, that furnishes information to universities and to industries including technology, and as such they also must be considered in this overall setup.

I realize that the library responsibility has never been generally put in the National Science Foundation, but I think it would have to be carefully considered.

Mr. Pucinski. I know of these things, and I would like a final question and perhaps an answer from each of you.

What advice can you give us on the committee to move ahead with this proposal? Dr. Licklider, let's start with you.

Mr. Licklider. First, Mr. Chairman, I think you basically want to introduce into the situation a very significant increment of forward thrust. I think that is the most important thing to be done now. I think you want to change the situation qualitatively by making it move very much faster.

I think there may be some miscommunication when that surge is stated in terms of starting out to make a national system or starting out to make a national network of systems.

I think it would take only a very small change in the wording to bring everybody along together. If something were said about a melding of research, development, pilot systems, and operating systems—about a coordinated complex of activities in which there is an urgent thrust forward making systems really operate, and in which modern technology is used to the fullest extent—then I don't think there would be much hassling about whether it is too early to start or too late to start.

I think you recognize, I think we all recognize, it is going to take significantly increased funding. I think we are all afraid that today might not be precisely the time. I agree with you, today is the time to get hopping on this thing. I hope you are successful, and I want to help all I can.

Mr. Pucinski. Dr. Cairns.

Mr. Cairns. I agree with what Dr. Licklider has said. As I mentioned earlier, I think they are frightened a little by the term "operational." It is not mentioned here explicity, but it is implicit when you say "systems," and if you evolve systems, if that is the force, and that is where we are today, it fits exactly in with what they are doing now, but it lends some force to creating the system.

Then we can leave the problem of how the overall systems or aggregate or network of systems are going to operate if the emphasis is on evolving the system rather than on operating the system. I think then we will get somewhere.

Mr. Pucinski. Mr. Riegel.

Mr. RIEGEL. I want to make only a remark about the operational side of a network of systems, that we do not fall in the trap of trying to make a division between a scientist or technologist, as to where he is located, whether he is in the Government or in an educational institution or in industry or with a profitmaking information-handling group.

They know no boundaries as far as they are concerned, and any systems that are designed and set up should not be—or rather should recognize that we all have a real common input and output from that system.

Mr. PUCINSKI. Right. Gentlemen, as you all testified here today, one thought struck me. Perhaps what we really ought to do is take this legislation and ask a panel of you distinguished scientists to offer us your own suggestions on what revisions you might suggest here.

I think Dr. Licklider has made some strong points and I certainly like the point that Dr. Cairns made about renaming this "network of systems" instead of a "system," simply because the present wording does create confusion.

The problem we have is to make these necessary changes, what we perhaps should do is to communicate with all of you and ask you to make whatever suggestions you might want to make in the actual structure of this legislation.

The other thing we might do, if it is agreeable, is invite a distinguished panel of scientists like yourselves, to help in the structuring of the report.

As you know, legislation itself very often is just a vehicle. It is really the report that spells out the machinery for carrying out legislation and its full intent. I would certainly like to invite you gentlemen to offer some suggestions on that, too.

Mr. CAIRNS. There are two groups presently in being that have certainly a strong interest in this area. Satcom is one, and I will bring up this subject at our meeting on Tuesday.

The Scientific Information Council, to which both of these gentlemen belong, in addition to Satcom, which relates directly to the operation of the Office of Science Information Service and NSF, is another body that certainly would have a cogent part.

Mr. PUCINSKI. Of course, your report will have, I think, some judgments.

Mr. CAIRNS. It shows a greatly enhanced need for Government support, as well as for support from other parties who are operating research and development activities, toward making more accessible the results of the research and development work.

But the predominant support has come in the past, of course, from the Government and hence the onus is on the Government to make more accessible the information that it creates.

Mr. PUCINSKI. I would like to close this hearing with this thought. This legislation stems from a debate that we had in Congress about 8 or 9 years ago, when there was, a series of critical attacks upon the scientific community of this country.

There are still strong forces in our Government that believe many of our scientists are wasting money, duplicating effort, and are spending for too much on pure research.

I said then, and I maintain that legislators are not capable of sitting in judgment on the efforts and activities of scientist, nor should we seek to.

Rather than imposing some artificial restraints and limitations on scientific pursuits, let us make available to the scientist all of the information that is generated on a given research project, and then let this scientist impose his own discipline against waste and duplication.

Therefore, the whole basis of this legislation is to provide a structure, a network of information, so that the scientific community itself will be helped to progress in its research activities.

With that thought in mind, I trust that we in Government can work to bring the enormous benefits of scientific and technical information to all our scientists.

(A statement submitted for the record follows:)

STATEMENT OF MR. A. C. SCHILL, VICE PRESIDENT, OF INTERNATIONAL SYSTEMS DESIGN, INC.

I am pleased for the opportunity to express to the committee our views concerning the need for a national system for the retrieval of scientific and technical information. It is obvious that if the United States intends to remain a leader in the fields of science and technology, the establishment of such a system as is found in the proposed legislation is essential.

It would appear that the initial step which must be taken in the implementing of such a system is to determine whether the present Office of Science Information Service, or any other agency, is actively pursuing the means by which such a network could be established. Having heard the testimony given during this hearing, it seems apparent that while the Office of Science Information Service is obviously performing a worthwhile service to the scientific community at large, it does not appear that anyone is presently implementing or investigating the implementation of a nation-wide system for the input and retrieval of all scientific and technical knowledge.

Having spent a number of years in research and development in the field of chemistry, I have personally been involved in the issue of retrieving vital information and have seen first-hand the waste of time that is inherent in any endeavor where the problem of duplication has not been circumvented. Considering the comparatively limited confrontation I had with the problem, it is obviously a staggering, but not overwhelming job, to undertake the initiation of a program which would permit the establishment of a retrieval system to handle the flood of information which would, of necessity, have to enter into it. However, as much of a problem as this may be, it is nevertheless one with which the scientific community must deal, and in so doing, must turn to the one organization capable of the funds and wherewithal to accomplish the task, the Federal Government.

I am grateful to see that there are those in the government who are as cognizant of the problem as are the people who come face to face with it on a daily basis. It is due to this interest that I would like to present certain facts which might otherwise go unnoticed and therefore unresolved. There are a number of factual points which should be made concerning the progress already achieved in the field of information retrieval.

The initial step in supplying input for the proposed system's data-bank involves the willingness of the suppliers of this information to cooperate to process their data for computer usage. This is a vital step in the gathering of such an overwhelming supply of material and as such must, if possible, be integrated into the over-all system. The reason for this first step is basic. If the means of moving from the conventional publishing service, which derives its economics through the simple expedient of subscriptions, to computer services which are based upon a complex arrangement of exchanges of ideas between the inquirer and central or remote data centers, is to be accomplished, the expediency of this step must be established. Thus, if the great portion of information produced by publishers could automatically be translated into computer form at the time it is initially being prepared for publication, there would be a vast savings of time and money, and would add greatly to the efficiency of the entire system.

Let us examine this reasoning in detail. First, the savings in time should be reviewed by producing computer input as a by-product of the initial publication stage of any piece of information, the availability of this information is that much quicker. Second, by producing the information in input form as a by-product of initial publication, we are saving additional time and cutting down on the number of personnel necessary to convert new data into computer input. The monetary savings would be in direct ratio with the amount of material converted to computer input during the initial step of publishing it. Finally, the efficiency of the entire system would be tremendously up-graded due to the absence of any possibility of overlooking information.

The question immediately arises as to how to gain the cooperation of all those companies engaged in the publishing of information such as that which is anticipated will be placed in the data-bank. The most direct method would undoubtedly entail showing them a means of increasing their revenue. This is not as impossible as it may sound.

There are plainly many readers of publications whose interests are extremely narrow in scope. Therefore, aside from producing regular publications, other personalized publications, or selective dissemination of information reports could be printed from the tape which is being produced during the initial publishing steps. Since these reports could be very specific in nature, charges could be made to the recipient, as it will be a time-saver for him. But, more importantly, advertisers could be encouraged to relay their message in these reports, thereby assuring themselves that the person for whom their message was intended was seeing it. Of course, should it be decided that original material is too bulky, the same services could be offered by the publishers for abstracts or digests of their editorial content. With the decided advantages of such a service they could therefore more easily avail themselves of a rich market-place for their by-products.

In addition to this, under the assumption that such a system as is envisioned by this committee will in no way interfere with private enterprise, the publishers could also market copies of their computer input to companies and government agencies which would be supplied with programs enabling them to use the data.

All of this would in no way interfere with the sales of the original publications, since they would continue to be used, as they are now, as general alerting bulletins. Surely the use of the anticipated data-bank will not completely delete the need for libraries and quick reference sources. Rather, it would supply the publishing industry with an answer to a problem which they have been facing for years: how to derive added income from editorial content through by-products.

Of course, before such a program can be implemented, it will be necessary to gain the agreement of the publishers involved to use a common system. Compatability is basic to any such systems, for only through a compatability of information systems can then be an interaction of data. In addition, the availability of many different files which can be accessed through one method of retrieval is essential to any over-all network. Through the previously mentioned advantages, it can be shown how the people involved in the publishing of information can benefit by contributing to a national information retrieval system, and therefore aid in its promotion.

A significant feature of this approach is that every scientist and scientific institution would be able to register his interest in advance with every publisher and disseminator of scientific information. By virtue of all publishers operating under a standard and uniform system the scientists explanation of his needs would apply equally to all publishers. This guarantees that the scientist will not be inundated with irrelevant material because of different interpretations placed on his needs by different publishers. In other words, a universal system incorporating a universal language will offer the ultimate in bringing the full power and context of scientific knowledge to each scientist and institution in this country.

Recently, we have seen that the New York Times has begun to establish a system for the retrieval of information found in that newspaper. They are to be congratulated for their endeavors in this area, for their newspaper is probably one of the finest in the world and as such is a wealth of information. However, while the management of the Times appears to be cognizant of their problem, it was necessary for them to go outside their company in order to implement their desires to put the data at their disposal into a computer form. It would have been equally difficult for the outside company consulted by the Times to attempt to develop a system based on the retrieval of newsworthy information, for they lack, through no fault of their own, the necessary experience of determining what is newsworthy, which is a vital prerequisite in the publishing field. It would therefore appear that in order to develop any system which is going to retrieve information adequately, while assuring that this information is of value to the users, it is necessary to combine the advantages and training of people from two separate worlds into one cohesive body. In the case of scientific and technical information, this body will no doubt require a leader in the field of science in order to give it direction. In this manner, a group of publishers, users, and softwear designers can best determine the whats and hows of the system.

While I am sure that an introduction to the capabilities of my company in this combined field of publishing and information retrieval systems design would be helpful to the committee in investigating the proposed bill, I feel that it would not be propitious in view of the fact there may very well be other companies wiht these same capabilities who have not been accorded the opportunity of presenting their credentials. We would be most happy to pursue the advantages of our system as it applies to the present problem should we be called upon to do so at a later date.

Another important aspect which must be investigated as an integral part of a National Science Research Data and Information Retrieval System is that of the abundance of available input and how to cope with it. It appears that while other aspects of the proposed legislation may be more immediately important, it will be necessary to devise a means of putting into the computer not only new information as it becomes available. but an unprecedented amount of back-logged data. Therefore, in any investigation of such a system as that presently under discussion, the operation and costs of optical scanning equipment must also be undertaken. This is a not too difficult task and upon request I will gladly supply any body of investigators with a listing of manufacturers of this equipment along with the equipment manufactured by each. I only mention this because I feel that the availability of such equipment circumvents any argument against a national system based on the idea that all of the available information could never be processed in our lifetime.

In order to implement the establishment of a national depository of scientific and technical information a great many more questions other than those discussed above will have to be answered. The reason for my delving into these particular questions is that they appear to be considered by many to be major stumbling blocks to the legislation. However, it is the belief of our company that these are not major problems, as witnessed at first-hand in our own endeavors to provide such services to our own clients. Thus, while on a diminitive scale compared to what we are discussing at this juncture, our work on the question of information handling leads me to believe that the problem is far from insurmountable, for a good deal of the mechanization of such a system, albeit on a much smaller scale, has already been accomplished by and for private industry in companies such as ours.

This leaves the major problem of deciding upon a feasible means of progress. With that mode of thinking as our guideline it appears that the best available method would be through the appointment of a President's Commission delegated with the authority to investigate and suggest ways of providing for the establishment of such a system as is provided for in H.R. 8809. This commission may very well decide that the steps to be taken are not in line with the thoughts expressed in the present bill. It is my thinking that changes will undoubtedly have to be made in order to assure the nation's scientists of a system which will be most advantageous to their needs. Nevertheless, this bill lays the all-important groundwork toward the inception of such a system.

There is no doubt in my mind that a data-bank for immediate access by our nation's and perhaps the world's scientists is a necessity. The only question which arises is how long this repository of information will be withheld. The challenges of our world today will not diminish but rather increase far beyond what we can imagine. The flood of papers, publications, and reports documenting each step and breakthrough will not allow for use as we now know it and will require methods far beyond those we now possess. However, there must be a starting point, and this must be decided upon now, for by tomorrow there will be that much more to be learned.

Mr. PUCINSKI. Gentlemen, you are very kind to give us so much of your time. We thank you for your testimony. I think you have moved us forward a giant step today.

(Whereupon, at 3:55 p.m., the subcommittee recessed.)

O