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Identifiers-Guba Clark Model

Multimedia can significantly improve education, but only to the extent that their impact is perceived and planned for. Planning migt be accomplished in a comprehensive, multimedia development laboratory, organized around methodology and functions rather than equipment or facilities. Such a laboratory might plan, supervise, evaluate, and influence the implementation of complete educational systems making optimum use of multimedia and telemedia in an integrated and continuous manner. Of possible simulation laboratories, a semi-manual computer-based laboratory might be the most effective, but its main contribution would be as a research vehicle: it would not bring about major changes. The methodology of this study consisted of seeking expert opinions, visits to innovative installations, and a review of the multimedia state-of-the-art. No experiments were undertaken, nor was a prototype laboratory built or tested. Annual cost of a comprehensive, multimedia development laboratory is roughly estimated at $2,000,000. It is recommended that the Commission on Instructional Technology favorably consider the feasibility of such a laboratory. A bibliography and descriptions of various operations presently making use of multimedia are appended. (GC/MF)

FINAL REPORT

Contract No.: OEC-1-7-071143-4419

FEASIBILITY OF USING AN EXPERIMENTAL LABORATORY FOR IDENTIFYING CLASSROOM MULTI-MEDIA PROBLEMS AND REQUIREMENTS

June 1968

U.S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE

Office of Education
Bureau of Research

Final Report

Contract No.: OEC-1-7-071143-4419

Feasibility of Using an Experimental Laboratory for Identifying Classroom Multi-Media Problems and Requirements

TM-WD-(L)-527

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The research reported herein was performed pursuant to a contract with the Office of Education, U. S. Department of Health, Education, and Welfare. Contractors undertaking such projects under Government sponsorship are encouraged to express freely their professional judgment in the conduct of the project. Points of view or opinions stated do not, therefore, necessarily represent official Office of Education position or policy.

U.S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE

Office of Education
Bureau of Research

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Acknowledgments

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Summary

This study emerges from a conviction that new media have much of value to offer to education, but that there are problems in deciding where and how to use them, in what combinations, under what conditions, and for what purposes. A review of the multi-media field (including standard audio and visual devices, television applications, computer-assisted instruction, instructional data-transfer systems, and so on) indicates that current practices are generally rather ineffective and that research and development efforts have been limited in scope. New approaches are evidently required.

The feasibility and desirability of laboratory approaches to educational media were investigated by this project. Systems methods formed the background of the investigation, though the project was limited to conceptual exploration and to the analysis of past and present experience. No new laboratory was constructed for trial and evaluation, but expert opinions representing many disciplines and backgrounds were sought out, written accounts were reviewed, and innovative installations were visited.

An important conclusion of the study is that "multi-media problems" neither exist nor can be solved in isolation from total educational systems, including their political and social environments. A laboratory to address these problems should be concerned with a complete spectrum of activities, including research, system planning, design, operation, evaluation, and diffusion.

Six types of laboratories are distinguished as being able to deal in various ways with educational media. Of these, simulation laboratories and "comprehensive development" laboratories show greatest promise of offering needed assistance.

Simulation laboratory approaches to educational problems have to date shown limited success in relation to costs. A semi-manual, computer-based laboratory utilizing time-sharing techniques is judged to have the greatest chance of improving simulation laboratory effectiveness, but its main contribution would be as a research vehicle. It would tend to bring appropriate models, data, and functional analyses into existence as both a condition and a result of its operation, but it could do little by itself toward reaching solutions to the major problems which lie in the areas of development and diffusion. It therefore does not represent a feasible approach to multi-media problems.

The concept of a "comprehensive multi-media development laboratory" is put forward. It would plan, supervise, test, and support systematic educational improvements in an integrated and continuous fashion. It would review, analyze, evaluate, and generate alternatives to current multi-media practices and to the assumptions and institutions in which they are embedded. It would be organized around methodology and functions rather than around equipment and facilities; techniques would be subordinated to educational problems.

A comprehensive multi-media development laboratory as described is needed, is technically feasible, and would have an excellent probability of making significant contributions to education without excessive costs. It is recommended that such a laboratory be established.

In view of the recent formation of a Commission on Instructional Technology under Title III of the Public Broadcasting Act of 1967, it is noted that the comprehensive development laboratory concept has considerable relevance to needs for improving the educational effectiveness of instructional television and radio. If a new overall approach to telemedia is desired, an organization along the lines of the comprehensive development laboratory could combine, as no other organization could, all the factors necessary for a complete approach.

I. Introduction

A. Project Purpose and Background

This document is the final report of a study performed by System Development Corporation (SDC), under contract to the Bureau of Research of the U. S. Office of Education, to determine the feasibility of using an experimental laboratory for identifying classroom multi-media problems and requirements. The study emerges from a conviction that new media have much of value to offer to education, but that there are problems in deciding where and how to use them, in what combinations, under what conditions, and for what purposes. The study has attempted to discover what type of laboratory approach could best assist in finding solutions to these problems.

Multi-media techniques for education include telemediated resources, computer applications, the myriad devices for classroom project. n of sight and sound, individual teaching devices, and some advances not yet implemented. They appear worthy of serious consideration, both because of their great promise and because important uncertainties surround their current and future use. More specifically, multi-media appear to offer the following kinds of advantages if properly implemented:

- Improved use of the nation's limited educational resources.

- Increase in student-teacher ratios without a lessening in the quality of education.

- Relief from the tedium which marks the classroom pattern of traditional education.

- Increased student involvement in the design and control of the learning situation, and increased active participation in and responsibility for learning.

- Improvement in the dissemination of quality education, the updating of needed skills, and the provision of educational opportunities for populations of increasing size, variety, and dispersion.

However, it also appears that multi-media will significantly improve education only to the degree that their total impact is perceived and planned for. They can change the whole concept of the institution of education and the schools through their revolutionary power, range and potential. On the other hand, they may have no effect on the schools just because massive institutional inertia can too easily diffuse the uncoordinated impact of random ideas and sporadic innovative trials.

Computers, for example, have received considerable notice in the popular press during the past several years; in particular, computer-assisted instruction has been hailed as a method of providing individualized instruction. Indeed, computer applications to education have been viewed as making it possible to convert education from a labor-intensive to a capital-intensive industry. As greater numbers of students enter public education, it has been predicted that correspondingly increased numbers of trained teachers will not be necessary; it will only be necessary to attach additional student terminal equipment to the computer.

Although computer technology shows some promise of increasing the efficiency of education by individualizing instruction and converting it to a capital-intensive system, thus far it has not delivered on its promise. In addition, the prospect of computer-assisted instruction raises serious problems on a larger scale. First, efficiency is not always a major goal of public education in an affluent society; it may even create problems. Second, individualized instruction may be inconsistent with the equalitarian movement in the United States and with education's implicit "custodial" or "babysitting" functions. Third, teachers represent a powerful lobby group that does not look with favor on any effort to replace them with technology.

Nevertheless, despite these obstacles, technology offers the capability of achieving a better allocation of educational resources. Clearly human instructors are poorly used as simple transmitters of information. Radio broadcasts, continental distribution of educational telecasts by means of communication satellites, widescale distribution of copying machines, audio tape equipment, and the dissemination of instructional material on microform copy with associated readers, are but a few of the methods that could handle the bulk of the information-passing function that is now the nearly unchallenged domain of the instructor and his blackboard.

A better use of the instructor could also be made by further differentiating his role. The instructor could be a manager of instructional resources rather than a transmitter of subject matter. He could direct the learner to appropriate learning resources (programmed instructional material, educational games, and so on) and become a partner with the student in the learning process. Greater use can also be made of another major instructional resource: the students themselves. Students often learn more from each other than from teachers and can be taught to help one another. Older children who help younger children also benefit themselves. This opportunity has been neglected in teacher-training efforts, yet the students themselves represent the single most important hidden resource available for the reduction of the teacher-pupil ratio.

It is also unnecessary to assume that every instructor must be a fully trained professional. Many parents or para-professional aids may be used for such functions as preparing and maintaining instructional material, working in the home showing the parent how to help the child, keeping records, tutoring, monitoring student activities, scoring tests, or taking students on field trips.

The uses of media and of differentiated staff roles as described above are methods of dealing with the economic problem of processing increasing numbers of students in the face of inadequate numbers of trained instructors. But these measures say little about improving the quality of learning. Yet nothing in the research literature reviewed for this project (see Appendix A) nor any experience of the project's staff and consultants, contradicts the conclusion that the only known method of improving the quality of learning consists of defining a set of learning objectives, evaluating discrepancies between those objectives and the performance of the instructional products and procedures, and continually changing the instruction to minimize the discrepancy. This evaluation-revision concept assumes that no instructional system is perfect, but that progressive improvement can be expected from repeated use of evaluation and revision cycles. The evaluation-revision cycle is a built-in self-correcting mechanism for quality control of the educational system.

The foregoing paragraphs are brief reminders that today educational theory and practice are both in a state of turmoil. Media have been a focus of much of the discussion and of many innovative trials. For this reason, it has appeared of some urgency to devise--if possible--a laboratory approach toward making effective use of multi-media.

B. Some Working Definitions

An important assumption of this project has been that the key terms "multi-media" and "experimental laboratory" were not to be understood narrowly. For this reason, and since the study has strongly emphasized systems aspects (so that not just media devices but their total educational contexts have been considered), precise and limiting definitions have not been framed.

For the purposes of this report, the term multi-media includes primarily the newer devices for presenting audio and visual stimuli and for collecting and recording responses, especially in combined, complex, or expensive forms. Examples include television (whether broadcast, closed-circuit, or videotape), student response indicators, computer-assisted instruction, language laboratories, and audio-visual-textbook course packages. "Telemedia" include television, radio, telelecture, and instructional data-transfer applications. Some of these technologies have become relatively commonplace, but some exist primarily in experimental versions. The emphasis in this study has been on the newer instructional technologies--those which are making possible and are requiring (or will require) radical changes in the basic structure of the learning situation. For these devices, special methods such as are studied by this project are necessary.

The meaning of experimental laboratory has emerged during the study rather than being set down as pre-condition. The laboratory which is ultimately described and recommended as feasible and highly desirable is quite unlike what laboratories are conventionally assumed to be. It contains no workshops, equipment, computers, experimental subjects, or white-coated assistants. Instead, it is defined as having a program, a methodology, and resources for application to making major improvements in education.

It is clear that a number of laboratories for the study of particular aspects of multi-media problems already exist. In fact, virtually every university and each producer of components or software maintain some form of laboratory for research in their particular area of interest. But these laboratories have made little headway in defining effective roles for media.[1] A reorientation of thinking about the meaning of an experimental laboratory therefore seems necessary, even though not easy. Existing definitions, concepts, and experiments provide comfortable modes for safe progress. New ideas for laboratory design, among them "simulation" and applications of computer technology, force the researcher to demand answers to whole sets of questions not previously raised in the field of education.

The evaluation-revision concept referred to above forms the basis for the meaning of "laboratory" which emerges during this study. Such a laboratory must adopt a long-term programmatic approach and guard against the fractionation inherent in an unrelated series of small projects, which is the orientation that typifies the research activities of many centers today. It would also have to take into account such factors as the staff training problem, the logistics required to maintain and improve the educational system once it is implemented, the strategy required for changing the existing education system, and the provision of a built-in self-correcting mechanism to assure quality control after the novelty of the innovation wears off. It is of course important that the laboratory be user-oriented. If the teacher, the administrator, the parent, and the student in schools where new approaches are to be implemented have not been involved in the design stage of development, little hope can be held for a smooth transition from development to implementation.

This project makes no attempt to conclude that such a laboratory either should or should not be supported by federal funds[2], since this question presumes further progress into laboratory implementation planning than has yet been made. (See Section IV. H below.)

Underlying this projects' analysis of laboratory methods is a basic problem: new methods raise questions for which data adequate for the techniques are simply not available. A requirement therefore remains for explicating a methodology (or plan of attack) which permits an experimental design appropriate to the nature of the questions. For this purpose systems procedures hold great promise.

<u>Systems strategy</u> means many things to many people, although the systems approach is generally described as a defensible set of methods, techniques and intellectual tools used to study and improve the achievement of objectives in an organization. It should be emphasized that system

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[1] See, for example, 3, 11, 17, 22, 26, 37, 48, 52, 75, 81, 105, 109, 111, 120, 132. [Reference numbers throughout this report are keyed to the Bibliography, Appendix A.]

[2] For governmental roles in related fields see, for example, 3, 8, 9, 28, 31, 36, 38, 41, 47, 66, 90, 94, 95, 97, 100, 104, 106, 120, 122, 124, 125, and 135.

analysis is significant in that it leads to system design and thence to systematic operation. The systems strategy is helpful in isolating components and in relating organizational subsystems. It is an excellent tool; however, it is neither a panacea nor a guaranteed plan. Complex problems, such as those present in an educational environment, have a way of never being totally resolved.[1]

In this study, the systems approach began with a premise that the educational enterprise achieves its apparent objectives primarily through people, rather than through machines. Furthermore, the systems approach of industry must be modified if it is to serve school enterprises properly, since industrial organizations generally utilize rigid barometers to indicate degrees of success and failure--such as profit or loss statements, measurement of tangible products, and quality assurance standards--while school systems generally operate in the absence of such definable criteria. In business, functions can be tightly described and policy decisions can be enforced; moreover, competition and the discipline of the balance sheet provide elements of automatic correction. Basic to the entire concept of systems procedures when applied to the educational environment is a belief that if the systems concept is to be helpful to educators, it is important recognize that schools exist primarily for students.

As used here, the systems approach in education is an orderly method of attack or a planned strategy for identifying the complex processes through which an educational organization operates as it attempts to achieve its objectives, with a view toward studying specific subsystem interfaces, coordinating subsystem operation, and improving the overall educational program through system redesign. The approach is further characterized by close attention to the following:

- Objectives, Priorities. It is important that objectives, or trends, or values, can be or have been generally agreed upon. It is less important that such objectives, or trends, or values have been or can be clearly and unambiguously written down to everyone's complete satisfaction, since operational agreements are easier and more significant than agreements on phraseology. A priority system for implementation of objectives, trends, or values in terms of meaningful changes in students is important, and helps to clarify statements of objectives. Objectives must be realistically attainable.

[1]There is a growing body of literature on the use of systems in education. The following present good theoretical frameworks and descriptions of applications: 3, 5, 6, 10, 23, 25, 30, 31, 38, 62, 73, 82, 102, 106, 115, 117, 118, 128, 135.

- Information Flow, Accuracy of Feedback. Before clarity can be introduced into decision processes, the decision makers must have a defensible mechanism for gathering valid, reliable, and reasonably comprehensive data on needs, problems, resources, accomplishments, and so forth.

- Alternative Procedures, Interdisciplinary Approach. The analysis must always consider the broad spectrum of alternative procedures which could be utilized in achieving goals. This process presupposes that the components in an educational environment can best be assessed by a grouping of persons trained in several fields and representing all levels of system operation (students, teachers, administrators, and researchers, for example).

- Resource Allocation, Environmental Analysis. Analysis and design must identify environmental constraints and opportunities, then indicate optimal allocations of resources.

- Evaluation and Improvement. Operations must be regularly evaluated against objectives, with a view toward planning and implementing system improvements.

C. Project Methods

The system approach described above forms a background to the methodology of the present study; however, the study does not carry the method through to completion by actual implementation and evaluation of a system. The project's method has been exploratory, conceptual, and critical. No experiments have been undertaken, nor has a prototype laboratory been built and tested. Instead, expert opinions representing many disciplines and backgrounds have been sought out, both inside and outside of SDC. Written accounts of experiences and of research with multi-media have been examined. [See Appendix A.] Innovative installations have been visited. [See Appendix B.] Above all, progress in the multi-media "state-of-the-art" has been critically scrutinized from the point of view of the educational systems approach. The project's guiding themes have been first, to assess the extent to which media have been effectively used as resources within a real-world context to meet significant educational goals; and second, to define a methodology and an organization which could lead to using media as integral parts of a greatly improved system of education.

An exploration of the literature on laboratory research and on the implementation of educational innovation did not provide a satisfactory basis from which to raise the question of an experimental laboratory. For example, there are presently conflicting studies on achievement using instructional television, indicating both greater and lesser achievement. One may locate research studies to defend instructional television or refute its use. The extent to which educational technology, learning objectives, student needs and cost-effectiveness are related is unclear, since the various interfaces are seldom investigated. It proved necessary, therefore, to move ahead of the literature by exploring significant developments as they were occurring. From this view of technological projects, viewed in the context of the preceding description of systems procedures, it was assumed that some common processes of design and decision would arise. These kinds of information might then provide a foundation for developing the data base required by modern exploratory techniques. This process of analysis would also help free the thinking of the project staff and permit a fresh view of multi-media problems.

This process of exploration proved its worth in earlier SDC projects in education, notably with the Traveling Seminar for Educators [108], sponsored by the U. S. Office of Education. Based on this experience and on recent change process literature which suggests the importance of broad experiencing, the project staff selected a number of locations which appeared to offer significant insights concerning the multi-media design process [Appendix B]. These sites were visited, meetings were held with significant individuals, facilities were toured, and the effectiveness of the installation was related to the goals described for it. By moving the project staff to the installation it became possible to observe the system created by the people. It was felt that a conference or large group meeting would have disassociated the project's operation from its discussion. Conference reports and speeches do not always accurately reflect operational reality; only a close view of what is actually happening can produce the kind of analysis required to justify additional laboratory expenditures.

In much of this report, little reference is made to specific media such as programmed instruction, language laboratories, motion pictures, educational television, and computer assisted instruction. Reference to such labels implies that the critical factor in comparing media is the mode of stimulus presentation rather than the content of the displayed message and the manner in which the student's performance is analyzed and used to determine the sequence of instruction. The usual global comparisons (such as ETV versus Motion Pictures to answer categorical questions such as which display mode is better) are no longer considered useful or relevant to the task of developing instructional systems, and have too often masked the need for all instructional systems to contain capabilities for collecting, processing, and monitoring student performance data. In this report, media are usually discussed generically. Although the resulting text is at times abstract, wherever possible educational problems are used as examples to provide a tangible reference. In addition, Appendix B contains a number of concrete illustrations.

Finally, this project's method has been interdisciplinary and iterative. SDC specialists in educational systems, psychological research, laboratory design, and simulation techniques participated, either as project staff members or as project consultants. The ideas and conclusions presented have emerged out of a number of preliminary formulations. Monthly progress reports were submitted to the Bureau of Research, Office of Education, meetings were held, and an Interim Report was submitted for review and criticism prior to the preparation of this final report. However, it must not be assumed that unanimous agreement of all persons concerned was reached on all points. The report represents the professional judgment of the SDC project staff, not necessarily of all participants or of all reviewers of intermediate statements.

II. Background for Feasibility: Current Multi-Media Problems

This project's approach in all cases is that techniques should be subordinate to problems. Before determining the feasibility of an experimental laboratory and the techniques it would use, it is therefore first necessary to specify the types of problems which need to be addressed. Appendix B of this report contains descriptions of representative multi-media applications, with indications of problems encountered. The present chapter contains a more abstract account of problem areas. However, this discussion of problems is of necessity not entirely divorced from consideration of possible solutions. Problem analyses and solutions do not exist independently of each other, and there is little point in analyzing problems in separation from the actual or potential environments out of which resources and methods must be extracted in order for solutions to be possible.

A. Problem Locations

A convenient framework for presenting some currently existing multi-media problem areas is provided by the Guba-Clark model of the educational change process [99, 130]. The stages of educational development have been variously described, but the Guba-Clark model has the advantage of dividing the total process of research - innovation - implementation into convenient units for analysis. One way of determining the need for additional laboratory efforts would be to show that a significant step in the developmental process was being either omitted or given inadequate attention, and then to show how a laboratory could satisfy the requirements. The Guba-Clark model includes the following activities:

Major Phase	Activity	Purpose
Research	Research	To advance knowledge
Development	Gathering operational and planning data	To identify operational problems
Development	Inventing solutions to operating problems	To solve operational problems
Development	Engineering packages and programs for educational use	To operationalize solutions
Development	Testing and evaluating packages or programs	To assess the effectiveness and efficiency of the packages or programs
Diffusion	Informing target systems about packages or programs	To make potential adopters aware of the packages or programs

Major Phase	Activity	Purpose
Diffusion	Demonstrating the effectiveness of the packages or programs	To convince the adopter of the efficacy of the packages or programs
Diffusion	Training target systems in the use of the packages or programs	To develop a level of user competence with the packages or programs
Diffusion	Servicing and nurturing installed innovations	To complete the institutionalization of the innovation

The Guba-Clark model is, within limits, an adequate representation of the developmental process. However, the version outlined above should be supplemented by explicit recognition of the non-linearity of real change. Innovations need not, and very often do not, arise in the first instance out of research activities. Innovations may occur by chance, or may be invented in response to the existence of comparatively isolated and particular problems. Diffusion, modification, evaluation, and research then may or may not follow, in any order.

We are concerned only in part, however, with how educational changes in fact take place. Our purpose is to determine how educational changes ought to take place, in order to produce beneficial results most effectively and rapidly. For this purpose, the following diagram[1] of the process of developing a complex man-machine system (Figure 1) is a helpful supplement to the Guba-Clark model. It represents an expansion of the development segment of a controlled educational change process, indicating the critical nature of interactions and feedback among the elements of the process, and emphasing the necessity for planning, management, and evaluation during the entire developmental effort.

Research with educational media may, for example, suggest advantages to be derived from computer applications. It is a long distance, however, from such a suggestion to successful installation and operation in actual educational situations. As Figure 1 indicates, successive stages of planning, design, description, specification, and production must be embarked upon, with adequate attention given both to equipment (hardware) and to lesson materials and human procedures (software). All adjacent stages interact (that is, imply mutually induced modifications). And the final operational stage reacts back upon all previous stages, since actual operation provides the ultimate basis for evaluation and improvement.

[1] Adapted from SDC TM-864, "Software Design and Implementation," 1962.

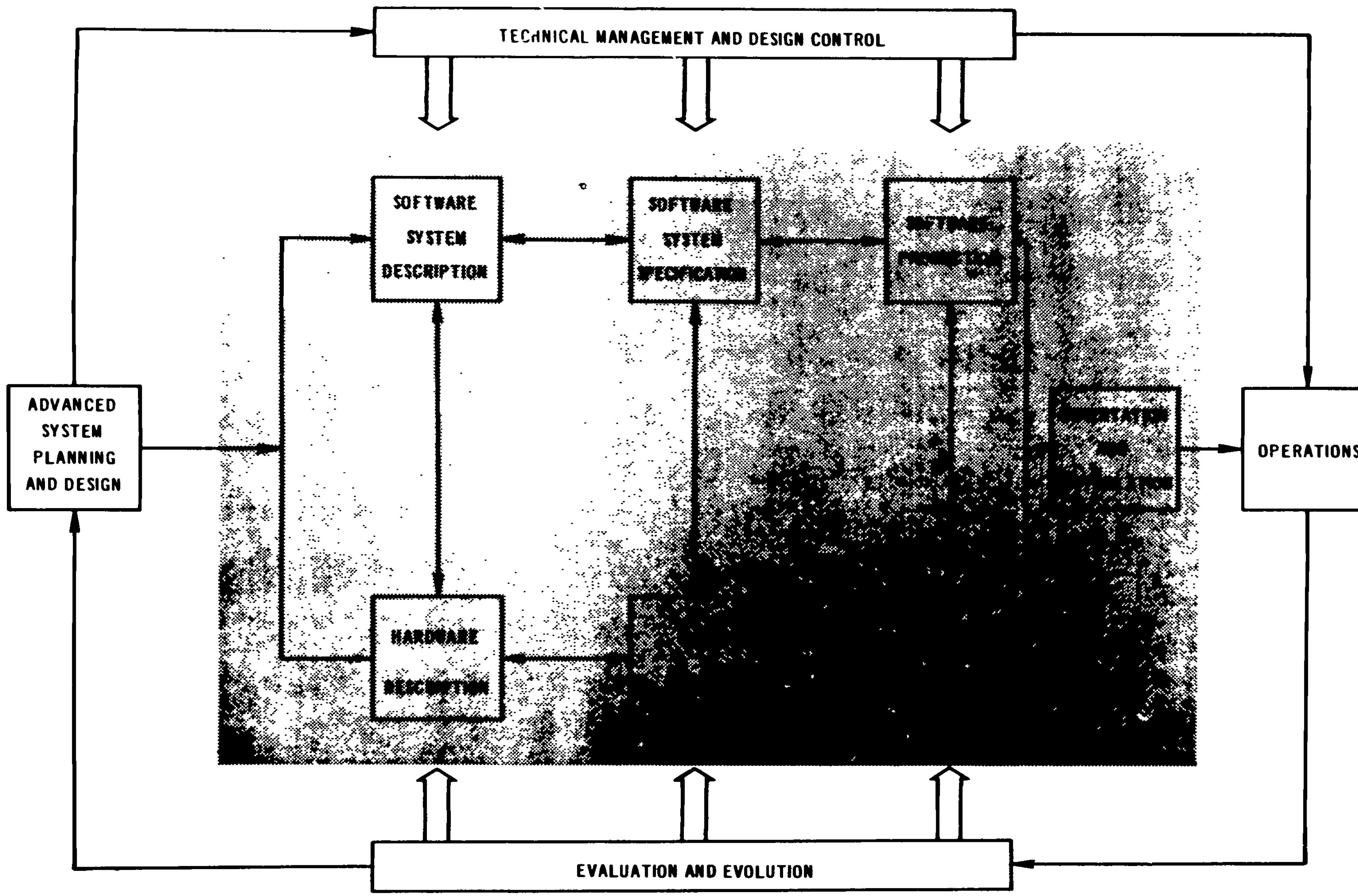

Figure 1. Schematic of Complex Man-Machine System Development Process

If education is thus regarded as a system, with media as one of its aspects or subsystems, it clearly follows that "multi-media problems" neither exist nor can be solved in isolation from the total system. In addition, the system's environment must also be fully considered, since the environment is the primary location of both system constraints and system resources. The environment includes both the explicit and the implicit political, economic, and social forces which impinge on the system. It causes system problems, and it can also provide problem solutions. For instance, suppose a program of training, emphasizing child growth and development, were provided for all expectant mothers. Such an alternative might produce greater results than similar expenditures for additional pre-schools, for nursery-level educational television, or for some other scheme. This essentially educational program, however, while affecting the K-12 input and thus the educational system, would require changes in areas beyond the limits of the ordinary school system, as well as adaptive changes within it.

In accordance with this point of view, "multi-media problems" should not be expected to be found in any single area marked out within a model of change or development. A laboratory to address these problems should not concern itself with research activities alone, or planning and design alone, or operation and evaluation alone. Each of these activities is one tool which can be used, along with the others, toward solving educational problems. None of them should be undertaken as an end in itself.

The remainder of this chapter reviews multi-media problem areas at a somewhat lower level of generality. (For specific examples, see Appendix B.) Current multi-media practices and research are briefly described, as a basis for identifying several critical needs which at present are very far from being met. The fundamental overall need (problem) is for systematic development, evaluation, and demonstration of multi-media uses in real situations for actual educational purposes. In comparison with what is required, present efforts are partial, sporadic, fragmented, and inconclusive.

B. Present Multi-Media Practices and Research

Multi-media as they are being used in schools and colleges are generally proving to be educationally ineffective. They are not accomplishing the educational objectives intended; they have not been found to be cost-effective; and they have raised a number of problems which were not anticipated. This condition persists despite the tremendous investment in mediated devices, the funding of considerable research, and the close analysis of a number of multi-media situations.[1]

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[1] There are innumerable analyses which lead to this conclusion, among the better ones: 5, 6, 13, 18, 20, 31, 37, 39, 40, 53, 55, 60, 69, 70, 71, 77, 79, 85, 99, 107, and 114. But see also the positive directions indicated by 120 and 137, among others. See also Appendix B, this report.

Multi-media have been used primarily to attack two problems which are especially relevant at the administrative rather than at the learning level. The first problem which multi-media were asked to solve was the presentation of material to a larger number of students than could be accomplished by a single teacher. This problem involved the reproduction, transmission, storage, and retrieval of information, usually in the same format as it would be presented by the live teacher. The second problem addressed by multi-media was the individualization of instruction through presentation of a controlled experience to a single student. Here the essential problems included the particular needs of the student and the adjustment of the learning experience to these needs.

In both of these applications, a number of essential questions were left unanswered. These concerned the appropriateness of the experiences provided, the relation of multi-media presentations to other activities in the learning environment, and their long-range effects on the pattern of education. The difficulty with these uses of multi-media stems from the fact that media were implemented within a system which was designed prior to their existence, and only very minor attention was devoted to the implications of their use for the rest of the system. While this difficulty may be expressed in terms of "too narrow a definition of the problem situation," other concerns are even more basic than this expression implies. The existence of multi-media (or any of the sophisticated media singly) makes possible the accomplishment of worthwhile educational goals otherwise not attainable, but the effective use of multi-media may require a complete reorganization of the present system of education. Multi-media and telemedia applications should be analyzed and planned within the context of potential radical changes in education.

While the application of technology to education, through the development of multi-media, telemedia, and other devices, may in the long run lead to a restructuring of American education, educators may still isolate significant uses of media in present educational environments.[1] The following uses, and the problems associated with them, represent basic areas of multi-media discussion within this report:

- Improving the relevance and rapidity of information transmission, storage, and retrieval.

- Improving the appropriateness of media for the communication of a message.

- The recording and immediately playing back of both audio and visual records of student behavior and/or teacher behavior for purposes of review, analysis, and control.

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[1]Actual and potential uses of multi-media resources are usually described in terms of fulfilling some function within the present environment. Good catalogs include for multi-media, 37, 53, 120; for computers, 17, 40, 49, 111; for television, 35, 87, 88, 96; for information system, 16, 15, 26, 117; in general, 19, 23, 31, 33, 94.

- Time saving and other operational efficiencies.

- Improving administrative procedures for the management of instruction, including the selection of appropriate learning tasks and immediate evaluation feedback, thus permitting individual adjustments in the processes of instruction.

- Overcoming the limitations of the native environment through the use of simulated environments and through the mediated presentation of other environments.

- Generating detailed analyses of the learning situation, forms of presentation, adjustments in the situation, and needs for information and redesign.

Considerable research in the multi-media field has concentrated on three important areas: tests of the effectiveness of media, tests of the superior effectiveness of one medium over another, and tests of the reactions of receivers to mediated messages [12]. This research either has had limited interest in the effects of environmental factors or has chosen to ignore them; as such, the research has not been generally applicable in useful ways to real learning situations in the schools. Other research efforts and studies have dealt separately with the support of media--physical facilities, light and noise levels, seating, and related concerns--in an attempt to improve the conditions in which media are used. Some attention has been devoted to administrative and management problems relating to multi-media implementation and use. A considerable and growing body of literature explores the nature of learning processes and interrelates multi-media, principles of learning, and the conceptual organization of subject matter. Although a tremendous amount of money and effort is being devoted to multi-media research, something seems to be missing. All of this research and development has failed to result in any major change either in the use of multi-media within the schools or in the tasks of education. This conclusion provokes two important questions. First, should major new efforts be undertaken in the development of larger technological systems, such as ITV, before something more is known of their values? Second, what kinds of activities are needed to discover these values and put them into effect?

C. Some Critical Needs for Analysis, Development, and Diffusion

In order to make fruitful use of the tremendous educational potential offered by new media, new kinds of investigation and development are needed. These range from conceptual analyses through test and evaluation to systematic installation and operation in actual schools. The following paragraphs discuss critical needs for new efforts.

1. Analysis of the Total Multi-Media Learning Situation. Extensive effort should be devoted to defining the elements of the multi-media learning situation and their significant interrelationships, since a fundamental weakness in present research efforts is the limited conceptualization of factors affecting media use. This situation can be improved only through deliberate efforts to analyze the environments

in which multi-media operate, to determine the significant factors within this environment, and to interrelate these factors in a total design schema. This statement suggests the application of various forms of modeling, simulation, gaming, and other modern techniques of research.

This consideration implies several other areas of concern which are basic to these analyses and which continue to remain enigmatic problems of education. Multi-media can be effective for the accomplishment of particular goals of learning, but the relation of these goals to the operation of the schools has so far defied analysis. The constraints imposed upon education by the nature of the institution, by the purposes of schooling other than for education, and by available funds and political energies will affect the multi-media environment. Analyses of learning situations, therefore, must include not only the immediate environment of the learner but also the myriad of forces which impinge upon the act of learning.

Research efforts, therefore, should be directed toward an understanding of the total learning situation and the interrelation of all the forces impinging upon it. Special encouragement should be given to the development of models and simulations of alternative learning conditions employing both mediated and non-mediated techniques.

2. Conceptualizing Education as a Man-Machine System. The majority of multi-media uses so far have been casual; that is, teachers have not really depended on media to perform specified functions within the classroom. If the movie projector fails to operate, for instance, the teacher presents the same information by the lecture method. In fact, it can be substantiated that a good deal of media usage arises from the desires of teachers to ease their tasks through using prepared material, "filling in" when a regular teacher is missing, or through serious but limited attempts at "enrichment." This last use implies that the media are at best something extra--not a natural part--of the learning environment.

A man-machine system implies the interrelationship and joint functioning of man and machine for the accomplishment of particular goals. Within the system, tasks are assigned to men and to machines, and each is held responsible for the achievement of its function. In those systems where this concept has been applied, certain tasks have been designated as appropriate for machines, while others have been reserved for men. As a total system develops, however, machines are designed to relate to men, and men are trained to operate and interact effectively with machines. Since both men and machines "fail" on occasion, back-up systems are designed to cover emergencies, but full operation is achieved only when men and machines are functioning properly.

The application of man-machine systems concepts to educational design and planning holds great promise. Indeed, such planning is requisite for the development of adequate mediated systems. Unfortunately, insufficient attention has been devoted to this area, in part because of exaggerated fears about the dehumanization of education by machines.[1] The planner attempting to employ such techniques is usually greeted with a barrage of ethical and moral quandaries concerning the nature of the individual, and, while these arguments are extremely signifiicant, they are usually presented in a form which impedes progress rather than suggests alternatives. The questions of appropriate functions for a man, or appropriate responsibilities for a machine, especially within an educational environment, are extremely real and extremely difficult, but their explication and resolution may be a necessary preliminary to the development of effective media systems.

3. Effects on Individual Learners. An increasing use of telemedia and multi-mediated learning modes can produce adverse effects on individual learners through preventing adequate and appropriate inter-group communication, teacher-student communication, or effective release of the creative potential. These conditions would be most in evidence as content and presentation are highly structured, even though this structure may include special considerations for individual learning styles.

There is little evidence to substantiate the loss of humanizing factors in situations which involve the use of multi-media or telemedia unless these uses were designed without adequate attention to the needs of the learner as a person. (As much can be said for non-mediated systems). The increasing sophistication of technological systems and the increasing dependence on technological components in the learning environment, however, require that deliberate attention be devoted to insuring that adequate opportunities for self expression, human interaction, and personal involvement be included in the total design.

Multi-media applications within classrooms and other learning environments should be examined from the standpoint of goals other than those connected with the presentation of learning of a formal body of knowledge. Areas of consideration should include:

- Enhancement of individual integrity and self-actualization.
- Effects on social values and interactions.
- Effective application of new knowledge within group situations.
- Development of appropriate life styles and roles including a high degree of flexibility.
- Development of initative in learning and self-direction in the selection of appropriate activities and tasks.

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[1] There is some indication that this situation may be improving, but planning has still not generally assumed a realistic attitude in this area. See references 46, 79, 85.

- Development of appropriate individual control and evaluation devices for the reception and integration of information.

Another critical issue raised by the development of learning systems, and by most multi-media efforts, concerns the degree to which the individual should be the creator of his learning situation rather than only the receiver of previously planned experiences. Throughout the ages, the classroom has been an arena for the presentation of information from a single source to multiple receivers. Any feedback which occurred was controlled by the single source of information, the teacher. Success was determined by criteria selected by the teacher as appropriate and respectable for the information being presented. While the progressive movement and the "discovery" and "problem solving" methods have produced some change, this pattern still remains dominant in the schools. Media can help to change this pattern if the significant element in classroom interaction is no longer simply the acquisition of information (or even the solution of specific problems), but too little attention has yet been devoted to explicating methods of using multi-media for active rather than passive learning.

4. Interactive Learning. Almost all present media uses have been based on traditional concepts of the teacher-learner relationship. It is unfortunate that there has been a consistent failure of multi-media (including telemedia) applications to increase the range of interactions within the learning situation. The assumption appears to continue that if material is presented more clearly, more intensely, in more dimensions, or more "kinesthetically," learning will increase. Every current example of multi-media use is based on the presenting of information from a single source (or group of mediated sources acting in concert) to one or a group of students. These students may or may not respond to the source. If they respond, they may do so individually or as a group, through a sophisticated technological system or by routine procedures. Within this context the material may have been organized quite expertly, and the latest developments in learning theory and psychology will be in evidence. In fact, some of the multi-media classrooms epitomize this style of learning.

However, little evidence exists of a change in the teacher's role as a result of mediated environments. Some teachers may revise their time schedules as a result of media, but the list of functions remains the same. No mediated classroom so far has made provision for the comfortable interaction of groups of students, or for direct student-to-student interaction within the context of the subject matter. Yet it appears that the true vitality of the new media rests on the ability to promote just such new and exciting modes of learning interaction both among individual students and other persons, and between the individual student and the technological system.

The great danger for telemedia and other forms of mediated instruction will be their failure to change the organization of learning processes. It appears clear, however, from the advanced literature, especially dealing with media experimentation in other areas, that important breakthroughs can be achieved. The new media are capable of increasing the range of interactions in the learning situation and of supplementing the traditional teacher-to-student-to-teacher classroom pattern. Research and development in this area should receive major support and encouragement.

5. Effects on School Organization. In the past, schools (like all institutions) have grown more in response to random pressures and opportunities than as a result of systematic planning, development, and improvement. Today, it is becoming possible for this state of affairs to change. It is true that theoretical dangers exist from over-planning and over-centralization of control of the schools. These dangers seem remote, however, as long as fundamental commitments to local control, to experimentation, to rigorous analysis and evaluation, and to competitive information exchange are preserved. The opposite dangers--of no planning, no systematic evaluation, and no coherent steps toward improvement--are much more likely and more threatening.

There is a clear and immediate necessity for American schools to be significantly improved. The new media can play a major role in this process. Questions about the shape and functions of the schools of the future become unavoidable. Even if schools as we know them do not some day cease to exist, they will surely undergo profound changes. Should these changes be unplanned?

For example, as telemedia networks develop, radical changes in the organization and operation of the schools will become advisable. Some areas of local decision may be transferred to central authority, simply because by their nature technological systems provide services beyond the needs of individual districts and, in turn, require resources beyond the local district. The organizational and political problems suggested by these statements indicate the need for development of implementation models describing predictable changes in control, new trends in the allocation of resources, and positive and negative socio-political factors.

Telemedia, and to some extent all mediated devices, require changes in learning spaces. The information function of education need not be limited to the classroom, and in fact reception of ITV in the home may be desirable under certain conditions. If this example is extended, the school as presently conceived loses its primary function, and its purposes and uses must be rethought. This concern is, admittedly, one of the distant future, but telemedia make possible the redesign not only of the school but of its support elements, its relationship with the home and other community institutions, and its relation to the total needs of the population it serves.

6. Allocation of Critical Resources. Decisions about the use of multi-media and telemedia technologies for education should be based on careful and continuing analysis of the comparative effectiveness of alternative allocations of available resources. These include not just the costs of media systems and their direct support, but implications for teacher time (in relation to costs of specific tasks and alternative staffing patterns), student time (including length of school day and year, early graduation, and alternative uses of time) institutional resources (maximum feasible use of buildings, library collections,

technologies, etc.), and other resources outside of the educational sphere but available to the community.

Models of resource allocation and conservation should be developed so that adequate information can be available for trade-off decisions. The new technologies may indeed make possible vast savings in student time, perhaps even the completion of twelve years of schooling in eight, but what will be the result of such a change in the economic and social patterns of the lives of youths? Other important trade-off areas are related to the costs of teacher preparation, procurement, and employment related to the use of technology to perform some teacher functions.

Education has been traditionally a labor-intensive industry, but the new technological breakthroughs indicate that this situation may change. Indeed, as the costs of providing adequate labor resources increase, pressure will be felt for the exploration of such changes. The literature of economics traces the effects on some industries of a change from labor-intensive to capital-intensive (and/or technologically oriented), but there is little such study in the field of education. This area should receive substantial consideration as sophisticated technological systems are developed.

7. <u>Real World Problems of Classroom Teachers</u>. For the foreseeable future, the effective use of media will continue to depend upon the classroom teacher and the support the classroom teacher receives within the building. The following areas are in need of particular attention:

Media Training for Teachers

Present teacher preparation programs offer only limited experiences for prospective teachers in the use of the new media, and in-service efforts do not keep pace with faculty needs. Several excellent models for such training have been developed and are in use, but the magnitude of the problem requires increased attention to the specific training requirements of teachers who will find themselves working with telemedia. A training segment should be an integral part of any media implementation plan. As well, efforts should be directed towards the development of on-site, self-teaching, mediated training programs for in-service use.

Criteria for the Selection and Use of Media

Models for the selection and use of media should be developed to guide classroom teachers in the effective use of multi-media under varying conditions. These models should include not only the description of appropriate content and presentation, but also some indications of the implications of their use, such as scheduling problems, space problems, etc. This information should be presented in such a way that teachers will be able to make reasonable decisions concerning the uses and advantages of the various media.

Resistance to the Use of Multi-Media and Telemedia

Teachers resist the use of multi-media and telemedia because of (1) generic fears of the unfamiliar, (2) problems related to procurement, operation, and classroom control, and (3) inadequate understanding of media functions and potentials. Attention should be directed towards understanding this resistance and towards building implementation models which realistically deal with it.

Multi-Media and Telemedia Materials

There is an extreme overproduction of low-grade material for use with media and a lack of adequate critical information to guide selection. This fact, coupled with distribution problems, causes many teachers to reject the use of media. Much of this difficulty can be traced to the management of media at the local school level, but some remains the responsibility of the producers and designers of packaged products. The production and distribution of superior materials should be encouraged and supported at both the development and implementation stages. In addition to ancillary materials, entire multi-media courses should be developed.

8. Evaluation and Demonstration. Virtually every conceivable form and combination of media use can be discovered somewhere within the United States. Some innovations have become popular and are replicated frequently, but others represent unique developments, usually in the research and early development stages. One difficulty with these early efforts at implementation results from the restricted funding which can support them. They are therefore limited in their effects, while only insufficient information is recorded about the problems of implementation and use. Later interested adapters cannot find adequate models upon which to base decisions about a media plan, and their developments must begin from scratch.

Present methods do not disseminate adequate information about experiences with mediated systems, and only infrequently can a school district determine what implementation problems will be faced if it chooses to implement a major technological innovation. A number of efforts, especially at the Federal level, have been initiated to obviate this difficulty, but they have been aimed only at pieces of the problem. What is required, it would appear, is the allocation of sufficient resources to the development and implementation of significant media innovations in representative school districts. These demonstration districts would be provided with the necessary resources to evaluate and record their experiences in mounting an innovation, and would continue as research and development centers for test and demonstration. Close ties with universities and production agencies would be required, and special considerations would be available for teachers and other personnel.

III. Feasibility of Alternative Simulation Laboratory Approaches to Multi-Media Problems

A. Types of Laboratories

The previous chapter indicates a great range of problems existing with respect to the effective use of educational media. The following six types of laboratories (or laboratory-like organizations) can be distinguished as being able to deal in various ways with these problems:

- Planning and Policy Institutes (studies and predictions of future needs; recommendations of goals and methods)

- Basic Research Laboratories (studies to discover and verify general principles)

- Component Development Laboratories (activities aimed at discovering, testing, perfecting, and demonstrating equipment, materials, and procedures in comparative isolation from their final intended environment)

- Simulation Laboratories (intermediate between component laboratories and laboratory schools; activities take place in quasi-total environments in which as many factors as possible are either actually present or represented by more or less realistic simulations)

- Laboratory Schools (activities aimed at discovering, testing, perfecting, and demonstrating equipment, materials, and procedures in actual educational situations; single classes, schools, or groups of schools)

- Comprehensive Development Laboratories (activities aimed at continuously planning, supervising, evaluating, and supporting systematic educational improvements; aspects of the five preceding laboratory types are coherently combined)

Of these six types of laboratories, at least three already exist and function more or less effectively. These are basic research laboratories, component development laboratories, and laboratory schools. In addition, educational planning and policy activities are fairly widespread. The two educational laboratory types which do not yet clearly exist, and which promise needed assistance in solving multi-media problems, are simulation laboratories and comprehensive development laboratories. The remainder of this chapter discusses the feasibility of simulation laboratories. The following chapter will consider the comprehensive development laboratory.

B. Simulation Laboratory Techniques and Purposes

Simulation is a general term meaning representation by analogy. There are three forms of simulation which can be conveniently distinguished. The first is physical, represented by flight simulations, in which a physical mock-up replaces a more expensive or less accessible original. The second form is symbolic, including verbal representations, drawings, and mathematical models. The third form of simulation is "digital," a general term for developments falling within the field of computerized simulation. Initial experimentation with digital simulation techniques raised considerable enthusiasm for their use in complicated research problems. Their success, however, has often been limited in relation to their costs.

Simulated objects and situations are used as substitutes for reality for a great variety of reasons. In all cases, however, the simulation must have some distinct advantage over reality, such as lower cost, greater controllability of variables or environment, convenience or possibility of accessibility and use, avoidance of danger to people or equipment, replicability, or ease of construction and operation. Sackman [118] distinguishes two forms of simulation, operations simulation and symbolic simulation. "By operations simulation is meant the simulation of operations in an information-processing system wherein people and computers are involved, and by symbolic simulation is meant the simulation of an information processing system through symbolic or digital representation of logical relationships, wherein real people are not involved but computers generally are involved." In either case simulation is basically "the representation of experimental objects, and the way the experiment is conducted to produce experimental results."

An effective simulation must portray an accurate description of the environment within a consistent degree of specification. Robert Fitzpatrick [44] lists these general classes of systems aspects which should be included:

1. Equipment components: These may be components in the usual sense, or they may be sub-systems, or even whole systems, so long as they consist only of "hardware."

2. Personnel: Included here are all individuals associated with the system, whether managers, operators or maintenance personnel. Also included are their job responsibilities organized as necessary according to tasks, shifts, etc. Not included is the organizational and social environment, as described in 3, below.

3. Organization: This category is intended to embrace both formal and informal organization of the work force, social status and interactions of individuals and groups, degree of isolation of individuals and groups, and communication procedures insofar as these are not specified in individual job descriptions.

4. Input data: Information, energy, and materials explicitly recognized as those which provide the necessary and sufficient basis, or "raw material," for system operation.

5. Output data: Information, energy, and materials explicitly recognized as those the system is designed to produce. Adequacy of the system is measured by the appropriateness, timeliness, accuracy, and comprehensiveness of the output data.

6. Systems procedures and processes: These are the rules by which the system operates, other than those specifying organization or job responsibilities of the personnel. Examples are computer programs, policies, and operating procedures.

7. Environment: Included here is everything not covered by the other items: the physical, political, economic, and other contexts in which the system is embedded, but which are not recognized as parts of the system.

Fitzpatrick expresses clearly the basic dilemma in the application of simulation techniques:

> "If simulation is completely representative so that perfect validity is obtained, the simulated system is just like the real system and hence equally difficult to control experimentally. Experimental control is best obtained when the number of operating variables is reduced sharply and each variable is defined narrowly, as in a laboratory experiment. The probable error of an estimate of a parameter resulting from a rigorous laboratory experiment is as low as possible. The relevance of the parameter to real life is often obscure, but the value of the parameter is precisely determined. This then, is the dilemma of simulation: High representativeness is thought to be required for high validity, so that whatever statements are made can be considered relevant to the real system. But high representativeness is achieved normally at the expense of control, so that the statements in that case tend to be approximations only. The basic problem in simulation is to compromise between the goals of validity and precision."

A discussion follows of the advantages of simulation techniques over "real-world" techniques, as well as of constraints on the uses of simulation, with particular reference to the various phases of the Guba-Clark educational change model. Each step on the model is discussed in terms of four aspects:

- Present types of real world activity

- Types of potential simulations

- Other research techniques

- Constraints on the use of simulation

Future Planning

Future planning involves the determination of needs, the description of alternative futures, and planning for changes in present institutional arrangements. Real world activities in this area are confined to observations, to somewhat impractical long views which are limited by the effect of operational environments, and by the impossibility of abstracting information for prediction. Simulations, therefore, are especially useful in this area, including the techniques of scenario writing, Delphi investigations, planning games, factor analyses (and predictions based on various combinations), computerized mathematical simulations, fictionalized predictions, and the analysis of alternative strategies.

The use of classical research techniques does not appear feasible for this type of activity. It should be recognized, though, that simulations are constrained by the present orientation toward the tradition of future planning, the present application of techniques, the lack of organized data bases for use in such planning, the absence of effective models, and failure to explicate alternative environments.

Research

The research potentialities of simulation techniques are covered at length in the later sections of this chapter. An additional research-related use of simulation is its application to research planning. "Real-life" activities of relevance include observations and analyses of "action research" for situational improvement, and evaluative studies of the adequacy of present research practices. Simulations would be useful in this area for the development of paradigms of needed research and predictions of costs and developments. Simulated models of alternative consequences of research expenditures and/or breakthroughs could be developed, along with scenarios of the implications of R&D on extant environments.

Classic research of all varieties has usually been used for narrow gauge examination and evaluation of the parts of research. The use of simulation would be constrained by the lack of statements of effects anticipated by research and the lack of a data base on R&D procedures in education. As well, there has been no determination of critical resources. Moreover, the continuing inability of education as an institution to modify its environment significantly suggests the need for re-evaluation of the goals of simulation.

Development (Invention and Engineering)

In this first sense of the word, development involves the inventing of solutions and the engineering of packages and programs. Present real world activities include invention and engineering limited to cut and fit in present situations, a fact which often warps the context by over-developing a single aspect (i.e., hardware ahead of software); or it may involve rearrangements of extant elements to achieve greater efficiency and reduce the need for invention. Simulations could perform a number of services in this area, including a prediction of needed inventions and alternative inventions, abstracts of the effects of invention on the real world, or needed reorganizing of the real world.

Classical research has provided for the testing of parts under carefully controlled conditions and analyses of relevant factors for simulations. Comparative and reductive analyses are valuable. Simulations, on the other hand, are constrained by a lack of sufficient information on the relevant factors in the real situation, a lack of sufficient exploration of some techniques which could be presently used, and failure to undertake predictive studies of needed inventions (partially because education relies too heavily on derivation from other fields).

Development (Testing and Evaluation)

In this second sense of the word, development involves the testing and evaluating of packages or programs. Present activi'ies include the use of the cut and fit method as constrained by the limits of the real-world, and the operation and assessment of experimental schools, still limited by a lack of predictive information and by building "from scratch" from plans developed earlier by simulated or classic methods. Simulations would be useful in this area of development for developing models of the total test environment for symbolic, prediction-yielding trials of alternative organizations of development. They could also be used to evaluate the effects of alternatives in simulated environments representing alternative real worlds.

Classical research studies in these areas have included factor studies and comparative studies, both of which are usually less valuable at this point. Simulations are constrained by the present lack of attention to models of educational realities and to creation of simulated environments.

Diffusion (Demonstration)

Diffusion includes informing and demonstrating, which in the real-world under present conditions would continue to reflect present strengths and weaknesses. Simulations could make effective contributions by reflecting specific situations, to include potential alterations in both situations and environments, indicating the feasibility of considering change. The implications of adaptions might be predicted over long periods of time. Scenarios, role playing, and Delphi techniques could elicit opinion and support for needed change. Portable walkthroughs and physical (operational) models could allow for try-outs.

Classical research presents only the possibility for the usual diffusion of its findings through the technical and professional literature. Simulation has been constrained in this area through a failure to think of alterations in the environments as an effective alternative to problem solution (through removing the problem by changing the environment).

Diffusion (Training)

Diffusion also includes training and upgrading, including the present real-world activities of seminars, institutes, and college programs. Simulations might aid these by the use of mock-ups, trainers, walk-throughs, role playing, scenarios, and computer heuristic and problem solving techniques which can provide for simulating the total educational environment, teacher behavior and reaction (interaction analysis), and practice in use and creative applications.

Classical research is not usually intended for active training, but simulation requires major development efforts to redesign attitudes about professional functions and the modes of training in education. This will take time and financial support.

Diffusion (Nurturing)

The third aspect of diffusion involves the servicing and nurturing of installed innovations. This is primarily a real world area to which neither research nor simulation can contribute uniquely, except by extensions of activities already described. Improvements, however, could be achieved through the uses of instructional management systems, predeveloped devices for "what if" predictions, and controls on the selection of experiences.

C. Experience with Simulation Laboratories for Education

Before continuing a general discussion of simulation laboratories and their uses, it is desirable to give a more concrete idea of simulation possibilities by referring to some actual examples. Appendix C of this report presents brief descriptions of a variety of actual simulations outside of the field of education, as a general background for the reader not familiar with applications of simulation techniques. The following paragraphs describe two applications of simulation laboratory techniques to education.

An example of a rather complex educational simulation effort was SDC's "automated classroom of the future". Designated CLASS--for Computer-Based Laboratory for Automated School Systems--this experimental operation was established within a general purpose simulation facility, the Systems Simulation Research Laboratory. It contained both a large computer and closed-circuit television; students' desks equipped with audio devices, film viewers, and response devices; special purpose teacher display equipment; and a computer-assisted counseling facility. Using students from local school districts, a research team investigated problems of programmed learning and automated assistance to education, with the long-range goal of developing more effective means of instructional support.

In the CLASS system, each student had a manually operated film viewer containing 2,000 frames of instructional material. In addition, he had a response device, linked to the computer, which indicated the sequence of slides to be seen by the student. This enabled the student to respond to questions and presented knowledge of results to the student in the form of a coded light. The computer maintained performance records for all students, supplying these records to the teacher, counselor, or administrator.

Provision was made for two teachers in CLASS. Each teacher had console facilities which made it possible for him to call up computer-generated displays showing the current progress of any student or group of students. Automatic alarm lights alerted the teacher to students who were performing unsuccessfully in any lesson. CLASS also permitted instruction through media such as television, films, slides, and conventional lecture and textbook methods, permitting instruction in either the individual or group mode.

A second educational application within the Systems Simulation Research Laboratory involved research activities designed to find new solutions for implementing instructional media through analysis and simulation of school organizations. The intent in general was to suggest new combinations of media and personnel that would accomplish the tasks of education more efficiently and more effectively. A systems analysis was undertaken of five high schools involved in the use of new educational techniques. This analysis formed the basis for designing the simulation models used. The simulation vehicle, essentially a detailed dynamic model of a real or proposed school organization, was designed to meet the following specifications:

- The capability of building dynamic models of real or proposed high schools.

- The capability of flexibly modifying models to represent different design configurations.

- Detailed recording of the events that take place during the simulation.

- The production of detailed output data that reflect the effects of various design changes within the model.

- The simulation of events occurring in relation to time.

The simulation vehicle was constructed so that any high school could be described in terms of school characteristics (resources, organization, procedures, and so forth) and of student characteristics that bear on the school's instructional plan--for example:

- The curriculum and its organization.

- The spatial arrangement of the instructional area.

- Resources such as programmed learning materials, teaching machines, equipment, teachers, counselors.

- Procedures for channeling students through the counseling system.

- Procedures for admitting and terminating students.

- Procedures for relating to exernal agencies directly concerned with helping students.

- Information-processing procedures.

- Characteristics of students that relate to instructional and counseling processes.

- Decision-making procedures.

Experiments undertaken in the area of school organization included:

- Analysis of a continuous progress course in algebra.

- Design and simulation of a school in which students schedule themselves under a continuous progress system.

- Studies of the information processing needs within schools.

- An analysis and simulation of an English course.

- The simulation of a flexible school.

> "The procedure followed in the development of the modeling study was to work back and forth between simulated data and data obtained from the real environment. In this manner, the model served the function of a theoretical model. It represented an explicit statement of the modelers' understanding of what takes place in the environment. The computer simulation technique both permits and encourages more detailed and dynamic explication of the experimenters' understanding...The real test of validity [occurs] when the experimenter can change the organization within the model and obtain predicted effects that later are substantiated by the same sequence of events in the real environment." [26]

These early experiments with the use of simulation for the study of educational problems were effective in providing new directions for educational research and planning. Most of the individual experiments undertaken, however, were limited in scope or in the number of variables included within the simulation. This deliberate simplification proved useful for projecting the consequences of changes in certain aspects of the system, but there continued to be a need for developing increasingly broad analyses. In addition, costs were exceedingly high. Even though the simulations took place in a laboratory also used for several other types of experiments, a great deal of expense was involved both in developing computer programs and special materials for the educational work, and in preparing for, conducting, and analyzing experimental sessions.

As a result of such experiences, with costs comparatively quite high and effectiveness rather low, enthusiasm for complex computer-based educational simulations has declined. It should not be concluded, however, that simulation techniques ought to be entirely abandoned. Instead, they should be examined more thoroughly to determine possibilities for reducing their costs and/or increasing their effectiveness. The discussion which follows is a contribution in this direction.

D. Simulation Laboratory Sub-Types

The range of possible physical laboratory facilities for the simulation efforts under consideration extends from conventional, manually operated facilities to the most advanced computer-based, time-shared center. This range can be characterized best by a brief description of four general types of facilities: manual, special purpose, and two types of computer-based laboratories -- dedicated and time-shared. SDC has had experience with and an opportunity to evaluate each of these four types of laboratory facility. Evaluation is offered in terms of costs, measurement potential, and adaptability.

1. Manual Laboratories. The simplest type of manual (that is, non-automated) facility consists of little more than rooms, furniture, paper, pencils, and people. From this rudimentary base refinements are introduced by subdividing rooms into subject booths, concealing observers with one-way glass, and augmenting data collection through the use of mechanical recording equipment--tape recorder, movie camera, TV tape, etc. In general, the manual laboratory consists of a collection of standard, off-the-shelf equipment primarily controlled and operated by people and configured to meet specific research goals.

Costs: The manual laboratory requires a relatively small initial investment. Its operational costs are also comparatively small, since production and implementation do not require large numbers of technical personnel. Maintenance efforts (restricted to repairs to CCTV, telephone systems, and standard recording equipment) are relatively low, although the services of skilled technicians may be frequently required. Aggregate costs will be far from negligible; it is only in comparison with other laboratory types that they are low.

Measurement potential: The measurement potential of the manual facility is, typically, both wide in range and crude in precision. It is wide in the sense that almost all types of data can be collected -- practically nothing is excluded by reason of instrumentation; or, conversely, some off-the-shelf instrumentation can be found for almost any data of interest. The resultant data tend, however, to be either unwieldy chronologies that require extensive data reduction, or focused measures that are too gross for fine-grain analysis. The inability to achieve the levels of measurement demanded by many lines of inquiry is clearly a disadvantage of the manual laboratory.

Adaptability: This type of facility is very adaptable and flexible, in that different kinds of research can be implemented without the need for extensive technical support. The adaptation of a research design into the laboratory setting can be comparatively rapid and easy, requiring only different sets of displays, different rules of operation, and different space and equipment configurations. Since displays and rule formulations do not have to be reflected into hardware or software, they can be produced or modified without great difficulty. Equipment, because it is standardized, presents few interface problems, thus lending itself to rapid reconfiguration.

2. Special Purpose Laboratories. Since the manual laboratory is confined, by definition, to off-the-shelf devices, its level of refinement is limited. Greater precision in investigation can be achieved by introducing special purpose equipment, and then the upper bound on refinement and sophistication will be essentially the practical one of capital investment. As the name "special purpose" implies, the equipment tends to be tailormade and project-specific. The limiting factor is that the utility of a given line of investigation must justify the expenditures necessary for it. Generally the special purpose laboratory is engineered and project-specific, with significant portions of control and operation committed to mechanical devices.

Costs: The initial investment for this type of facility varies greatly with the research purpose, but a general observation can be made about amortization: no matter whether it is a complicated mock-up of a complex system or special equipment for a simple two-choice experiment, most of the capital costs must be amortized in the life of a single project. Operational and maintenance costs will also vary with the complexity of the equipment; but, again generally, the specialized nature of the equipment will tend to require more technical support than standardized off-the-shelf devices. Production is largely mechanical, so production costs can be relatively small.

Measurement potential: The special purpose laboratory, as a departure from the manual type, is directly and primarily addressed to the problem of achieving more precise situations and means for their measurement; potential in this direction is, then, almost directly related to resources available for development. It is therefore difficult to make any but a relative assessment of measurement potential--almost any degree or type of measurement is possible if the costs can be justified. This principle clearly has a logical upper bound when the desired degree or type of measurement is beyond the technological and/or methodological state of the art. A practical upper bound is encountered when the measurement requirements can only be satisfied with equipment having the data processing capacities of a large scale computer; at this point the function of the laboratory is usually, though not always, reconceived as a general purpose, computer-based laboratory.

Adaptability: The greatest liability of a special purpose laboratory is, patently, its singleness of purpose, usually not just restricted to an area of study but to a specific line of inquiry. Adaptation to other investigations generally requires significant redesign and redevelopment effort.

3. Computer-based Laboratory: Dedicated Computer. The dedicated computer-based laboratory uses a digital computer, with associated general purpose input and output devices, to support research. The computer can sequence events to be presented, generate information to be displayed, format and display this information (usually on cathode ray tube display devices), accept responses from subjects, and record sequences of events and responses.

These general capacities are adapted to specific research needs through computer programming (software). The capacity of the computing equipment may be limiting, but more often the source of limitation resides with software. Generally the computer based laboratory is a complex of general purpose equipment which is capable of displaying and gathering information, but these capabilities must be applied to specific needs through extensive computer programming. The usual aim is for control and operation to be entirely automated, that is, to become a computer function.

Costs: The initial investment costs of the dedicated computer laboratory are relatively high. In addition to acquisition of the computation system (the computer and its complement of peripheral equipment--general storage devices, general input and output mechanisms), the "laboratory" components must be incorporated into the complex. Participant display and response devices usually require design and fabrication of special computer-to-subject interface equipment and a general laboratory operating system of computer programs must be developed. In all, the initial expenditures are high, but due to the general purpose nature of the system they can be amortized over all laboratory users. Production costs for a given study will involve additional computer programming. Variations within a line of inquiry can be handled by simple parameter or control settings, but the programming required for a newly formulated study will require additional man-months of work by experienced programmers and significant amounts of developmental computer time. Maintenance costs involve a computer maintenance contract, laboratory technicians, and system programming staff. Again, these costs are relatively high but can be amortized over all users. Operating costs--primarily the cost of the computer--run in the hundreds of dollars per hour. Such costs would be prohibitive without provision for substantial numbers of participants in a given run; with a multi-station laboratory the participant-hour costs begin to approach those of many special purpose and manual facilities.

Measurement potential: The measurement potential of a computer-based laboratory is generally unexcelled. Since the central processing unit is primarily designed for digital and symbolic manipulation, it can handle a wide range of data with great precision. The fact that data must be digitalized is not a significant limitation, since even though certain situations may require analogue devices for greatest simplicity and precision, digitalization is always possible. It is, however, in terms of range that the computer-based facility presents the greatest advantage. Of particular significance for behavioral investigation is the ability to handle language in written form--the ability to store, retrieve, and present texts--and, to a limited extent, to interact linguistically with participants.

Adaptability: Caution must be exercised in assessing the adaptability of a computer-based laboratory. Many factors seem to point to extreme flexibility and generality: the computer itself is general purpose in nature and the participant presentation and response devices are also usually general purpose, so that only the software need change from one study to the next. This characterization is accurate in the sense that two entirely different studies (say, an economic trade game and a programmed instruction study) can be run back-to-back with only the software changing (a process that is measured in minutes); but this is deceiving in the sense that one completely developed investigation program is being swapped for another. Adaptability must also be assessed in terms of development--the delay between the time a project is designed on paper and the time it becomes implemented in the laboratory. The period required for computer programming formulation, coding, debugging and check-out can be a deterrent to bringing studies into the laboratory. In this regard a computer-based laboratory shows no particular advantage over the special purpose laboratory.

4. <u>Computer-based Laboratory: Time-shared Computer</u>. The time-shared computer-based laboratory performs the functions described above almost as if it had a computer dedicated to it alone. However, it is only one user among many simultaneous users, thus sharing the operations, capacities and costs of a large-scale computer.

Costs: The initial, maintenance, and production costs for a time-sharing computer are comparable to those of a dedicated computer facility. Any difference would be in the direction of increased costs since time-sharing systems are more complex than dedicated types. It is, however, in the area of operating costs that a substantial saving is realized, since these costs are shared by all concurrent users of the computer. Overall, this economy is sufficient to make time-shared computer-based laboratory facilities generally competitive with special purpose and manual laboratories.

Measurement potential: Again the measurement considerations are roughly equivalent to those already discussed for a dedicated computer laboratory. With regard to timing precision there is some loss due to the fact that a time-sharing user does not have exclusive access to the control of the machine; therefore there can be no guarantee that the program will return to given user within a specified period of time. Studies with narrow tolerance in timing may be pre-empted from a time-shared laboratory.

Adaptability: Adaptability considerations are essentially the same as with a dedicated computer, since time-sharing characteristics do not as yet usually significantly facilitate interstudy turnaround or intra-study development effort. However, time-sharing has begun to make on-line, interactive, development increasingly possible. Eventually this could lead to a considerable increase in adaptability.

E. Computer-Based Laboratory Capabilities

The power and promise of the computer-based laboratory can be reviewed under the following five headings, which represent general dimensions of laboratory investigation: stimulus generation, response monitoring, response network, respondent role, and presentation/response range. These five aspects can be further subdivided as indicated below.

- Stimulus generation: definition of presentation content by program (system, experimental vehicle, instructional vehicle).

  Static: presentation content prescribed; generally not modified by participant interaction with program.

  Dynamic: presentation content determined in degree by participant interaction with program.

- Response monitoring: frequency with which participant (user, subject, student) responses need to be monitored by the program (system, experimental vehicle, instruction vehicle).

  Periodic: monitoring only at specified occasions.

  Sporadic: occasional but irregular monitoring--participant and/or program instigated.

  Continuous: uninterrupted monitoring.

- Response network: relationship between response sets of different participants.

  Single or Unison: parallelism in response sets; all participants always at same nexus in program.

  Temporally Independent: all participants traverse substantially the same paths in the program, but rates are individually determined.

  Content Independent: participants can traverse individually different paths in program.

  Interactive: participants (at least two) are potentially interdependent in evaluation of their response sets; group-produced phenomena are a special subclass of the interactive response network.

- Respondent role: relationship between the program (system, experimental vehicle, instruction vehicle) and the participant (user, subject, student) in terms of the participants' conscious control over program delineation.

Reactive: participant reacts to a prescribed program.

Directive: participant directs (at least in part) program development.

- Presentation/ response range: modes and type of presentation (situation, problem, stimulus) to participant and response (action, answer, response) from him.

Narrow: presentation and/or response prescribed and limited.

Wide: presentation and/or response open-ended, essentially controlled by participant.

Special: presentation and/or response not necessarily prescribed but circumscribed, usually by participant abilities or research content.

In order to anchor this framework with a concrete example, one of the better known multi-media approaches to education, computer-aided instruction (CAI), will be characterized in terms of the foregoing distinctions. The initial attraction to CAI was clearly based on the capacity for producing tutor-like characteristics of continuous response monitoring within a temporally independent response network. The deficiencies of the earliest and most rudimentary forms of CAI were, as clearly, in the areas of respondent role (the almost totally reactive aspects were considered limiting) and of presentation/response range (they were typically restricted to static, usually discursive, presentations and multichoice button responses). Developmental efforts in CAI since have largely been directed toward extending the response network to include content independence (branching and multi-subject content vehicles), toward making the respondent role more directive (permitting student definition of problem areas, providing assistance to the student at his initiative, etc.), and toward widening the presentation/response range (utilizing many audio-visual devices for presentation and incorporating--some with tolerance for insignificant error, ambiguity and synonymity--simply composed responses). It might also be noted that considerable work has been done with specialized presentation/response ranges especially as they are related to participant abilities; non-literate students have been accommodated with auditory and graphic presentations and with pointing and positioning responses through light pen and joy-stick devices. Finally, there has been some limited development in CAI of interactive response networks. Computerized versions of group problem solving tasks, simulations, and other pedagogical "games" would fall in this class.

While this characterization of CAI efforts has been primarily intended as a grounding example for the investigatory classification scheme, even such a cursory review is telling with regard to the differential contributions of hardware and software in determining research capabilities. With computerization as a given, an instruction program achieves continuous monitoring and (at least) a temporally independent response network nearly straightway, but further sophistications depend almost exclusively on software development. A possible exception appears to be related to the improvements in the presentation/response range; and while these may involve the incorporation of new hardware devices, software modifications are usually required for implementation and are always necessary for full utilization. In short, the definitive aspects of research capability in a computer context are largely related to software.

It should be noted that the foregoing discussion of CAI illustrates the computer in a dual role, namely both as an educational medium and as a laboratory tool. However, the illustrated dimensions of investigation are equally present in situations in which computers have only instrumental (not instructional) roles, as well as in manual laboratories where no computer is present. The following paragraphs summarize some of the more generic characteristics of the various types of simulation laboratory facilities, as related to the different dimensions of research.

Stimulus generation. Manual and special purpose laboratories can be adequate for the static type of stimulus generation. For the dynamic type of stimulus, however, manual and special purpose laboratories are severely limited; extensive pre-planning and considerable ingenuity are required for even a comparatively modest achievement. Computer-based laboratories have virtually unlimited stimulus generation capabilities, provided that enough money is available for necessary development effort.

Response monitoring. A manual laboratory is optimally cost-effective for periodic response monitoring; a time-shared computer for sporadic monitoring; a dedicated computer for continuous monitoring. A manual laboratory requires a high experimenter-to-participant ratio for continuous monitoring, and then encounters significant data-reduction problems. A special purpose laboratory can overcome many of these with sufficient investment in special equipment. Time-sharing makes continuous monitoring by computer impossible, but often an adequate approximation to continuity can be devised.

Response network. For a single or unison response mode, the manual and the special purpose laboratory can be adequate. For more complex networks, the manual laboratory will generally soon lose control, and more or less extensive special purpose equipment investments will be necessary. Computer-based laboratories can handle all types of response networks, although elaborate software development is likely to be required, especially in order to achieve the content-independent and the interaction capabilities.

Respondent role. For the directive mode, in which the participant partially directs program development, the manual laboratory is currently the most cost-effective, eliminating needs for extensive equipment or software development required by the other laboratories. For the mode in which the participant reacts to a prescribed program, the manual laboratory is generally the least satisfactory of the four types of laboratories.

Presentation/response range. For the narrow range, standard equipment and/or software is sufficient. For wide and special ranges, either the flexibility of the manual laboratory is required, or specialized equipment (special purpose laboratory) or specialized software adaptation of general purpose equipment (computer-based laboratory) must be provided.

From the foregoing paragraphs it is obvious that on the whole a time-shared, computer-based laboratory is the optimal single facility for the types of investigation being considered. For direct support of research studies its capabilities are nearly equivalent to those of a dedicated computerized laboratory, the major difference being with respect to the periodicity of stimulus generation and response monitoring. From the point of view of operational economy, the time-shared computer-based laboratory is clearly superior.

Beyond this general assessment the major comparison to be made between laboratory capabilities relates to their potentials for extending research in new directions. Such estimations are tenuous because they do not, and they cannot, take account of the ingenuity of the investigator. A clever and inventive researcher in the most rudimentary manual laboratory would probably be more productive than a plodding hack surrounded by the most sophisticated electronics. This critical unknown aside, it is possible to draw some very general conclusions about research potentials strictly from the characteristics of the physical facilities. With this provision one can say that certain research possibilities are virtually excluded by the limitations of a non-computerized laboratory.

A seemingly important class of studies in terms of educational import are those in which social interaction phenomena are central. To the extent that social skills and interpersonal behaviors intercept with the educational process, interaction studies are a viable area of investigation. Control and strict accounting of interpersonal interactions almost requires the power of computer control. Thus, if manipulation is an essential aspect of inquiry--a need, say, to insure that peripheral members would assume a position of centrality in a group task--this presupposes a degree of control that is best realized through computer mediation capabilities. By and large, interactive studies have been restricted to measurement (e.g., sociograms) or gross manipulation (e.g., Sherif and Lewin) because on-line controls and assessments are nearly impossible without computer assistance. Positive behavior modification in the interpersonal area generally requires closer control and observation than have heretofore been available; in this respect the computerized laboratory could open up an important new area both to training and research.

Comparable observations can be made with regard to investigations that have situational complexity as an essential of study design. One can conceive studies or instructional procedures, for instance, that are specifically designed to aid the participant by minimizing his own need to have otherwise requisite skills for a general task--a design, say, to exercise decision-making with minimal accompanying demands on immediate memory, or problem solving with little or no need for computation. In either case the technique for minimization might be to supply the participant with aids for those prerequisite but nonessential aspects of the general task. It is easy to see how this might be accomplished by putting electronic data processing capabilities at the respondent's command (the computer could handle retrieval or computation on request). In general, for complex simulations the advantages of computer administration are immediately obvious--data representing the environment can be maintained, updated and retrieved automatically or on demand; observational data gathering and recording can be placed under program control, and generally the computer can assume any of those functions that the investigators find to be obstructive to the purposes of their study. Once these obstacles are overcome new possibilities emerge. New sources of data can be tapped (e.g. continuous interviewing controlled and administered by the computer), new uses of simulation can be explored (e.g., a simulation history and a real history with the same origin can be run in parallel for pedagogical purposes), new techniques can be used (e.g., extrapolation and interpolation guidance can be offered to the participants). The possibilities are practically as boundless as the investigator's imagination, but they will not emerge as long as the investigator is nearly taxed to capacity with the mechanics of the simulation.

A computer-based laboratory presents another distinct advantage over noncomputerized facilities in that just by virtue of the computer's presence, it is possible to have adjunct support for evaluation. Physical presence bears relevantly on the case of coordination between the investigator and those developing and maintaining the data management programs. The closer the relationship between the researcher and the data analysis services, the greater the potential for developing tools that are of real use: productivity can be increased simply by housing both functions in the same facility.

Computer-based simulations offer a new approach to research which can be called "structured induction". The structured induction approach combines the merits of induction with the analytic merits of formal theoretical guidance; that is, it allows the researcher to recreate a practical concrete setting in the laboratory, and within these embedding conditions, to design decision situations that conform to a formally described decision model. This can be seen, for example, in a comparison of the evaluative tools required for data handling under the "classical" and the "structured" inductive approach.

In raw form the results of the classical inductive method are complete data records; the aim, of course, is to find descriptive generalizations that will account for the recorded particulars. At the simplest level the procedures are obvious--a straightforward test of whether all instances can be unexceptionally accounted for by a summary generalization; but positive results are rarely obtained at the simplest level. Beyond that there are two effective but difficult procedures for finding generalizations. One procedure simplifies the data by reconceptualizing them, so that otherwise diverse data are counted as comparable by virtue of an underlying commonality; the second procedure is to introduce complexity and contingency into the generalization, so that otherwise exceptional instances can be incorporated on the basis of explicit qualification, These are difficult procedures to support. Reconceptualizing data, even supposing the requisite formation of concept, entails the need to transform all pertinent instances. This type of data manipulation has not been generally developed; for the most part it has been left to the energies of the investigator and his assistants. The second procedure of introducing complexity into the generalization--which is entirely compatible with the procedure of simplifying reconception--presents sizeable practical difficulties without mechanized assistance. When the generalization reaches even modest degrees of complexity, it becomes virtually impossible to evaluate by hand. The only practical recourse then is to forego the inductive aims or ignore the exceptional cases.

In order to support the inductive method there is clearly a need to develop better evaluative tools. This is possible through a program of data management within the framework of structured, induction. There is a need for data analysis support beyond that which is provided by standard statistical evaluation. A basic statistical capability would be required in any event, but that can be obtained, with computer capability, almost for the asking. The additional need is to develop new evaluative tools especially to meet the needs of inductive analysis. At a minimum there is need to attend to two separate but complementary aspects of the problem: (1) to develop computer programs for the management and manipulation of data, (2) to develop means of computer assistance in the formulation phase of inductive analysis. The first would afford the researcher greater facility in handling the masses of data that he encounters; the second would provide him with inductive algorithms to aid him in finding relationships in his data. Some preliminary steps in both of these directions have already been undertaken; a brief description of each is given to underscore the possible lines of development.

Computer data management and manipulation. Data are being amassed in unprecedented amounts in both the public and private sectors of our society. This fact is related in an important way to the advent of electronic data processing. With an expanding society there would be simply a proportional rise in data growth, but with advanced data acquisition techniques there has been a significant increase in the amount of potentially accessible data.

The potential value of this vast increase of information is great--but too often this potential goes unused because the overwhelming abundance of data makes even the least complex approaches to organization, collation and assessment exceeding expensive and time-consuming.

Conventional approaches are of little assistance in inducing or discovering a fundamental order in such a body of data. Techniques such as factor analysis, for example, are only marginally effective, especially where assessment calls for dividing the data in different ways, omitting selected subclasses from comparisons, using different observed values in operational definitions, and repeatedly recombining, regrouping and recalculating to observe the effects of manipulation.

TRACE--Time-Shared Routines for Analysis, Classification, and Evaluation--is a computer-based system for assessing and structuring large, complex sets of data prior to subjecting them to statistical processing. TRACE was created in an attempt to solve these data analysis problems. The system assists the investigator by enabling him to explore, from a number of different or newly suggested points of view, the relationships that may prevail among complex sets of data. The investigator is in direct and essentially continuous contact with the computer via teletype and cathode ray tube display. He receives immediate feedback of the results of each computation or manipulation and so may modify his analyses as he proceeds. The end effect is an efficient interplay between the investigator's conjectural and judgmental skills and the computer's capacity for rapid and accurate data processing.

Computer-aided induction. Classical induction algorithms such as factor analysis, multiple regression, and early forms of cluster analysis have been employed successfully to reveal a limited class of structures for particular classes of data. Even contemporary forms of cluster analysis, as used for example in numerical taxonomy, are restricted either in the structure to which they can respond or in the type of data to which they apply, or in both respects. However, when the structure or pattern becomes less well defined and less well specified, man's experience, hunches, and intuitions often enable him to function where such algorithms fail to apply. In order to overcome the limitations and restrictions of pure machine-induction, we are seeking a workable interplay between the investigator's judgment about and knowledge of his data, and the data handling power of a time-shared computer. To this end a computer-induction program, IDEA, has been designed either to run on its own, or to interact with the investigator by (1) presenting him with the facts he requires to evaluate each major "decision" in the analysis, and then (2) accepting his concurrence or overriding judgment before continuing on to the next major decision. In addition to its "interactive mode", IDEA has two other distinguishing features: (a) heuristic computation procedures are used in those cases where the combinatorial aspects of the analysis would require extensive computation, and (b) different heuristics are used for different types of data, enabling IDEA to operate on a mixture of nominal (categorical), ordinal (ranked), and interval or ratio-scaled measurements.

In summary, the IDEA concept is concerned with the development of an interactive package of heuristic computer-induction programs. The resulting system should enable an investigator to explore his data base in search of any structure inherent in his data. In particular, the search is for those relations among his variables that best enable him to predict any variable of interest from a knowledge of the data on the other variables. It appears that such interplay between the investigator and his data holds promise for a more effective inductive analysis than either man or algorithm could produce alone.

F. Feasibility of a Computer-Based Multi-Media Simulation Laboratory

The potentialities of a simulation laboratory (in particular, one supported by a large-scale digital computer) for approaches to multi-media educational problems have been described above under several separate headings. These explorations can be brought together here by proposing a maximally-effective configuration for a laboratory, by presenting examples of projects which could be undertaken within this configuration, and finally by assessing such a laboratory's utility.

A semi-manual, computer-based laboratory is here proposed as a maximally-effective configuration for the types of laboratory functions heretofore discussed. From the foregoing discussions of types of simulation laboratory facilities, the most apparent conclusion to be drawn is that the greatest assets lie on either end of the continuum. On the one hand the manual laboratory is the most adaptable, with particular strength in low production costs and short implementation times; on the other hand the time-shared computer-based laboratory provides a wide range of measurement potential, sufficient degree of precision for all but a limited number of studies, and great efficiency in operating costs. The most promising laboratory facilities, then, would combine the best features of both.

The utility of a semi-manual, computer-based laboratory can not be fully understood apart from the process of developing a new line of investigation. Ideally, research can approach experimentation through successive stages of investigation--an idea, a paper-and-pencil version, perhaps a breadboard model, and finally full instrumentation--with each step affording an opportunity to refine the formulation and procedures. For simpler studies this approach works well; but for more complex studies, especially where the data handling capabilities of a computer are required even in part, the process tends to be foreshortened--the intermediate steps between initial broad conception and final implementation drop out. This occurs because the natural but unnecessary tendency is to conceive of the study as wholly computerized if computerized at all, and this conception carries an implicit commitment to a nearly complete programming formulation and specification of the research vehicle at the outset. The investigator must arm-chair the investigation without benefit of the concretized intermediate stages of development; but since most investigators are not well conversant with computer capabilities, this task is made all the more difficult. There is, in short, a frustrating problem of interface between the investigator and the laboratory programming. This problem is further complicated because preconception of a wholly computerized mode of operation entails a commitment to the limitations of electronic data processing, and some of these, ironically, present little or no problem for human judgment. This point can be generally illustrated with any study permitting freely composed responses from the participant--say, an instruction program employing recall test modes. It is extremely difficult to program around the problems of recognizing correct but not exact answers (misspelling, synonymity, ambiguity, etc.), since computers evaluate by absolute matching. The problem is not insurmountable, but is an inordinately difficult obstacle in the developmental phase of the investigation since the matter of inexactness would presumably be only incidental to the main line of inquiry. This problem can be temporarily if not permanently circumvented by simply looping the response through a nexus of human judgment in the system; but this expedient, simple in concept and execution, is usually bypassed because of the overriding commitment to complete computer implementation. This problem is not isolated or unique. Since electronic data processing has no tolerance for the sorts of inexactness that humans find not only tolerable but highly functional and, within limits, adequate to their purposes, investigators are often chagrined to find that direct and complete computer handling of even modest studies would incidentally entail full understanding of fundamental cognitive processes. This, of course, leads to compromise, distraction, or withdrawal. In any event the computer that is optimal for certain aspects of the investigation becomes unduly obstructive in other respects.

The reconception of the computer-based laboratory as a manual type of facility with special information handling characteristics permits the user to redefine the process of investigation development from an armchair procedure to one of successive approximation toward the final product--looking for the best mix of computer and human processing and controls. In effect, this procedure allows the researcher, by essentially simulating his investigation, to interact directly with the laboratory vehicle almost from the outset of its development.

All of this presupposes a general program that will permit quick entry into the laboratory; such a program would represent an all-channel, computer-mediated network with one or more of the positions assigned to experimenters. Communication paths could be closed by parameter settings to produce the operational network desired; initially all but information presentation and data gathering functions would be manually controlled; those functions that prove to be too difficult for humans to fulfill can be assigned to the computer until, in the judgment of the investigator, an optimal mix has been achieved.

This developmental procedure would be applicable to all types and levels of investigation but its greatest utility would be realized with studies of moderate to great complexity (simulations, complex games or multi-condition experiments) where, without the intermediate steps of development and freedom from commitment to an all-computer vehicle, research aims tend to become obscured in the process of implementation.

The activities of a laboratory constructed along the foregoing lines can be illustrated by hypothetical examples of studies for which the laboratory would be appropriate. The hypothetical studies described below are drawn from five sample problem areas: education of the handicapped (blind students), education in the sciences (fostering inquiry skills), education of the culturally disadvantaged, means of extending teacher effectiveness, and communications/decision-making in international relations. Each example is designed to illustrate a more general point, namely, that extended research facilities will open up new techniques of investigation and training--not necessarily in the specific ways embodied by these example studies but, as these studies illustrate, by enabling the researcher to range beyond current methods. Generally, then, these examples can all be characterized as investigations requiring a degree of control and manipulation of complex and/or social processes that would make optimum use, in a self-contained laboratory setting, of the semi-manual computer-based facilities described above.

1. Education of the Handicapped. The blind student represents an especially difficult problem for educational institutions because his most pronounced and debilitating deficiency is in the area of social skills. In this respect, the blind student and the deaf student show quite different patterns of development. The deaf are often mistakely characterized as mentally deficient since auditory experiences appear to be especially critical to early stages of intellectual development. Blind children, on the other hand show (with the proper adjustments in methods of assessment, of course) the normal range of intellectual skills. Given the proper techniques for overcoming the obvious handicap in reading, schools have been able to effect a near parity in intellectual opportunity for the blind student; this, coupled with more intensified attention and a compensating freedom from visual distractors, has sometimes produced even better than normal intellectual development. The problems for the blind are not primarily in the intellectual areas but rather in the social. Once they overcome the problem of reading, they are intellectually restricted only by the availability of Braille materials; but there is not comparable assistance in areas of social interaction. Ironically they can more easily learn to relate to books than to people.

In at least two respects a computer-based laboratory might prove effective in dealing with this situation. First, in a computer-based laboratory with isolated participant stations, it is possible to create social interaction situations that have no face-to-face relationships. Whereas investigators normally employ such situations as control devices, it is apparent that these conditions are the blind child's standard social milieu. It is thus speculated that one could create a "natural" social context for the non-sighted person which would seem to be basic in any attempt to develop something like Braille techniques applicable to social skills. Secondly, the problem of communication for the blind in such a setting is well within the capabilities of the computer, since translation to paper tape output in Braille form (as opposed to visually reproduced material) has already been accomplished--computer generated Braille is already within the current state-of-the-art. Thus, a computer based laboratory presents possibilities for social skill training of the blind that are particularly appropriate--in terms of context, control and capabilities--to one of the most crucial problems in education of those with visual handicaps.

2. Education in the Sciences. Science education, particularly at the secondary education level, has been greatly augmented and refined under the encouragement provided by NDEA programs. One of the major thrusts in this development has been directed toward the processes of inquiry in contrast to conclusions, toward method in

contrast to content. This is a particularly difficult area for instruction, not only because we know less about the process of discovery than we know about discoveries that have already been made, but also the because instruction task itself, to be effective, must be dynamic, so that it is difficult to manage on even a moderately large scale. By definition, inquiry training requires a responsive environment; but by using nature as the environment, the instructor relinquishes much in terms of control and assessment in the situation. Especially critical is the fact that the student, already familiar with the environment, may through his prior knowledge, pre-empt the inquiry learning experience.

All of these considerations seem to point in one direction of simulation--toward a situation involving a responsive environment that is content-free and yet under the instructor's immediate surveillance and control. This type of environment can be created in a computer-based laboratory. A different world can be represented internally in computer programs; it can be responsive to trial and error, to hypothesis testing, and even, where appropriate, to theory building; overt inquiries can all be recorded for subsequent assessment and analysis, and generalized aids to inquiry (guidance procedures) could be offered if desired. Along with this versatility it would be a large scale teaching device. The creation of such an inquiry vehicle would be a difficult undertaking; but even if one had such a model in hand, its dynamic, responsive and complex nature would preclude its being managed in any setting other than one that is computer supported.

3. Education of the Culturally Disadvantaged. The special educational needs of the culturally disadvantaged child are matters of increasing concern for the school system. There is a growing awareness that remediation--even the best sort of remediation in the usual sense--is not sufficient, because it presupposes more rudimentary skills that have heretofore been taken for granted. Thus, many reading difficulties are now seen as being antedated by lack of exposure to the most basic communication experiences (e.g. not having heard many of the words that comprise the listening and/or speaking vocabulary of most middle class children). In many regards, then, the educational programs for the culturally disadvantaged can be characterized as explicitly adapting to the absence of experiences that were implicitly assumed by standard educational practices. Where these experiences are simple, the means of basic remediation can be direct--either basic communication experiences can be provided by direct exposure to something not unlike the everyday environment of a middle class home, or reading instruction can be provided in the children's own language (instead of in the foreign middle class language). But where the experiences are more complex (e.g. deferred reward experiences, social efficacy experiences, etc.) the same sort of direct approach does not seem practical.

Where the direct approach is not practical, the most promising indirect, but still concrete and personalized, experience would seem to lie in simulation. If it is not practical to make the disadvantaged child's father a status figure in the community for the child's educational benefit, it is nonetheless possible to have the child himself seriously play the social and economic "games" of the dominant culture. It would be possible to give the child employment experiences while he still has room educationally to benefit from the preview; it would be possible to reverse the roles (so that he would be interviewing himself) to better appreciate the employer's concerns and requirements; generally, in fact, it would be possible to give him a range of posteducational experiences to which he could relate his educational progress. But in all this it would be especially important to be able to manipulate and closely control the simulation in order to preclude a reversion to more familiar and comfortable modes of response; in other words, a "free-floating" simulation game would not be as effective as one in which the behavior was bounded and directed toward specific objectives. The degree of manipulation required for this sort of "structured" experience would require a type of logical control available only with very sophisticated laboratory resources.

4. Means of Extending Teacher Effectiveness. The need to extend teacher effectiveness stems from two sources. One is circumstantial--the shortage of qualified personnel and their cost of employment means that the available teacher's efforts will be dispersed among more students; the other is categorical--quality of instruction is always open to improvement under any circumstance, especially in light of constantly improving technology and understanding of the learning process. Those who approach the teacher effectiveness problem from a research perspective are generally prescriptive in their orientation--the results of design, testing and evaluation are passed on as implicit or explicit recommendations for practice. In the multi-media context this means testing the relative effectiveness of new methods using recent advances in technology, and then handing them over to the educational system as a package for implementation. (The implicit assumption of this orientation is that the demonstrated superiority of the multi-media context will be the primary motivating factor for the system's adopting a multi-media approach). A contrasting orientation to the problem is the "enabling" approach, where the intent is to make the technology itself directly available to the practitioner's use. This contrast is evidenced in the most recent developments in the audio-visual field; many institutions now provide instructional aid centers where the emphasis is on constructing one's own aids rather than selecting from a library of pre-packaged aids. An analogous emphasis with regard to computer supported instruction would have implications for an approach to the problem of extending teacher effectiveness.

Looking at the computer-based laboratory as a prototype of future classroom facilities, one might explore in a direct manner the question of how to enable practitioners to exploit this potential to their own designs. The laboratory in this type of investigation would become the major independent variable in a meta-research design and hence an indispensable factor in this approach to extending the effectiveness of instruction.

5. Communications/Decision-Making in International Relationships. Research into decision-making serves well to illustrate the structured induction approach within the context of this project. This is true

both because decision-making is a critical process which pervades the educational experiences of students, teachers, and administrators, and because the study of decision-making illustrates many of the subtleties and complexities appropriate to laboratory simulation.

Classical theories have required the decision-maker to have complete and accurate knowledge about the consequences of all decision alternatives--a distinctly unrealistic assumption. Some recent decision theories formally take uncertainty into account and relax several other assumptions, but their mathematical rigor still requires rather stringent assumptions about the decision-maker; for example, that the decision maker 1) never overlooks a message, 2) extracts from a message all the information it bears, 3) names things properly and at the appropriate times, 4) forgets nothing, 5) stores and recalls information without distorting it, and 6) never acts on preset rules but always on the basis of the assessed consequences of a choice which best realizes the chances of achieving his goals. Such assumptions are also clearly unrealistic when applied to mortal man in practical situations. Thus, none of the existing mathematical theories seems to offer a suitable model of communication-decision situations which could be applied to the real world.

Most experimental studies of decision-making also suffer from oversimplification, for the sake of experimental rigor, to the point where they too have little connection with real life decision-phenomena. Furthermore, the traditional inductive approach, based on memories of actors in the situation, on naturalistic observations, on historical case studies, and so forth, is also of limited scientific value.

Simulation, at its best, offers the researcher a chance to admit selected elements of reality into the laboratory, where they may be controlled and measured without the time-consuming frustrations produced by the unpredictable variability of the real world outside. In short, the simulation laboratory allows the researcher to combine merits of induction with the analytic merits of formal theoretical guidance. It allows the researcher to recreate a practical concrete setting in the laboratory, and within these embedding conditions, to design decision situations that conform to a formally described decision model.

There is some modern theory which can help, such as the formulations of March and Simon. Here the concept of "rational man" is shifted to that of "limited rational man", who attempts to find not the best alternative, but simply one which is "good enough" for his purposes. A distinction is made between decisions made by rule-following and decision situations proper--where the evaluations of alternatives are many, complex, and not easily summarized; where relative merits seemingly shift unpredictably with unique configurations of the environment; or where no available alternative clearly and uniquely leads to desired goals. The latter cannot be delineated by specific rules, since even if rule-following routines could be enumerated, books the size of telephone directories would be needed to list the rules for all conceivable combinations of circumstances.

Another shift toward realism is reflected in viewing the communication decision process as the full span of activity, from detection of the decision situation, through the act of choosing, and post-decision behavior. This shift in emphasis brings into focus the entire process of search and evaluation which leads to choice.

With the use of a computer-based laboratory, each decision situation, the subjects' perception of the situation, the consequences noted, the alternatives omitted and considered, the evaluations made of these, his search, and finally his choices can be coded. These coded perceptions and interactions can then be time-ordered, and matched or contrasted with real life situations or with designed situations. Basic predictions derived from theory attempting to explain these situations can be checked, and new hypotheses can be generated.

This approach cannot be called rigorous hypothesis testing at this stage, since the data are soft. So long as we retain the conditions of complexity and reality, where the kinds and degrees of control which can be imposed are limited, this will be the case. Nevertheless, this ability to break through the rigid limitations of traditional approaches is invaluable in providing fresh insights and a new order of analytical data.

Laboratory games (simulations) focusing on communication and decision making have in recent years been conducted for purposes of both education and content research. (Nations are represented by teams of students who act out the roles of decision-makers; they must make a number of decisions affecting their nation's interest in both domestic and foreign affairs.)

For education, the aim is to give students an appreciation--a feel--for the complex and subtle dynamics which operate the real world, which could not be conveyed through conventional teaching methods.

Research use has tended to focus on one of two types of content: policy research--to study particular situations; and basic theory, intended to develop explanations for real-life behavior phenomena. For example, What kinds of communications do decision makers use in crisis situations: Under what conditions are threat communications perceived? How is the use of communications related to individual personality characteristics?

Most of these simulation efforts have used manual laboratories consisting of partitioned rooms, chairs, tables, paper forms, means of passing written messages among teams (runners), and on-the-scene observers. Accordingly they have suffered fundamental limitations, many of which can be overcome with the computer-based laboratory concept noted below. For example, a recent large-scale educational simulation, not untypical, has been criticized on the basis that it was the manual mechanics of the game, rather than the realistic communication decision process that claimed players' attention and determined outcomes (leading to the charge that perhaps the wrong things were being learned).

In exploring theory content, this type of simulation attempts to abstract critical system variables from real life, (based on hypotheses and conjectures appearing in standard textbooks) and to model their interactions. It emphasizes operational definitions and, where possible, the quantification of variables and the systematic recording of data. Replication of runs is used to demonstrate the stability of results obtained. These simulations have been criticized on a number of well-founded grounds, such as the questionable significance of the system variables selected and the representation of their relationships; the omission of critical situational factors that operate in the real world; the use of naive, inexperienced players, driven perhaps by inappropriate motivation; the grossly unrealistic manipulation of simulated events for experimental purposes.

Policy-research games attempt to avoid such pitfalls. Rather than being general, they tend to be intensive single-case studies of likely situations close to reality and involving real countries, as perceived by experts. Policy-oriented games typically use realistic political-military-geographical settings; they use seasoned political experts as decision makers; they give attention to a wide range of relevant historical and current events; they use realistic action scenarios--the product of expert judgment--to guide the game; they require players to prepare national-position papers, which are reviewed by a control team of experts, who also manipulate the game in a way judged to be realistic for the simulated situation.

Because the policy-oriented researcher is less concerned with testing theory than with gaining an understanding of decision making processes in particular situations, and he does not typically attempt to subject his detailed data to systematic recording and analysis. Data implicit in the player's position papers, the umpiring decisions, the player's values, perceptions, motivations, etc., in conjunction with given moves and the progress of the game, are not objectively assessed; the methodologies are typically unevaluated.

In summary, these simulations appear to suffer from fundamental limitations that appear critical for their further development and validity for education and research. Neither type of approval produces sufficient explicit data to allow a detailed micro-analysis of ongoing behavior processes that may be essential for understanding the step-by-step development of events, the predicted molar relationships, and the final results. What is not fully acknowledged is that when a simulation game reaches a certain point of complexity, it is no longer feasible to attempt to demonstrate patterns of cause and effect exclusively by extensive replications of runs. This is true not only because of the prohibitively high costs of replication, but because of the sizable interrun variability that may be anticipated for even the most carefully executed and controlled complex game.

To combine the assets of these different approaches requires a reformulation of the data collection and analysis problem. Even where extensive replication by itself is a feasible alternative to establish reliability and validity of results, it appears necessary to augment the data collected in the standard simulation experiment by embedding it in an extensive matrix of fine-grain observations. Simpler experiments have demonstrated that these details of response permit a more adequate reconstruction of the perceptions and attitudes as well as the responses of the participants, and the interplay of these as they unfold in the sequential interactions of events and responses to events.[1] These systematically sampled data points allow us to map the micro-processes and to demonstrate patterns that underlie the predicted and unpredicted molar relationships. To record all these phenomena, and to afford experimenter control over them, requires a capability for on-line recording and evaluation that only the computer-based laboratory is capable of realizing.

Three distinct uses are made of the computer in this type of simulation:

a. Computer-administered experiment. The laboratory configuration consists of rooms or cubicles which isolate groups of decision makers from each other. These groups communicate with each other through teletypes, linked through a computer: the computer acts as an experimental tool for on-line presentation of the situations to the subjects, which may be controlled at the discretion of the experimenter through preprogrammed actions or on-line manipulations. Each group sends its messages, bids, threats, offers, via the interactive console to another group which receives it on its own console display surface. All such actions are routed through the computer. In this way, the computer programs can administer the experiment--umpiring the legality of moves, providing displays of game-relevant information, and recording all moves, messages, and times.

b. Computer-controlled, in-play questioning, to augment multiple inquiry data. The answers to many questions on communication-decision behavior can be found in the detailed process data of moves and countermoves and in the in-play subject reports that reveal how communicators shift their evaluations, alter their goals, and attempt to induce changes in those they are communicating with. A complete analysis decision behavior requires not only data on the overt pattern and sequence of verbal exchanges, but also requires a parallel assessment of the communicator's intentions, expectations, and perceptions of relative status of those he is dealing with. Data are also needed on the temporal unfolding of communications and on associated shifts in player perception that indicate what the communicator intends to do, believes he is doing, plans to do--and why.

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[1] Shure, G. H., Meeker, R. J., Moore, W. H., Jr., and Kelley, H.H. Computer studies of bargaining behavior: The role of threat in bargaining. SDC document SP-2196. February 9, 1966.

In addition to administering the experiment, the computer is programmed to aid in the assessment of game moves by collecting associated subjective data at critical points during the bargaining process itself. Between game messages and moves or between trials, the computer, through displayed questions, can ask the subject to rate or rank various bases of his actions, his current intentions and expectations, his perception of his opponent, or, through subtle or disguised items, it can indirectly elicit the subject's attitudes about the bargaining situation. Thus, an important type of behavioral data that is otherwise practically unobtainable is gathered, together with the more detailed process data. This enables the investigator to identify and pinpoint the dynamics of the communication process both at the individual level (the reasons and motivations behind certain actions) and at the interpersonal level (action-reaction effects).

c. Data management and analysis. If computer experiments of the kind described are conducted "on-line", the amount of data the system is capable of collecting can become impossibly large. When these data are hierarchical, sequence-ordered, and of variable length, the problem of data management becomes overwhelming, particularly that aspect of it that attempts to identify and classify configurations of moves and to map stage-by-stage changes in patterns of use. For the collected data to be of maximal inductive value, advanced techniques must be used to cope with problems of data scanning, reduction, and analysis.

The foregoing pages have proposed a maximally-effective computer-based simulation laboratory and have presented illustrations of types of projects related to multi-media problems which it could support. The question remains, then, as to whether such a laboratory is feasible and useful.

In the restricted sense of technical feasibility, a computer-based simulation laboratory for studying multi-media problems is indeed feasible. One could be constructed and operated on the basis of existing technology. A more important question, however, concerns the value or cost-effectiveness of such a laboratory. Taking this broader point of view--which can be referred to as "cost-effectiveness feasibility"--there are very serious doubts implied by the foregoing discussions as to whether this type of laboratory should be recommended.

As Chapter II made evident, current multi-media problems will not be solved merely be developing new techniques to facilitate investigation, in the sense of finding ways of doing traditional studies with greater finesse. Moreover, even going beyond a simple linear extension of current research methods and thus attaining a more comprehensive concept of research would still be far from enough. The enormous technical apparatus of a computer-based simulation laboratory is not what is needed in order to review, analyze, evaluate, and generate alternatives to current multi-media practices and the assumptions and institutions in which they are embedded. Obvious problems exist, and alternative solutions are already being proposed and--to a limited extent--tried out. But even the optimum simulation laboratory described above could do little by itself to define and implement solutions to multi-media problems. Additional basic research, it may be assumed, will always be required. But today there is no specific evidence that the great educational problems are awaiting further research results before they can be solved. The difficulties which seem critical today are those of putting into effect what we already know--of making educational goals explicit, and of caring enough to reconstruct educational practices and institutions so that they effectively reach these goals.

In the terms of the Guba-Clark model, the problems of development and diffusion are currently of greater importance than those in the research area. It may even be a mistake to claim that research is of primary long-run importance, since (as has been repeatedly demonstrated in the past) research conducted in isolation from development and diffusion tends to be inconclusive, difficult to apply, and generally of doubtful value. For these reasons, the simulation laboratory approach to multi-media problems appears infeasible, in the sense that such a laboratory could do little by itself toward reaching major problem-solutions.

IV. Feasibility of a Comprehensive Development Laboratory for Multi-Media

A. Concept of a Comprehensive Development Laboratory

As was indicated at the beginning of Chapter III above, the concept of the "comprehensive development laboratory" has as its distinguishing characteristic that it is concerned with integrated and continuous planning, supervising, evaluating, and supporting systematic educational improvements. As such, it combines in a coherent fashion aspects of each of the other five types of laboratories: planning and policy formulation, basic research, component development, simulation, and experimental schools.

No laboratory of this comprehensive sort as yet exists--at least in the full degree envisaged by this report. Educational Facilities Laboratories, established by the Ford Foundation "to help schools and colleges solve their physical problems by encouraging research, experimentation, and the dissemination of knowledge regarding educational facilities," is perhaps the closest approximation to the concept. EFL, however, does not emphasize systematic operations to the extent of ensuring fully integrated planning - development - evaluation activities.

Some of the Regional Educational Laboratories which have been established by special legislation also approximate to some degree the concept of a comprehensive development laboratory. None of these organizations, however, has undertaken to systematically attack the complete spectrum of problems related to the design, development, and implementation of major multi-media and/or telemedia innovations. There is reason to believe that the laboratories might reconsider their abilities to deal with such problems, but their primary contribution appears to lie in other areas. The kinds of problems envisioned for a comprehensive multi-media development laboratory will require a concentration of attention, and a freedom from pressures for short-term visible results, which do not presently tend to be characteristic of the Regional Laboratories.

The general concept of the Comprehensive Development Laboratory is illustrated in part by Figure 1 in Chapter II above, "Schematic of Complex Man - Machine System Development Process." This figure indicates the interrelations which are necessary among the various phases of system and sub-system planning, design, description, specification, production, installation and operation. Overall needs for "technical management and design control" and for "evaluation and evolution" are stated. These are brief reminders of vitally important system principles which were learned the hard way--by violating them or by ignoring them. Too many complex systems have been built and have failed (or have needed major reconstruction) because of insufficient attention to advanced planning (analyzing system goals, environmental constraints, and available resources), to specification of hardware - software - personnel functions and interfaces, to orientation and training, to testing sub-systems and the total system against stated goals, and to the need for evolving as new or unanticipated problems and opportunities arise.

Figure 1 implies research activities, and least in the sense of applied research, in connection with prototype developments which are usually advisable at various times during complex system development. Basic research is generally of a longer-range nature, and would not be attempted as an actual part of the process of developing a specific system. Experiments with parts, aspects, or simulations of a system under development are highly appropriate and necessary, however. They should be planned for and carefully managed, to insure genuine contribution to solving developmental problems. Applied research in a broader sense, including operations research and environmental analysis, is also pertinent.

Diffusion and dissemination are also here intended as essential functions of the comprehensive development laboratory. In this respect, Figure 1 is inadequate and needs to be supplemented by the Guba-Clark model, as well as by indications of strategies and tactics for successfully sustaining operations in an increasingly wide environment.

The concept of the comprehensive development laboratory, then, contains all the foregoing elements, plus an overriding commitment to a total approach which will develop optimum multi-media applications within the context of a genuinely effective--and improving--educational system.

B. Implications for Organization, Facilities and Personnel

1. Organization. The comprehensive development laboratory concept outlined above has definite implications for the types of activities in which the laboratory would and would not engage. Implications for laboratory organization are closely related, since organizational structure should facilitate and reinforce laboratory tasks. Figure 2 indicates a possible functional organization based on three fundamental types of activities--plans, operations, and evaluation. In addition, a "meta-development" activity is required in order to bring the laboratory into effective existence; various support activities are also necessary.

The organization illustrated in Figure 1 contains a number of functions which are separately important and which must not be overlooked. It is equally important that no one of them be permitted to dominate the others, as often happens in organizations. Planning, operations, and evaluation are all indispensable; but generally speaking, it is unwise to give operators the sole responsibility for planning or evaluating their own activities. Similar comments apply to the possible dangers of permitting either planning or evaluation to be undertaken for their own sake, without being thoroughly integrated into ongoing operations.

From another viewpoint, the organization of the same laboratory could distinguish those operations directly related to multi-media equipment from those which are more conceptual, reflective, or analytic in nature. In that case, a "research and development laboratory" could be distinguished from an "institute of advanced studies". This distinction, however, would be inappropriate for the laboratory here conceived, which emphasizes the integration rather than the separation of thought and action.

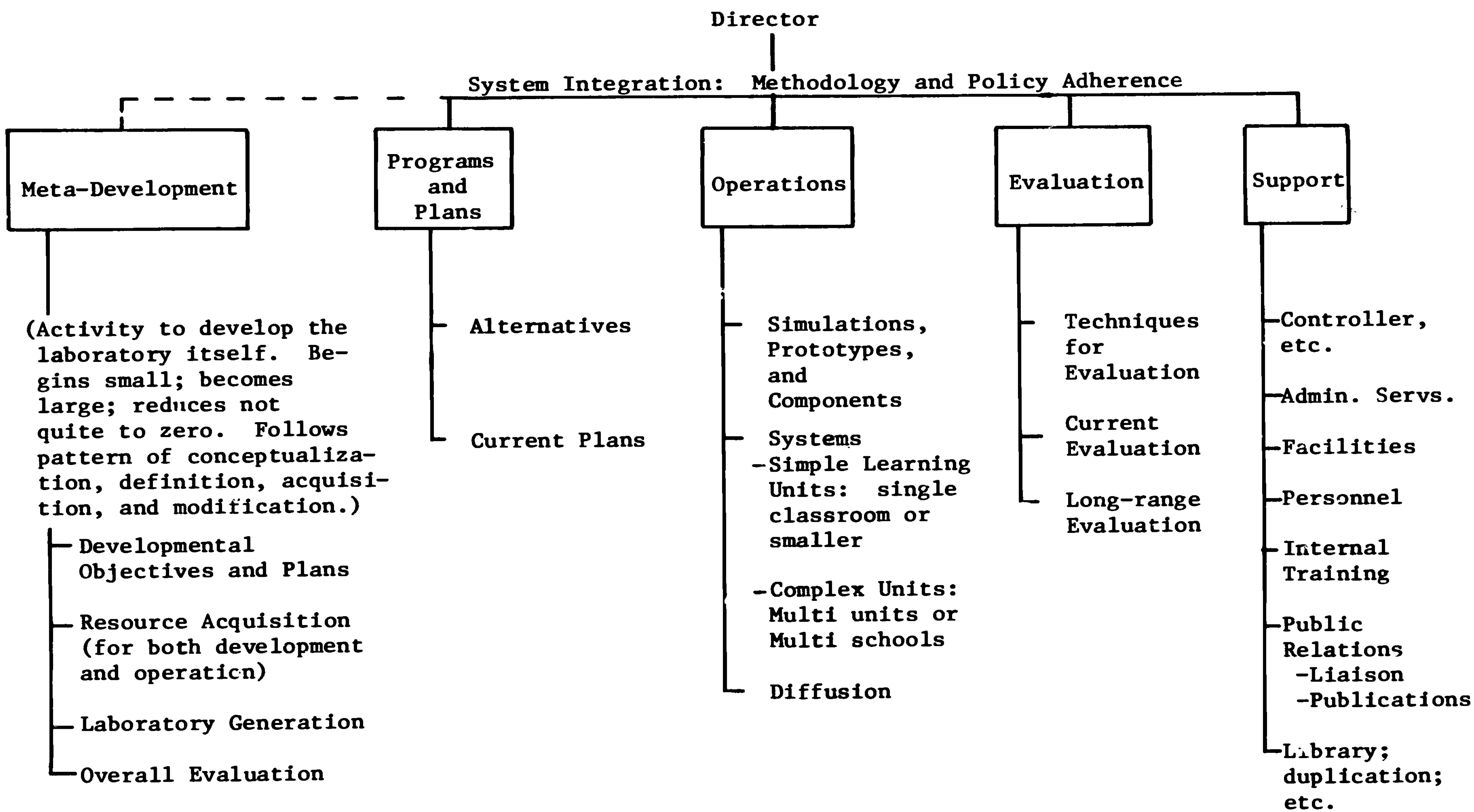

Figure 2. Comprehensive Development Laboratory Organization

2. Facilities. The organization here presented will plan multi-media applications, directly or indirectly carry them out, and evaluate them as contributions to widespread improvements in education. At the outset, it is doubtful that such a program would require extensive physical facilities. Indeed, it would be safer to begin with the assumption that physical facilities other than office space are not needed, to emphasize that the success of the organization is to be judged by its impact on education, not by the magnitude or expense of its inventory and arrangements.

Without experimental facilities of its own, without a computer, and without a demonstration school to operate, such a laboratory can nevertheless be in a strong position to organize and direct a fruitful and influential program of activities to be carried out in a variety of schools and research centers. But of course the laboratory must be well-managed, imaginatively directed, and adequately funded. It must have a strong, capable staff, dedicated to its purposes and techniques, and intimately involved in all details of the activities it sponsors. It must have access in a variety of ways to on-going school programs for purposes of observation, trial, and evaluation of designs. All sponsored activities must be well-planned and clearly defined as integral parts of a coherent program.

It is possible that as the multi-media laboratory develops its programs, it will identify tasks which can most effectively be carried out directly by the laboratory's own staff. If so, it may acquire experimental facilities of its own. These, however, should be made to depend on later analysis and assessment, and should not be included in original planning. Such facilities would vary with particular programs of research, but might eventually include some or all of the following:

- Menus of multi-media devices, equipment, and support facilities

- Resources for the development of experimental software and other programs for the multi-media devices

- Sufficient computer capability to permit the design of simulations, games, and other applications

- Facilities and equipment for "walk-through" simulations and related techniques

In the pre-equipment stage of the laboratory (which may continue indefinitely), geographic location can be based on a comparatively limited set of factors of convenience, including the availability of research personnel, cooperative school systems and other educational organizations, and related research and development efforts. Proximity to a major center of air transportation would be of interest.

3. Personnel. The basic structure of the laboratory would evolve around a team organized for the systematic development of programs and tasks. Although various activities might require special staffing, the basic laboratory staff would include permanent expertise in the following

areas:

- Educational systems analysis, design, and development
- Multi-media equipment design and operation
- Multi-media materials development and production
- Engineering and design of learning spaces
- Learning theory, concept organization, and child psychology
- Testing, evaluation, and psychometrics
- Modeling, simulation, and gaming
- Educational management, economics, and politics
- Cost-effectiveness analysis

This group would constitute an interdisciplinary team who would find their common theme in the integration of their various specialties around major problems involving the design and implementation of multi-media systems. Each of these groups would analyze needs in its own area and would be free to recommend needed projects. Although skills devoted to major problems would change according to the problem situation, the essential task would remain the design, evaluation, and eventual implementation of complete educational systems optimally incorporating media.

C. Functions

A comprehensive multi-media development laboratory conceived along the lines indicated above would be engaged in a broad spectrum of functions. The general mission of the multi-media laboratory would be to develop, test, and actively disseminate systematic cost-effective uses of telecommunications, media, and other technological innovations for educational purposes, in such a way as to begin and sustain changes of major significance throughout American education. In fulfillment of this mission the multi-media laboratory should devote its attention to:

- Problems of system design and implementation
- Measurement of alternatives
- The development of implementation models
- The development of improved information systems and feedback
- The recording of replicable experiences
- The assistance of interested groups in mounting and evaluating multi-media instructional programs

- The dissemination and demonstration of worthwhile prototypes

Comments on aspects of these functions follow:

<u>Operational Testing and Development</u>. One of the most important functions required is developing and testing designs which embed instructional media and techniques in operational teaching-learning environments. This would permit the examination of technology utilization within a context of complexity of the actual environments in which technology must be used, i.e., as part of a total instructional system. It would be possible to identify those factors that complement, enhance, or hinder the effectiveness of the technology; and required modifications to media and other system components can be determined. By making the required modifications and engineering the total system as dictated by evaluated experience, the advantages and limitations of technology can be determined and the necessary conditions for its appropriate utilization specified. The objective would not be to perform comparative evaluations of the effectiveness of competing media, but to test and develop, by iterative cut-and-fit procedures, media and other components of the total instructional system. The end product would be demonstrably effective instructional media and techniques with documented specifications for their appropriate utilization in the school environment.

<u>Empirical Research</u>. A laboratory, in a more conventional sense of the term, may be used to perform studies aimed at acquiring new knowledge through direct observation of the behavioral results of technology utilization in learning situations. It is useful in considering the specific focus of the laboratory to distinguish between experimental and exploratory studies. Experimentation and exploration are distinguished here on the basis of the extent to which the observation and data recording and analysis are guided by precise hypotheses and the degree to which rigid controls are exerted.

- <u>Experimental Studies</u>. Some problems of educational technology may be amenable to rigorous experimentation, i.e., the formulation of testable hypotheses, the controlled manipulation of prescribed variables, and the measurement of concomitant variation in other variables. Such research requires formal theory to guide the formulation of hypotheses. Since it is doubtful that adequate theory exists for classroom learning in general or for educational media in particular, it will usually be necessary to resort to less formal techniques of empirical exploration.

- <u>Exploratory Studies</u>. Even where understanding of a given problem is meager, that problem may profitably be represented in a laboratory or examined in the field for purposes of direct experience and exploratory observation. This approach is appropriate when there is inadequate theory to identify critical relationships and generate testable hypotheses. However, orderly search can make important contributions to the clarification of problems and to the stimulation of new insights and hunches that may lead the way to more formal experimentation or systematic trial.

Analytic Research. A computer facility within a laboratory could contribute directly to analytic research, not only through straightforward computational support, but also through symbolic simulation. In order to deal simultaneously with a large number of intricately related variables, it may be possible to develop analytic models of those variables and their interrelationships which may then serve as the basis for computerized simulations. By this means it may be possible to approximate solutions to otherwise unsolvable problems through artificial sampling and other solution-by-analogy techniques. However, computer studies within a laboratory should themselves be carefully planned and evaluated. There have been far too many instances where computer operations have absorbed a disproportionate share of research resources, yielding results of little if any superiority to those derivable by less elaborate means.

Demonstration. A laboratory can serve as an effective means of two-way communication between researchers and educational practitioners. It can provide the capability for live demonstration of the results and products of a technology research and development program, which in turn will provide direct experience to experts throughout the educational community as a basis for critically examining demonstrated results and posing new problems. This may well be the most effective means for promoting increased participation and expert criticism in educational research and development. This increased involvement may lead to improved user acceptance, and should accelerate the transition of technological advances to classroom application.

Integration. A laboratory should provide the opportunity to integrate the problems, results, and methods of other research and development activities. Where related problems or educational elements have been isolated for purposes of study and analysis, these problems and separate study results may be related and combined. There may also be advantages to be gained in integrating not only the content or subjec matter of the research, but also the research methods of themselves. For example, the use of classic experimental techniques with analytic simulation in some iterative combination may provide a power, scope, or efficiency not possessed by separate methods alone. The laboratory, by providing common tools and informational bases, at least supplies the opportunity for concerted, cooperative attack on significant problems by a variety of analytic and empirical methods.

D. Techniques

An important aspect of the comprehensive development laboratory will be its conscious and explicit subordination of techniques to problems. For this reason, it will avoid commitment to a limited set of favored techniques. It should be prepared, on the other hand, to use any techniques which may be required and which are justifiable as probably yielding returns commensurate with their demands on the laboratory's resources in funds, people, and equipment.

Simulation techniques, for example, have been discussed in the previous chapter. Although they did not appear promising enough to justify a laboratory devoted exclusively or primarily to their use, they should be considered as among the possible tools for a comprehensive development laboratory. Since the laboratory will have no predetermined commitment to simulation, balanced judgments should be possible on the value of simple or complex simulations in particular cases. The status of an issue may be such that simulation is not the right tool. Some problems are too vague for rigorous experimental treatment and require preliminary definition by means of field research or other research methods. Some problems are so highly specific, on the other hand, that simulation is too elaborate. Methods such as small scale experimentation or graphic analysis should then be considered.

Similar comments apply to digital computer techniques. The computer has made possible vast new potentials for the understanding of educational behavior through its ability to deal with tremendous amounts of data at fantastic speeds. In fact, so great is the computer's potential for dealing with mass data, that its abilities have often overreached the current state of analytical sophistication.

Any consideration of new laboratory techniques must include the computer as a possible analytical tool, but the critical issue at this juncture is the determination of its appropriate use. The computer functions in social science research in one of three ways: (1) it analyzes data and performs statistical computations according to a predetermined format; (2) it organizes data and determines appropriate computations based on prescribed conditions; and (3) it extrapolates and predicts trends and future conditions according to interrelationships among inputs. The computer is, in short, a computational tool, an analytical tool, and a problem-solving tool. Its application to research in education, however, depends on the "state-of-the-art" of the efforts which support these applications.

Often, a computer's principal influence on a process or an investigation has been through the impetus it has given to careful analysis and evaluation. Since computers are expensive and precise, they tend to demand unusually painstaking formulations of issues and of results. It then frequently turns out that although clarification has been achieved and decisions have been improved, the computer in itself made no contribution, since its actual computations were either self-evidently true, or irrelevant, or derivable by other and simpler means. A multi-media laboratory should avoid wasting its resources on elaborate computation, when the actual requirement is for penetrating analysis.

In general, a developmental, problem-solving laboratory should be prepared to use and defend less formal methods than those which are usually associated with the idea of laboratory research. This will not be easy, since wide knowledge and considerable good sense will have to be substituted for methodological formulas. Traditional experimental methods will not often produce results having real impact on anything so complex as public education. In order to achieve the precision and control required by traditional methods, the phenomena of real interest are usually stripped out of the problem. The result is often a precise, unambiguous answer to a question that nobody has asked.

In order to obviate the difficulties of traditional experimental methodologies, and at the same time to avoid the pitfalls of new yet incompletely developed techniques, the following methods appear useful for the field of education:

Cut-and-Fit Methodology

This method requires establishment of behavioral objectives and a process of try, fail, try, succeed. The "success" may not be optimal and its causes are not always clear, but the process allows the elimination of the ineffective and some insight into the degree of change necessary within a situation. First trials should be small-scale and short-term, gradually building into more complete attempts.

Problem Analysis

A good research strategy for studying problems occurring in large, complex systems is initially to embed--really or symbolically-- the system of interest in a noiseless environment, i.e., one which is completely deterministic. After having determined how the system behaves in this environment, disturbing elements can be added one at a time to determine their effect on the system's behavior. This procedure will not isolate all of the possible interaction effects or in general satisfy the requirements of ideal research design. But it is a systematic way to deal with very complex systems and does permit the addressing of problems that are unmanageable by traditional pure methods.

Informal Simulation

Informal simulations of some aspects of the educational situation are feasible and can contribute to educational improvement. Enough is known about student behavior so that its limits can be specified and the interesting points on a continuum can be identified. These and their assumed relationships to other educational factors can be incorporated in a model which can then be used in sensitivity studies. Such studies will not uncover new knowledge, but they can indicate where the potential pay-offs lie and guide subsequent empirical research and development.

Walk-through simulation is another promising technique for multi-media development. This consists of analyzing some complex process and then having a group of technicians "walk-through" or role-play the steps or events in the process. It can provide important insights and avoid mistakes prior to a full-blown field test. Walk-through simulations of this type are similar to new developments in micro-teaching, and offer great promise as relatively inexpensive, uncomplex research devices.

Delphi Techniques

The Delphi Method [63] has as its purpose the utilization of expert opinion in situations which lack a theoretically convincing reason for selecting a particular action or a particular policy for action. It replaces direct debate by sequential individual interrogations interspersed with information and opinion feedback from earlier parts of a program. The methodology can have important consequences for educational research, especially as concerns the complex situations in which multi-media operate. A careful analysis of expert opinion across the many subject fields and specialties involved in the design and development of the learning situation could help to resolve both major and minor implementation problems.

Educational Planning Games

Great interest has been expressed recently in the use of games for educational purposes, and an educational planning game has been developed by Clark C. Abt. [See in 66.] It uses four teams of educational experts, two of which represent groups of professional personnel, one represents community interests, and the fourth represents "inhibitors" or "reality screens". The first two teams develop a plan or strategy for attacking a significant educational problem and are then confronted by the countervailing forces represented by the other groups. The result, if the game runs long enough, is a compromise position which takes into account all of the factors pressing upon an issue. In this manner the participants recognize the forces acting in a situation and are able to develop a realistic solution.

The Delphi Method and Educational Planning Games hold significant potential for research in multi-media and telemedia and their application to educational situations. Both approaches permit the necessary conjecturing about changes in present systems, and they allow a full consideration of the forces affecting a specific problem.

E. Programs

A great variety of activities would be appropriate for a comprehensive development laboratory with the structure and functions described above. However, it would not direct its energies primarily toward inventing or developing particular multi-media devices; producing software packages, instructional packages, or curriculum packages--except on a prototype basis; training personnel in large numbers; building or operating a school or institution for a long-range program of education; or carrying out controlled, experimental activities aimed at basic research or the creation of knowledge. Its programs of course might result in suggestions for any of the above activities, and in such cases recommendations would be made that they be supported by other agencies.

The laboratory's basic concerns would be with working out and demonstrating systematic sets of solutions to important educational problems. It would focus its efforts on particular tasks which could be formulated in terms of evaluatable goals, and which would give reasonable promise of contributing significantly to the advancement of education. The laboratory would intend to make a major difference in the conduct and results of education, not just a difference in theoretical understanding or in superficial appearance.

Sample program areas consonant with the laboratory's concerns and methods would, at a general level, include the following:

- Improved learning of particular subject matters.

- Increased range of student-to-student interactions for learning purposes.

- Improved educational opportunities for isolated or scattered populations.

- Development of criteria for mix-ratios of professionals, para-professionals, and technology within the present context of the school so as to effect cost savings and educational improvements.

- Practicable models of improved learning environments and of alternative configurations of elements.

More specifically, project areas such as those referred to in Section III.F above (Feasibility of a Computer-Based Multi-Media Simulation Laboratory) would be candidates for defining comprehensive development laboratory tasks. There would be significant differences in emphasis and treatment, however, as indicated in the following comments.

1. Education of the Handicapped. The simulation techniques which were described in III.F in connection with the social education of the blind were partly for instructional purposes, partly for observation and analysis. That is, simulation was both a teaching vehicle and a laboratory control vehicle. It was hypothesized that computer techniques could be used to generate and evaluate social learning experiences for blind children. The simulation laboratory would conduct experiments to evaluate the merits of this hypothesis.

A comprehensive multi-media development laboratory concerned with this problem area would not take the same approach. It would instead attempt to evolve a description of a complete instructional system for the blind, identify possible multi-media contributions to such a system, and enable operational trials to take place and be evaluated in realistic environments. These activities of course would necessitate the clarification of educational goods for the blind, a review of present systems of attaining those goals, generation of feasible alternative systems, analysis of cost-effectiveness trade-offs, simulated and/or prototype trials, and sustained commitment to evaluations and revisions as needed and justified to improve system performance.

This comprehensive task would be conceptually much larger than the previously described computer simulation task and should have more significant results, but its costs should be no greater -- and perhaps less. The principal effort would go into comprehensive analysis, design, and trial, rather than into concentration on particular equipment or techniques.

2. Education in the Sciences. Similar comments apply to this problem area. The computer-based approach to scientific inquiry previously described in Section III.F. may have merit. However, it is risky to embark on an experimental investigation centered around this computer-based approach, partly because of the costs which would necessarily be involved, but also--and more importantly--because once a commitment is made to a computer-based experiment it is difficult for the experimenters engaged in it to be objective about the value of the experimental systems they devise. The commitment of the comprehensive development laboratory, on the other hand, is not to investigation of a particular hypothesis or technique, but to imaginative generation and careful comparison of alternatives. Objectivity therefore tends to be encouraged and reinforced; it is also facilitated by the comprehensive laboratory's organizational separations between plans, operations, and evaluation.

3. Education of the Culturally Disadvantaged. Reference to the description in Section III.F. of experimental work in connection with the education of the culturally disadvantaged will once more reflect the prevailing overemphasis on technique. The question implied is, "Will this technique work?" rather than "What is the role, if any, of this technique in reaching an optimum solution to the educational problem?" There is a profound difference between these two questions, and the methods for answering them are also very different. To start answering "Will this technique work?" implies a commitment to the technique and then repeated trials to see what can be done with it. To start answering "What is the role, if any, of this technique in reaching an optimum solution to the educational problem?" implies deferring trials of the technique until goals and alternatives are well-understood, and then trying out the most promising alternatives.

4. Means of Extending Teacher Effectiveness. The discussion in the preceeding chapter of the "enabling" approach to multi-media (and thence to teacher effectiveness in general) represents a significant but incomplete step toward the comprehensive development laboratory. It recognizes the need for doing more than merely developing and testing multi-media devices and materials in isolation. However, it suggests only one favored method for improving the situation (teacher participation in media package design and construction), rather than insisting on the need for a comprehensive approach to the total problem of teacher effectiveness.

5. Communications/Decision-Making in International Relationships. The simulations described under this heading in the previous chapter represent highly specialized research activities and/or complex, costly educational experiments. In either of these aspects, these simulations would be inappropriate for a comprehensive multi-media development laboratory. By their nature, they embody sustained exploration of a technique to which a commitment has already been made. No claim is made or intended that their starting motivation was from a recognized educational problem, or that the educational techniques being explored are to be systematically and objectively weighed against alternatives. In this connection, it should be pointed out that the comprehensive development laboratory would never allow its consideration of techniques

to begin with expensive commitments. It is entirely possible, of course, that highly complex and expensive approaches to educational problems may eventually be developed and defended on the basis of their high returns in educational effectiveness. Indeed, the comprehensive development laboratory should actively generate, collect, and investigate ideas for complex problem-solutions. But its investigation will begin with paper plans and conceptual trials, and then move through limited and comparatively simple tests, before embarking on full-scale system construction and operation.

F. Difficulties

Establishing a comprehensive development laboratory along the lines described above will not be easy. Many of the difficulties, though, will be more or less routine, in the sense that they could be expected in connection with any new laboratory or organization. These are such matters as securing adequate funding, acquiring an appropriate staff, and building up staff agreement on the significance of laboratory policies and methods.

Other difficulties which may be anticipated are present or potentially present whenever educational changes are tried out. Because of the fears which prospective changes always tend to create, the sensitivity of the field of education, and justifiable concern for the effects of research techniques and new developments on children, strong constraints may be placed on experimentation.

Special difficulties with a comprehensive development laboratory may be anticipated because educational situations, including those to which multi-media can make a contribution, rarely permit the explication of a clear-cut statement of aims and goals broad enough to account for the total educational experience, especially over a considerable period of time. While this complaint is often heard, and frequently countered by pointing to the development of "behavioral objectives" (or arguing that education is an art anyway), much remains unaccounted for in any deliberate educational experience. Frequently, any one experience will contain a number of incompatible goal systems operating within the same environment. This confusion of educational purposes makes output analysis difficult.

In addition, only limited information is available on the inter-relations among significant elements in a total educational situation. There has been considerable research on parts of the problem, including the adaptation of mediated instruction, but there has been insufficient attention to the nature of the total situation and the effects of varying one or more elements.

Other special difficulties would be caused by the facts that many of the techniques referred to in Section D above are in early stages of development, and that personnel who understand their uses and limitations are in very short supply.

The existence of these several types of difficulties, however, does not mean that a comprehensive development laboratory must be deferred until all difficulties cease to exist. On the contrary, it is implied by the laboratory's concept and methodology that among the laboratory's functions will be clarification of educational goals, analysis of interactions among elements in total educational systems, improvement of its own techniques, and training of its own staff. All laboratories engage in shaping their own conceptual tools and in developing their own personnel. The comprehensive development laboratory is committed to iteration and evolution. Its participants will learn (through actual trials, through evaluation of successes and failures, and through progressive improvements) both how to think about and operate the laboratory itself, and how to improve education.

G. Feasibility.

A comprehensive multi-media development laboratory of the sort described in this chapter is needed, is technically feasible, and would have an excellent probability of making significant contributions to education without excessive costs. The preceding discussions have pointed out that "multi-media problems" exist, and that opportunities for fully effective educational uses of media are unlikely to be realized unless a much more comprehensive and systematic approach is taken than any that is being used today. There is no technical reason whatsoever to prevent a comprehensive multi-media laboratory from coming into existence and operating successfully. The difficulties would be those of inertia, institutional resistance, and a lack of support.

Financial support is the ultimate key to the feasibility of the comprehensive multi-media development laboratory. With adequate support, there is good probability that the laboratory would rather soon demonstrate its value and begin to establish the credibility of its methods. However, support should include sufficient guarantees of stability to ensure that there would be no undue pressure for quick results, and that well-qualified personnel would be attracted to participate in it. Annual costs of around $2,000,000 are suggested by the following rough estimates:

25 full-time professional staff at an average of $16,000	$ 400,000
Non-professional support, office space and equipment, publications, travel, and employee benefits	600,000
Field operation and evaluation (equipment, materials, and services)	1,000,000
ANNUAL TOTAL:	$2,000,000

An adequately funded laboratory of the sort described should be able to make major contributions to the development and diffusion of improved educational systems. In fact, if such a laboratory can not make significant contributions, then nothing else can, except perhaps through accidental or chance occurrences. The laboratory as defined would have a clear mission, effective methods, and resources and personnel capable of sustaining its efforts through the stages of discovering and designing what is needed, trying out and improving its designs until they can accomplish their goals, and catalyzing their widespread dissemination.

H. Implementation

There are several ways in which implementation of a comprehensive multimedia development laboratory could be carried out. For example, the laboratory could be established as an entirely new organization, or it could be based on some related existing organization which would be given a new direction and charter. The present project, however, has not attempted to review existing laboratories, schools, or other organizations which would be possible candidates for undertaking to carry out the mission of a comprehensive multi-media development laboratory. This would be a matter for early attention once the implementation of the laboratory is seriously intended.

Some general observations on implementation methodology follow, along with implications noted for the Commission on Instructional Technology recently formed as a result of Title III of the Public Broadcasting Act of 1967.

1. Methodology for Laboratory Implementation. As is indicated earlier in this chapter in Figure 2 (Comprehensive Development Laboratory Organization), a "meta-development" activity is required in order to develop the laboratory itself, in distinction from the educational systems the laboratory will eventually be concerned with developing. Figure 2 refers to meta-development as involving a "pattern of conceptualization, definition, acquisition, and modification." This is a reference to a methodology worked out to a rather high degree of sophistication by the U. S. Air Force Systems Command, to assist in managing the implementation of complex man-machine systems. The intention here is not to suggest that this Air Force system should be followed literally and in detail as a methodology for implementing an educational laboratory, since very important differences obviously exist between educational systems and electronic systems. Nevertheless, explicit management techniques have been found extremely useful in developing large and complex systems, and there are good reasons to believe that they can also be useful (if properly handled) in developing comparatively simple educational systems (such as a laboratory), as well as complete large-scale educational systems (such as, for example, a network of educational cooperatives).

Systems management is the process of planning, organizing, and controlling the activities of participating organizations to accomplish objectives of time-phased system programs which require the combined efforts of diverse functional agencies. The process is relevant to the comprehensive multi-media development laboratory both internally (with respect to its various organizational divisions) and externally (because of its commitments to field trials, evaluation, and dissemination).

As applied to the process of developing a system, the system mission, functions, and configuration are established in the so-called "Conceptual Phase". The present feasibility study is a contribution to that phase. Next should come the Definition Phase, in which desired accomplishments (objectives or "end items") are specified in greater degree; the Acquisition Phase, in which the laboratory staff and organization are more fully specified, then assembled and evaluated as potentially contributing to desired accomplishments; and an ongoing Operations-and-Modification Phase, in which improvements are suggested, implemented, and evaluated on the basis of actual experience. In the Acquisition Phase, of course, considerable attention is paid to analyzing, identifying, and acquiring the resources necessary and justifiable for attaining objectives.

An "adaptive" methodology is implied by the foregoing remarks, as well as by discussions earlier in this report of the techniques the laboratory itself should use in developing effective multi-media applications. That is, explicit designs and plans are constructed, but it is expected that they will need continual review and revision as experience is gained during their implementation. No one yet knows enough about educational technology to be able, merely by reviewing past experience, to write complete and ideal specifications for a comprehensive multi-media laboratory. What is needed (at two levels--both for developing the laboratory, and for the laboratory itself in developing multi-media educational systems) is a systematic program of planning, thought, tentative decision, trial, evaluation, and revision. Full-scale trials are usually comparatively late, and are preceded by simulated, prototype, or small scale trials. Adaptive methodology is required in order to increase chances of success in approaching situations which are not completely understood. Educational systems eminently represent such situations, and they eminently require an adaptive methodology for their design and improvement.

2. Implications for the Commission on Instructional Technology. A Commission on Instructional Technology has recently been formed as a result of Title III of the Public Broadcasting Act of 1967. This commission is charged with conducting a comprehensive study of instructional television and radio, including relationships with other media. If the commission wishes to consider methods of improving the educational effectiveness of instructional television and radio, the concept of the comprehensive development laboratory as outlined in the present report is recommended as highly relevant. It is very unlikely that instructional television and radio will achieve anything like their true educational potential if they are developed and implemented unsystematically, without proper attention to total educational contexts and purposes, to short and long range planning, and to comprehensive evaluation. The laboratory described in this report could make a major contribution to the design and implementation of complete educational systems making optimum use of instructional television and radio.

It is probably true that a comprehensive development approach to instructional television and radio would not satisfy enthusiasts who are already committed to the general value of telemedia. Starting from that commitment, the important questions have been how to secure additional funds, how to develop new applications, and how to improve quality--not how to define an optimum role in a total educational context. But if the Commission finds, as this report has done, that educational telemedia are at present generally quite ineffective, it may also conclude that a new overall approach to telemedia is desirable, and that an organization along the lines of the comprehensive development laboratory could combine--as no other organization could--all the factors necessary for a complete approach.

If the Commission agrees, its next step would be to recommend that the laboratory be more fully defined and specified, and that it should then be implemented.

V. Conclusions and Recommendations

Conclusions. This study has found that present multi-media uses are generally rather ineffective, and that research and development efforts in the field are limited in scope, either in their selection of media or in their definition of the educational situation of which the media are a part. These facts indicate that a comprehensive multi-media laboratory, designed to deal with educational problems involving the use of multi-media (and tele-media), is needed; that it could contribute significantly to the improved implementation of media in present school situations; and that it could be of important significance in the design of future learning situations. These conclusions are amplified in the following paragraphs:

Problem Locations (Section II.A). "Multi-media problems" neither exist nor can be solved in isolation from the total educational system, including its environment. A laboratory to address these problems should be concerned with a total spectrum of activities, including research, planning, design, operation, evaluation, and diffusion.

Current Multi-Media Practices and Research (Section II.B). The fundamental overall need is for systematic development, evaluation, and demonstration of multi-media uses in real situations for actual educational purposes. In comparison with what is required, present efforts are partial, sporadic, fragmented, and inconclusive.

Some Critical Needs for Analysis, Development, and Diffusion (Section II.C). In orde. to make fruitful use of the tremendous educational potential offered by new media, new kinds of investigation and development are needed.

Types of Laboratories (Section III.A). Six types of laboratories can be distinguished as being able to deal in various ways with educational media. Of these, simulation laboratories and "comprehensive development" laboratories offer greatest promise of needed assistance.

Feasibility of Simulation Laboratory Approaches (Sections III.B, C, D, E, F). So far, simulation laboratory approaches to educational problems have shown limited success in relation to costs. A semi-manual, computer-based laboratory utilizing time-sharing techniques would apparently offer maximum effectiveness for simulation experiments. Such a laboratory is technically feasible (that is, it could be constructed), but its main contribution would be in the research area. It could not adequately review, analyze, evaluate, and generate alternatives to current multi-media practices and to the assumptions and institutions in which they are embedded. It could do little by itself toward reaching solutions to the major problems which lie in the areas of development and diffusion. It therefore does not represent a feasible approach to multi-media problems.

Concept of a Comprehensive Development Laboratory (Sections IV. A, B, C, D, E). A comprehensive development laboratory, which would be distinguished by planning, supervising, evaluating, and supporting systematic educational improvements in an integrated and continuous fashion, does not yet exist. If one were to be established with an emphasis on multi-media, it should be organized around methodology and functions, rather than around equipment and facilities. Techniques would in all cases be subordinated to problems.

Feasibility of a Comprehensive Multi-Media Development Laboratory (Sections IV. F, G). The laboratory as described is needed, is technically feasible, and would have an excellent probability of making significant contributions to education without excessive costs.

Recommendations. The foregoing conclusions lead to the recommendation that a laboratory should be established and adequately supported, broadly conceived to design, evaluate, and influence the implementation of complete educational systems making optimum use of multi-media and telemedia. An adaptive methodology should be used for its implementation as well as for its activities.

Implications for the Commission on Instructional Technology (Section IV. H. 2). It is recommended that the Commission on Instructional Technology, formed as a result of Title III of the Public Broadcasting Act of 1967, consider the relevance of a comprehensive multi-media development laboratory to the problem of improving the educational effectiveness of instructional television and radio.

Appendix A. Bibliography

This bibliography is not intended to represent a complete survey of the literature in the field. It is limited to documents which formed a background for the present project. The investigators, of course, had access to standard works and were aided considerably by the bibliographies produced by the Department of Audio-visual Instruction (NEA), the National Association of Educational Broadcasters, other SDC projects, and various projects funded by the Bureau of Research (USOE).

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Appendix B. Contacts and Visits

The project staff attempted to reach a broad spectrum of opinion and information on the present and progressing state of technological practices by contacting and visiting as wide a range of individuals and institutions as time permitted. These meetings were generally informal, since the technical reports and publicity information supplied by most institutions contained adequate descriptive statements of the projects.

A. Guidelines

The project staff was concerned in meeting with people to discover information in these areas:

- What motivated your use of technology?

- Why did you choose this particular configuration?

- Who made the decisions?

- Who allocated the funds and/or determined cost effectiveness?

- What predictors of success did you employ?

- How did you define the problem and did you consider alternatives to this analysis?

- Have you found your installation successful? Why?

- What major problems have been encountered?

- Could you have avoided these difficulties through improved planning?

- What have been the reactions from students, teachers, and others?

- In what way were these people involved in the planning?

- Are their reactions justified?

- What spin-off effects have you encountered which were not predictable, or which were predictable but were originally discounted?

- What kinds of information would have helped you improve your planning?

- Did you employ systems analysis techniques (including PERT, CPM, etc.)?

- Did you employ a conscious process of change, innovation, and adoption?

- What elements of your system (e.g., buildings, environments, student personal needs, etc.) did you plan for which later proved to be unnecessary parts of the plan?

- What evaluation criteria did you pre-establish? How? Why?

- What will be your basis for determining the success of the installation?

- How do you see a simulation laboratory (or other prior-to-installation procedure) aiding your planning by providing inputs not presently available?

In addition, information was requested on costs of the installation (per student or on some other basis), the relation of these costs to planning procedures, the potential predicted for increased cost efficiences, and the effects of cost efficiencies on benefits lost or added. Some discussions were undertaken to determine the factors which determined the need for change and the resources considered critical. These discussions generally proved unsatisfying, since there appeared almost a universal lack of concern for considering (or for reorienting) extant patterns of thinking about resources.

An attempt was made to visit a representative example, in an actual school setting, of each new technology operating. Meetings were also held with specialists in the design of component aspects of new systems, especially those aspects not usually connected with novel hardware or software, such as facilities, furnishings, and textbooks. The intention here was to determine the relevance of these components to new systems, and to determine to what degree multi-media technology was affecting the design of items in the educational environment not usually associated with technology. It was hoped that several examples of integrated technological planning could be observed in addition to the installations of specific technologies, but this proved more difficult than was anticipated. Most of the apparently integrated operations proved to be based either on an electronic development to which appropriate teaching styles were added, on a clever arrangement of many individual devices (adding convenience but not originality), or on the application of some advanced nuance of a standard psychology. In this respect the present state of educational technological practices remains disappointing.

B. Institutions and Individuals Contacted or Visited

The following institutions and/or individuals were visited or contacted during the course of the study for the purpose described at the right.

Location and Primary Contact	Activity, Additional Contacts
Dr. Louis H. Brown Educational Media Specialist Institute University of Colorado Boulder, Colorado	Discussion of factors inhibiting effective use of media in the schools; research, development, and training needed for more effective use of media. Eugene Waldmann, Colorado Department of Education, and other institute members

Location and Primary Contact (cont.)	Activity, Additional Contacts
Mr. Alan Green Educational Facilities Laboratories New York, New York	Discussion of design factors in media planning, the RPI model classroom, and EFL as a type of laboratory.
Mr. William Ryan Office of Institutional Research Rensselaer Polytechnic Institute Troy, New York	Discussion and tour of multi-media installations including the model classroom. Dr. Walker, Professor of Biology
State University of New York Albany, New York	Tour of campus, including multi-media, library, and CAI facilities.
Dr. William McKeefry Academic Dean Southern Illinois University Carbondale, Illinois	Small group conference on the design and use of the multi-media classroom and student response system. Mr. Lloyd Rivest, GE R&D Mr. Dick Rankin, GE R&D Mr. A. S. LeBlang, GE R&D Dr. Kenneth Fishell, Syracuse University Prof. Carrol Truss, University of Miami
Dr. Donald Ely, Director Center for Instructional Communication Syracuse University	Discussion of multi-media planning and research; tour of the multi-media, response classroom. Dr. Kenneth Fishell Mr. Michael Molenda Dr. DeLayne Hudspeth
Mr. Charles Sheridan, Manager SDC, Rome Facility Rome, New York	Problems of design and implementation of CAI and computer-based instructional programs for neighboring secondary schools.
Dr. Patrick Suppes Mr. Cornelius Butler Ventura Hall Stanford University Palo Alto, California	1. IBM 1500 Computer Tutorial mode, Brentwood School, Ravenswood School District, East Palo Alto, California Mr. Karl Anselm, Director Mr. Bill Rybynsky, Principal 2. Drill-and-Practice CIA Programs Dr. Max Jerman, Director Miss Luanne Berkowitz, Curriculum Specialist Clifford Street School Redwood City, California Mr. Frank Messer, Principal

Location and Primary Contact (cont.)	Activity, Additional Contacts
Dr. Donald Tosti Westinghouse Learning Corporation Research Center 1840 Lomas Street Albuquerque, New Mexico	1. Contingency Management Media Projects Mr. Ken Kammerman Dr. Lloyd Homme 2. Educational Achievement Center Mr. Clifford Chadwick Mrs. Barbara Salazar
Station KNME (ETV) Dr. Claude Hempen Station Manager 1801 Roma Street, N.E. Albuquerque, New Mexico	ETV Studio and Personnel Dr. W. Bundy
Dr. Carol Nolan CCTV Consultant Chicago Public Schools 228 N. LaSalle Street Chicago, Illinois	The Chicago Cluster CCTV Project The Byrd School Dr. Hogan, Principal
Evanston High School School Dr. Lloyd S. Michael, Principal 1600 Dodge Avenue Evanston, Illinois	Integrated multi-media high school program, including CCTV, VTR, Dial Access (proposed), and classroom media. Mr. Phil Frost Mrs. Wanda Mitchell
Evanston Elementary District #65 Dr. Gregory Coffin, Superintendent	Proposed laboratory school plans and board of education committee to study technology. Dr. J. Robert Parkinson
The Raymond School Dr. Raymond Jerrems, Principal 37 Wabash Street Chicago, Illinois	Classroom media and non-media oriented instruction in an inner-city school.
SDC Research and Technology Division Santa Monica, California	Seminar on the Feasibility of Multi-Media Simulations and Model Designs Robert Filep Gloria Grace John Coulson Harry Silberman Gerald Newmark
Media Teaching Project (AACTE) Miss Freda Douglas 1246 16th Street, N.W. Washington, D. C.	Use of Media and Teacher Instruction

Location and Primary Contact (cont.)	Activity, Additional Contacts
National Association of Educational Broadcasters 1346 Connecticut Avenue, N.W. Washington, D. C.	Colloquy on Models and Strategies for Media Planning, Implementation, and Systems Design Mr. Lewis Rhodes Mr. James Fellows Mr. Al Friedman
U.S. Air Force Academy Maj. Michael J. Grady Jr. Directorate of Instructional Technology	Visit facilities and review program
Oral Roberts University Tulsa, Oklahoma	Learning Resources Center Dial Access System
Dr. Ralph Gerard, Dean University of California, Irvine	CAI and Computer facility
Project GENESYS University of Florida Cape Kennedy, Florida	Closed circuit television
Melbourne High School Melbourne, Florida	Multi-media Techniques Individualized Instruction
Oakleaf School and the University of Pittsburgh Learning Research and Development Center	Instructional management system
Dr. Ray Cobb, Director of Education Government of American Samoa Pago Pago, Samoa	Television-assisted instruction

C. Comments on Representative Visits

Oral Roberts University, Tulsa, Oklahoma

The dial access component of the Learning Resources Center at Oral Roberts represents perhaps as sophisticated a technological implementation for education as exists anywhere. Twenty-five audio channels and three video channels are available to over 160 student carrels located throughout the library, in classrooms, and at terminals in dormitories. The system appears to be in relatively constant use. In addition to this operation, classrooms are equipped with specially constructed teachers' desks containing tape recorders, slide consoles, and overhead projectors. Many classrooms are equipped for television (CCTV, VTR, and open reception). There are several front projection multimedia classrooms with response apparatus. Back-up facilities include a fully equipped television studio, graphic arts rooms, and a complete media library. There is no question that this building represents as complete a unification of teaching resources as is presently available.

One difficulty with the planning of the Learning Resources Center was pointed out rather strongly. There was little involvement of the faculty in the initial planning and installation of the equipment. While some resentment has resulted, the more serious effect is a comparative lack of creative implementation and use of the resources for affecting changes in the teacher-learning process. For the most part the tapes available on dial access are old lectures given by professors. Some use is made of the graphic facilities for slides and overhead, but apparently there has been little real change in the teaching process. The director of the learning resources center indicated that beginning this next year, all faculty will be encouraged to submit proposals for the redesign of their courses following the principles of a learning system. Direct faculty instruction in systems planning techniques will precede these proposals. There is reflected in this action a genuine concern that the facilities could be used in a more appropriate or cost-effective manner.

University of California, Irvine

It is the intention of the University of California, Irvine, to implement a "computer facility" on the campus so that virtually all administrative, research, and instructional segments will be controlled by a system of computers. The expectation is for over 700 terminals to handle the teaching load for the entire student body. Irvine clearly considers itself, and is acknowledged as, a leader in the development of computer applications in education.

At this juncture, there are twenty-four operating terminals servicing approximately one-third of the student body in various ways. Some use the computers only for computation; others for review (drill and practice). Only one course, Sociology I, is completely contained within the computer. Students interact with a terminal, receive reading and other assignments from the computer, and do not have contact with a "live" professor during the course. Although one may express some concern that the initial use of full computerization occurred in this critical human interaction area, it is still too early to judge the success of the involvement with the machine.

There are a number of problems at Irvine. Some of these arise from the nature and the condition of the computer language being developed and used. Some aspects of the language have not been finished, and other problems are being dealt with in the initial runs. The scarcity of computer programmed material limits the forward movement of the operation. Irvine has chosen not to share programs from other campuses, one important source of additional material. A critical problem is money.

The Irvine campus is on the road toward developing a powerful and sophisticated technological system. Yet it is not possible to escape serious doubts about the pedagogical implications of these applications unless greater change is made in teacher-learner interactions, the nature of the learning process, the scope of materials and experiences presented to the student, or the nature of higher education. This last point is critical: advanced technologies can and should lead to a reorganization and revitalization of the university function; they should not be merely sophisticated devices for storing and presenting acknowledged ineffective systems of education. There is too little evidence, however, that such a reorganization of learning is given high priority at present. Instead, immediate pressures emphasize getting new technological machinery into smoothly running condition, without great regard for interrelations with the overall educational system.

U. S. Air Force Academy

The Directorate of Instructional Technology at the United States Air Force Academy, Colorado Springs appears to represent an ideal instructional technology component within a total educational program and agency. Their operating budget is large, they are thoroughly equipped and adequately staffed, and they provide broad services to all parts of the Academy within an appropriate organizational context of responsibility and interaction. Essential features of the program appear to be the splendid equipment and support situation and the fact that individual users are not billed for services. This situation encourages experimentation and continued use, since users can try any mediated technique without direct effects on their own departmental budgets. The Academy is presently constructing a total of 168 classrooms, arranged in clusters of five, for the use of CCTV. In addition several multi-media classrooms are under construction, designed in part after one in use at the Harvard Business School. These rooms will provide for the use of CCTV as well as front screen and rear screen projection. A responder system will be available.

Project GENESYS and Melbourne High School

Contrasting uses of media can be seen at the University of Florida's Project GENESYS installation at Cape Kennedy and at the nearby Melbourne High School, Melbourne, Florida. Project GENESYS results from a deliberate plan for the use of CCTV to solve the problems of space, time, and communication which arise in a program of advanced, specialized education for scattered, part-time students. Each of the three off-campus GENESYS stations provides for on-site professional staff, some research facilities (mostly staff-oriented), a library, and live lecture situations, since each station broadcasts to the others. The CCTV is equipped with a telephone feedback, so that a student may query a professor at any time. The studio is equipped with a teacher-operated zoom camera and a closeup camera for transmission of printed matter. The system employs high resolution receivers. During broadcasts a teacher may operate his own cameras, but a technician is on hand at all times. Several of the reception rooms are small and allow for group discussion during broadcasts, although attention to the lectures would tend to render this situation inappropriate. Nevertheless, this appears to be a unique opportunity for student-to-student interaction during the learning situation. Although a feedback method may not always be necessary, its use in this project is important. Generally, the project's design quality and appropriateness in terms of stated problems are impressive.

Melbourne High School uses only the minimum of media, but each use appears excellent. A large group in art is instructed through the use of an overhead projector, the teacher creating the transparencies ahead of class. Approximately three hundred students receive instruction in typing simultaneously through the use of a loudspeaker broadcast system in an oversized classroom. One double class--roughly 50 students--in a slow learning core situation (history and English) contains virtually all of the usual classroom media devices, including a transparency-making rig. The head teacher is supported by an art teacher whose special interest is in the use of visuals in education. Together they are designing some interesting programs for this group. The major proposed additional use of media in this high school will be for increased individual instruction. The tutorial program at the school requires that attention be devoted to providing more individual experiences and a greater menu of instructional resources for the broad spectrum of projects undertaken by students. Media are seen as necessary parts of this program, although planned costs may not be justifiable except on an experimental basis. Melbourne is an excellent high school, thoroughly designed in its various aspects. Within this total design, media can play a part; but unless media are carefully implemented, their use could throw the school's overall program out of focus.

The Oakleaf School, and University of Pittsburgh, Learning Research and Development Center

Members of the project staff visited the Oakleaf School and representatives of the Learning Research and Development Center, University of Pittsburgh, to explore the development of Individually Prescribed Instruction (IPI). This experience proved to be highly provocative and illuminating in examining the use of individual instruction and the selection of media appropriate to the nature of the learning requirements. The system appeared to be highly effective for improving learning in the target subject areas, although adequate evaluative data were not available. Discussion with the principal, Dr. Donald Deep, revealed a high level of satisfaction with IPI but indicated some significant omissions in the total plan.

At this stage, the Oakleaf Project has apparently not addressed itself to the statement of long-range goals or the purposes of education for the achievement of these goals. "What do you want the product (i.e., the student) to look like when he leaves, and how does IPI contribute to this aim?" was not a first question in the planning or a comfortable one now. In addition, while the IPI portions of the day were carefully designed and controlled, the rest of the school day was not so designed or monitored, so that values other than those implied by the IPI experiences are still subject to chance occurrence.

Brentwood School (Stanford University)

The Stanford CAI system is designed to present instructional materials to 16 students simultaneously, permitting each student to work at his own pace and on different learning sequences. When an instructional sequence is completed, a complete record of the sequence of materials presented to the child and a chronology of his responses is made available.

The heart of instruction for the student is the rewarding, sensitive voice in the headset. This computer-operated teacher responds through circuitry at the speed of light to the student's manipulation of the lightpen and typewriter input devices. The teacher's voice directs the student to look at an image on the TV screen. For example, a first grader might be asked to note that a horse and a cow are at either ends of the screen, near the top. At the bottom of the screen is a farmer. The child is then asked to touch his light pen to the TV screen and to move it along the screen to show how the farmer could get to the horse. (The computer causes a flashing arrow to appear in front of each of the described objects, horse, cow, farmer, as each word is first repeated). The computer then assesses whether the child responds acceptably and at what degree of acceptability. If the child responds within a reference frame acceptable to the curriculum designer, the story or problem continues. If not, the problem can be presented in another manner. The computer can distinguish the student who doesn't know the difference between a horse and a cow. In such case, the computer activates the random access projector and a full color illustrates and narrates characteristics of various animals. The sequence is as available to new direction as there are ideas in the minds of curriculum workers.

The student is able to interact kinesthetically with a computer program by touching his light pen to a TV screen (a cathode ray tube). The student also reacts to visual clues on another display screen, follows his teacher's voice in the headset, uses a typewriter input device, and tapes his own verbal responses. If one accepts as a learning premise that the greater the number of senses brought into the teaching situation, the greater will be the degree of understanding, then CAI of this degree of complexity should be superior to CAI with typewriter interaction only.

The Byrd School, Chicago, Illinois

A television studio, including control room VTR remote facilities, auxiliary offices, and materials preparation facilities, is located in the Byrd Elementary School. By means of rented lines, programs of this studio's two channels are transmitted to four other elementary schools. These five schools form a "CCTV cluster", and there is some established interaction among them as a result of the TV project.

Each classroom is equipped with two television receivers capable of receiving regular broadcasts and (through signal translation) the ETV broadcasts, as well as the two CCTV channels. Advanced notice is provided the classroom teacher of special materials required to accompany broadcasts but no particular readjustments were noted.

The television team consists of a two-man technical staff, one full-time television teacher (a specialist in elementary science), and a TV coordinator. This individual works with teachers, develops methodologies for classroom implementation, assures that supplies are available, and provides feedback and assistance with problems.

A brief description of an observed television lesson follows: Two television receivers were at either side in front of the students. A globe was on a table, centered between the television sets, because the program was concerned with how to use a globe. The students had evidently cleared their desks in preparation for the broadcast. The television teacher asked questions and suggested activities to involve the students, but there seemed a distinct unwillingness to respond. Since they did not have paper or pencils available, they were unable to jot downs words or ideas from the broadcast. The classroom teacher circulated (patrolled) the room, occasionally admonishing students. The television teacher talked too fast and many of her map and word displays were unclear. There seemed, in short, little appropriate learning design or use of the media. As an isolated case, this observation is of little significance. Unfortunately, however, too many instances of the use of educational television illustrate similar deficiencies.

The Samoan Educational System

The educational system of American Samoa has undergone almost a complete overhauling since 1961. A significant element in this change has been the design and use of an educational television component. The effect has been a virtual revolution in educational thinking and planning, especially in the deliberate application of an advanced technology to the solution of persistent and chronic educational problems. Since a tremendous amount of information has been published on the Samoan experiment, this report will be limited to a short section of background information and a description of aspects of particular interest to the present project.

American Samoa consists of seven islands located in the South Pacific, with an estimated total population of about 25,000. The largest island of the territory, Tutuila, is the home of about 80% of the population.

In 1961, only about one-half of the eligible children were attending school with any regularity. The schools they attended were grass-roofed huts, typically poorly maintained and ill-equipped. Their teachers had the equivalent of an elementary school education; none possessed mainland teaching certification; and most of them could barely speak English--although all instruction was supposed to be in the English language. Since then, the educational system has undergone a revolutionary process of change. In all-new consolidated schools the Samoan child views television for from one-quarter of the school day in the early grades up to one-half of the school day in the high schools. Each classroom also has a native Samoan teacher who views the television lessons along with the students, manages the operation of the classroom, and attends to individual needs in preparing for and following up the television lessons. All of the television programs and printed materials used in the schools are prepared at the Department of Education's Educational Resources Center especially for use in Samoa.

The television medium has an enormous potential for bringing rich and varied educational experiences to its receivers. Most importantly, it has the potential for being immediately responsive to the changing needs of its users. New content or teaching methods can be diffused throughout the system immediately, without having to wait for the training of a new generation of teachers or the retraining of the present ones. Lessons can be repeated, altered, or delayed upon demand. Similarly, the curriculum of the schools must constantly be revised to keep pace with the accelerating changes in the Samoan culture, the growing linguistic and mental abilities of students at all levels, the rapidly changing demands of the world of work, and the new interests of children experiencing a society in transition.

There are four essential elements in the present educational system: the production process, the television transmission system, the lesson design, and the local school. The design of each element seems to have hinged on first a careful analysis of the nature of the Samoan child and the particular educational problems resulting from peculiarities of language and culture, and second on a careful analysis of the problems imposed by the nature of the extant system, especially the critical problem of the shortage of qualified teachers.

When planning for the new system began in 1961, the primary instructional mode was rote learning of verbalized English. Neither the teacher nor the student, however, understood the English, and so the repetition was meaningless. As well, the teachers were highly authoritarian; questions or indications of a failure to understand were not permissable student responses. The first concern, therefore, was to insure true teacher-student communication in the learning process through providing meaningful learning situations and training the teachers in new modes of behavior.

Following the decision to use as much English as possible, but not to demean the Samoan dialect as had previously been done, Dr. George Pittman directed a thorough analysis of the native speech and its relation to English. This analysis made it clear that commercially produced texts were totally useless, and the decision was reached to produce all materials locally. In advance of a lesson, usually a week, all teachers receive study guides directing their activities during the pre and post television sessions. These guides include equipment lists, motivation suggestions, actual questions, and statements of learning goals for the lesson. Teachers prepare themselves in accordance with these guides, and they meet with the mainland principal for inservice education based on them. The stronger teachers tend to go beyond the guide, but the unsure individual is well supported by its careful delineation of functions and its suggestions for questions. Many learning materials have been produced in addition to the lesson guides. These include some very handsome readers both in English and Samoan.

Almost all lessons are videotaped in advance, partly because there are only four studios to supply six channels, but also because the television teachers are then free to watch the broadcast from a school room. Since the broadcast schedule dictates that the television lesson must be seen at a specified time, all other activities in the classroom revolve around this factor. All students in a given level are, therefore, studying the same material at the same time. The broadcasts, however, represent only 25% of the school day, so the feeling of regimentation is avoided while, on the other hand, it provides a firm structure for the Samoan teacher.

The classrooms in the consolidated schools were designed for television reception. A 21" receiver is directly in front of the class at an appropriate height. Just before the lesson a student opens the closet doors to expose the TV, turns it on, and shuts off the lights. The picture and the sound are clearly seen and heard at all points of the room. After the lesson, the student shuts the closet, and the room then appears as any non-television classroom.

The children greet the TV teacher, respond as directed, and are genuinely involved in the lesson. This is not passive viewing of entertainment or "enrichment". The TV is an active (and interactive) part of the child's learning process. It is this quality of the television experience that is most difficult to explain and will remain only vaguely appreciated unless observed. This aspect of rapport with television is perhaps at the crux of the technology in education issue, since many critics point to the dehumanizing characteristics of machines. In this case, television functions in appropriate ways to perform only part of the learning task, but in addition the children respond to two aspects of the broadcast. First, the television teacher talks directly to the child, says good morning, etc., and they respond by name. This and similar devices insure a close rapport and, in fact, develop a warm feeling in the children for their TV teachers. Second, the children respond to the quality of the instruction and the quality of the lesson. Attention to the television teacher is greater than it would be for the classroom teacher because the presentation is superior for those parts of the total instructional process found appropriate for television. There is no question about the appreciation for quality in the instructional process on the part of even the youngest children. The television teachers also visit classrooms in person, talk with students as well as teachers, and receive daily feedback on the quality of their performances. These measures certainly add to the interpersonal nature of the presentation, but are secondary still to the characteristics of appropriateness and quality.

The lesson format seemed to be the same for all the classes observed, and quality did seem to emphasize the aspect of regimentation. The format is extremely effective device for insuring the adequate development of instructional presentations. There did appear to be some unnecessary duplication between the local teacher's activities and the television broadcast, but this could be the fault of the individual teacher rather than of the plan. There also seemed less than sufficient planning for individual responses (usually students responded in a group), a lack of communication between and among students (the primary pattern remains teacher-to-student: ask; student-to-teacher: answer), and very little imaginative or creative interpretation of the lesson.

Critics of the Samoan experiment have noted a lack of empirical data on achievement and on the operation of the system. There are, nevertheless, several favorable elements obviously present. First, there is a well run, creative atmosphere caused by a dedicated, sincere, and talented staff. Second, there is a strong sense of purpose and contribution on the part of the staff, and there is excitement, attention, and involvement on the part of students. Third, there are still signs among the faculty and in the schools of changes so radical that adjustment to the upgrading and improvements is a continuing activity.

The Samoan system spends under $500 per child per year (not including the initial capital investments). Within this budget all curricular materials are planned, developed, and written; the television system is supported; and transportation, food, and support services are funded. This cost figure is not directly comparable with the mainland because local teachers receive considerably smaller salaries than their equivalents in the states. Their considerably inferior training and somewhat less total sphere of responsibilities, however, forces the question of appropriate staffing (i.e., increased use of paraprofessionals in support of mediated efforts) and the concomitant reorganization of critical resources within a school district.

D. Summary of Visits and Interviews

The general impression gained from these experiences might be stated briefly in this way: there is a general lack of systematic and thorough planning in the application of multi-media to perceived problems of educational improvement. Having made this statement, it is immediately necessary to qualify it by indicating that many projects are motivated by the need to develop and test a hardware or software system, and that their justification is to be found within an experimental or developmental context. Usually, however, results are not applicable to another situation, nor is information collected to permit the comparison among alternatives.

As stated throughout this report, the chief cause for the problems in present media use appears to stem from either a lack of perception or a lack of appreciation for the necessity to redesign the total learning situation, or at least to begin with a clear statement of learning goals and a comprehension of the system presently working to achieve these goals. Media can perform certain functions which are appropriate to their nature and which can support learning. They cannot, however, replace or supplant a teacher performing these same functions unless the role of each is designed in relationship to the other. The necessity for designing man-machine systems and for analyzing critical needs which then can be met by alternative methods cannot be overstated.

Media planning should begin with a problem, not with a technique. Such problems have included individualizing instruction, improving intra-school communication, overcoming a shortage of expert teachers, transmitting at great distances, or equalizing educational opportunities for deviant populations. The contributions of various media to such problems can then be judged in relation to the other factors in the situation, alternative means, and the values of the community. Far too often, however, commitments have been to techniques rather than to the development of optimum solutions to problems. As has been stressed throughout this report, the effective use of media in such situations may require designing beyond the customary limits of institutional thinking. For instance, there is little realistic value in an expensive dial-access system to store a professor's lectures if the lectures are either poor or dated, and if their replay results in only test passing rather than interactive learning (unless the values for the system are consonant with its use).

The greatest difficulty with present experimentation and implementation activities with media stems from the fact that they are generally promoted in a context of protective enthusiasm. This results in low motivation for problem analysis, clarification of objectives, design of alternatives, cost analysis, systematic information collection, and objective evaluation. Each situation considers itself unique, probably a necessary concomitant to the obtaining of support, but this straining for individuality precludes objectivity and replication. One frequent explanation for a reluctance to be concerned with costs is related to the relatively high costs attached to experimentation and development. Most innovators feel their project includes expenses which would not be involved in future installations. In some cases, this seems true, but it does not detract from the need for careful accounting during the decision process and installation.

In most media implementations, initial decisions are made by the formal leadership, with little involvement of faculty or students. This results in later difficulties in the acceptance of the innovation. In cases where the faculty, or at least their representatives, had been involved, there was less tension and greater acceptance.

Despite these criticisms of the planning process, some excellent installations of particular media were observed. Although each evidences problems, the direction of the future is clearly toward breaking away from past media limitations.

Appendix C. Some Previous Experiments with Simulated Environments

The use of simulated environments for the study of educational problems has not been undertaken on a large scale, although two significant developments were reported in the body of this document. There exists, however, a substantial body of experience with the application of simulation techniques to other areas. These simulations have on occasion been limited to physical representations, but they have also included the development of complex computer programs for simulated training and longitudinal research. This appendix will present a brief review of some major simulation efforts within SDC. Some of these projects offer insights concerning the potential of simulation techniques for the field of education.

A separate project, currently in its final stages, has involved a study of past simulations and related experiments. The work, directed by Henry M. Parsons, is entitled A Review and Analysis of Man-Machine System Experiments and Laboratories, sponsored by the Aerospace Medical Research Laboratories. Parsons has cataloged virtually every major simulation laboratory and has reviewed the strategy and methodology of man-machine experimentation. His work has provided an extremely important input to the present study.

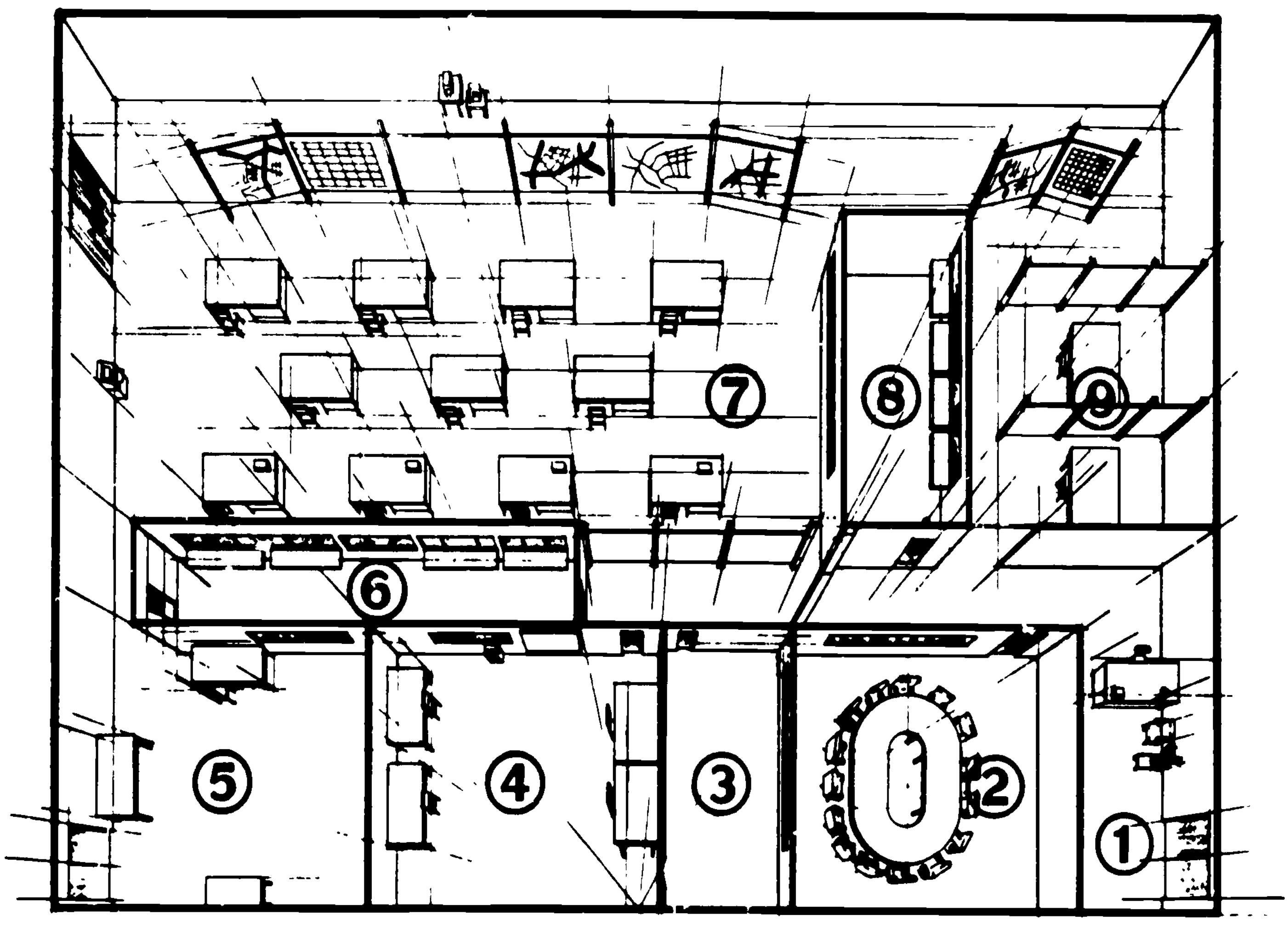
Many of the simulation projects described below embody techniques of doubtful applicability to educational problems. It would be a fatal error to establish an "educational simulation laboratory" on the basis of a primary concern with simulation techniques. Educational problems must determine which techniques are to be used to solve them, rather than letting techniques determine whether and how educational problems are to be approached. The main text above discusses uses of simulation for multi-media problems. This appendix is provided for the reader who wishes further concrete examples of the uses of simulation methods.

Emergency Operations Simulation Research Center

System Development Corporation maintains a facility in Santa Monica capable of simulating environmental emergencies and hazards. Called the Emergency Operations Research Center (EORC), the center offers the ability to evaluate and realistically practice methods of coping with emergencies without waiting for a real crisis to prove or disprove their effectiveness. The EORC makes it possible to examine and strengthen an organization's command relationships, communications, decision-making effectiveness, resource distribution and use of information under stress.

The EORC is capable of simulating air pollution episodes, such as occurred in Donora, London, New York City and elsewhere, and the response of official agencies and the public to these episodes. It is capable of simulating a second and third stage Los Angeles alert and the effectiveness of plans to curtail traffic and to shut down industry. This process can involve responsible officials at all levels of government and the experience can contribute to achieving cooperation and management breakthroughs in the solution of chronic problems. It can also contribute to a realistic analysis of the entire air pollution management system.

Constructed as a general-purpose laboratory, the Emergency Operations Research Center was designed to meet a wide variety of experimental situations within a single facility. Most walls and fixtures are easily movable, thus allowing for rapid and economical changes in configuration. The laboratory is divided into two major areas (see Figure 3). The first contains facilities for briefings and the actual conduct of simulation. The second is designed for use by participants in either single or multiple experiments with adjacent observation decks. Therefore, the design and physical layout of the EORC effectively provides facilities for all aspects of operations exercises; briefings; recording, monitoring and analysis; realism in the simulation; and debriefings.



1 Simulation Laboratory Foyer | *2 Briefing Area* | *3 Observation Area (raised platform)*
4 Simulation Area | *5 Communication Center Area* | *6 Observation Deck (raised platform)*
7 Emergency Operating Center Area | *8 Observation Deck (movable)* | *9 Small Experiment Area*

Figure 3. Emergency Operations Research Center

Cameras in the EORC provide SDC analysts with information on participants' actions. Wired into the laboratory's own telephone switchboard are monitor cabinets allowing observers to listen in on phone lines assigned to them. Tape recorders are also connected to the phone lines to operate whenever the phones are used. A recorder started with the exercise gives the experimenters a time reference as a base for reducing and analyzing the data. Teletype input and receiving equipment, closed-circuit television, a 14-channel simulated radio system and a public address system allow observers and subordinate, lateral and higher echelons of authority to present messages to the group being exercised.

Observation decks designed specifically for this facility allow critics and students to note the effects of actions taken in the control of the simulated disaster. To prevent the presence of observers in the deck area from distracting the exercise participants in any way, the deck is provided with one-way glass and is completely soundproofed.

During the exercise, the participants represent the major service organizations of an actual city. Thus, the knowledge they gain during the exercise can help them improve real emergency operation plans. Personnel in the simulation area adjoining the operations area note the effect of participants' actions and also present new situations to the operating staff. These same people often assume the roles of the lateral, subordinate and higher echelons of command.

Digital Flight Simulator Study for the C-141A Jet Transport

SDC conducted a study of two different types of digital flight simulators for the C-141A jet transport, its purpose being to analyze, compare, test, and evaluate the two simulators from an overall system performance viewpoint. One of these simulators is activated by two medium sized general-purpose digital computers. The other simulator is activated by a special-purpose drum-instruction memory computer. The comparison includes an analysis and discussion of: (1) equipment characteristics, (2) mathematical modeling techniques, (3) software capability, (4) adequacy of system documentation provided, (5) simulator usage, and (6) acceptance testing.

Simulated Naval Plot (SIMNAVPLOT)

SIMNAVPLOT was developed by SDC as part of a research project involving a laboratory simulation of a Naval command post in operation, supported by a data base system and displays. The operational mission of the command post was the surveillance of ocean traffic, the classification of situations at sea that might require the alteration of tactical Naval forces, and the allocation of forces to respond to these situations.

SIMNAVPLOT was comprised of a simulated command-post staff and a computer program system operating under the AN/FSQ-32 time-sharing system to handle the simulated functions of surveillance, classification, of situations, force status monitoring, and force allocation.

The primary purpose of the data base and simulation development was to test the effect of variations in equipment configurations, staff composition and organization, and operting procedures on command post performance.

Digital Simulation for the Orbiting Astronomical Observatory (OAO)

In support of NASA's scientific space satellite program, SDC performed as technical advisor and as developer of software for ground-based computer control functions. In initial work, SDC performed an analytical research study to determine the computing system required in support of the Orbiting Astronomical Observatory.

A major product of the project was a Digital Acceptance Test System (DATS), which was composed of an acceptance test plan, acceptance test specifications, and a simulator of the spacecraft and control station system. DATS testing was extended to the OAO's Operational Control Computing System (OCCS), the system that controlled spacecraft operations in orbit. The DATS provided digital simulation of all OCCS functions, including the transforming of experimental requirements (list of stars to be observed, etc.) into commands to the spacecraft, reading out status and experimental data, pointing the spacecraft in the proper direction, and monitoring spacecraft status.

Model for Scheduling Satellite Tracking Operations

This model is designed to schedule the major equipments and operations of a satellite tracking network by means of computer simulation. Inputs to the model define such factors as the scheduling period, stations, satellites, priorities, and equipment usage. The model performs many functions that make it valuable as a planning tool. Among these are the following:

- Computes the rise and set times for every pass that each vehicle makes over every station.

- Detects conflicts in which:

  (a) two or more vehicles are over the same station at the same time,

(b) two or more stations would see a vehicle at the same time,

(c) the radio frequencies of two or more vehicles would interface.

- Resolves the conflicts among vehicles and stations by means of a variety of priority schemes, dependent upon the values of certain input parameters.

- Produces summary and statistical data on utilization of system equipment.

- Schedules for as many as thirty-six vehicles and thirty-six stations in operation at the same time.

- Permits selective suppression of outputs.

- Provides for orbital parameters to be input by various modes to suit the user.

Airborne Warning and Control System (AWACS) Simulation Vehicle

A ground-based or airborne command and control system is simulated for the control of friendly fighter aircraft. This system can maintain radar surveillance of the airspace, and direct friendly aircraft in accordance with pre-defined algorithms.

Friendly fighter aircraft on ground alert may be simulated and assigned to hostiles that are being tracked. After assignment, a fighter is scrambled and is directed to intercept the hostile aircraft. Upon reaching the vicinity of the hostile, a combat phase maneuver is simulated. At the end of the mission, the fighter is either placed on Combat Air Patrol or returns to the nearest base, depending on its weapons and fuel status.

Operator intervention is provided. The AWAC aircraft flight path and the routes and assignments of the fighters can be controlled to simulate differing operational concepts and tactics.

Some events that occur in an air battle are predictable only on a statistical basis, and a Monte Carlo routine handles such events. As an example, friendly airborne aircraft are subject to abort throughout their flight on a random basis, at some prescribed rate, requiring the control system to reassess the tactical situation and perhaps make a new assignment.

Statistical analysis techniques have been devised to allow a maximum of information to be extracted from each simulation exercise or series of exercises. Using such techniques, statistical confidence factors can be assigned to the validity of hypotheses derived from the simulation results, and expected-value relationships can be derived from a limited number of exercises.

The simulation vehicle has been used as a took in refinement of the Operational Employment Concept for AWACS in continental air defense.

The sensitivity of system effectiveness to tactics and to hardware parameters has also been examined.

A Dynamic Computer Model for Simulating Military Command Systems

This model simulates a command system comprised of a command post and a network of subordinate weapon control centers, weapon launch platforms, weapons, sensor, and their interconnecting communication links. Its major purpose is to serve as a general simulation tool that can readily be adapted to simulate a variety of command systems and conflict situations. As such, it can aid in evaluation of performance and effectiveness of command-control systems, operating as vulnerable networks in dynamic conflict with a reactive enemy.

The model's programs are highly parameterized, so they can be adapted conveniently to simulate many different types of military systems and conflict situations. It operates in either of two basic modes: (1) as an algorithmic model in which its programs run as a closed system within the computer; and (2) as an open simulation, in which humans in the command post interact "on-line" with the program system. The humans monitor the simulated conflict situations, as reported by the modeled sensors and weapon control centers, make special requests for information, and issue orders to commit weapons or to change their level of readiness.

The approach used in design of computer programs follows closely the philosophy set forth by several simulation systems such as SIMPAC (SDC), SIMSCRIPT (RAND), and the General-Purpose Simulation System (IBM). The functional design for the model was first interpreted in terms of four basic simulation concepts: (1) Activity, (2) Operational Resource, (3) Queue, and (4) Message.

An Activity is a basic information processing task in a flow network; it is distinct from the Operational Resource that is utilized by the Activity. In this model, an Activity is a program under direct control of the cycling routine; examples are the Engaged Sensor Activity, the Launch Control Center Activity, and Weapon Flight Monitor Activity (all in the Engagement Analyzer). The cycling routine is responsible for sequencing operation of Activities in time and for monitoring the model clock.

An Operational Resource is the simulated man and/or machine that actually enables performance of an Activity. The Operational Resources are distinct from the Activity itself, and are maintained in the system data base. Examples of Operational Resources are sensors, weapons, and communication links.

A Queue is a waiting line in which information to be processed is kept, and in which information already processed is placed. Most Activities have both input queues and output queues. Paths indicating flow of information through the system have been defined, when all Activities and Queues in the system to be modeled have been described.

The last modeling concept is that of Messages that flow through the system. Messages are generated by Activities, transferred between Activities through Queues, and then received and operated upon by Activities. Examples of types of messages in this model are the detection reports generated by sensor activities and orders to launch weapons generated by the Scenario (or humans).

The control program contains the Event Cycler, which controls the sequence for operating the functional modules and the input-output programs. During a simulation run, the Event Cycler checks each functional module and input-output program, in turn, to see if it is ready to operate. If, as a result of this check, the operation of a particiular functional module is required, the Event Cycler allows the module to initiate and complete the necessary computations, and then it resumes control. For example, if an order to fire a weapon has just been received by the weapon platform module, it will be ready to operate (that is, "fire" the weapon) when it is next checked by the Event Cycler. If the module is not ready to operate (for example, no "firing" orders received), it is bypassed and checked again during the next "cycle". The Event Cycler operates some of the functional modules on a periodic basis, that is, every Δ t minutes, where Δ t is a parameter. An example is the functional module that "moves" the weapons through space.

All messages that flow between functional modules in the system are sent through the communications module, where appropriate delays are introduced. The communications module stores messages in temporary buffer storage, and sends them on after the appropriate time delay has passed, but only if the communication link is operating.

Simulation of a Time-Sharing Computer System

After the initial SDC Time-Sharing System became operational, a simulation model was constructed to predict and evaluate effects of proposed system design and hardware configuration modifications. As an evaluation tool, the model:

- Creates a work-load environment by producing a series of entities, called jobs, with exponentially distributed inter-arrival time. Each job may queue up as backlog but eventually is assigned to system channels, where it passes through the various stages of logling in, loading, and repeated service cycles.

- Creates a hardware configuration. The configuration is parameterized with respect to such factors as number of channels, core and drum size, and access and word transfer rates. Equipment configuration malfunctions are generated. The run duration, recording, and data reduction functions are also parameterized.

- Generates events (job arrivals, computer malfunctions, and service requests at the channels) in simulated time with processing taking place on a next-event basis.

- Outputs both to the teletypewriter and to tape include a running account of major events to the teletype, permitting the user to monitor the run; more detailed recorded data directly to tape; job generation, completion, and back-log counts, yielding throughput information; individual job arrival and completion times to give some measure of turnaround time; demand and response-cycle distribution to measure system operations; percentages of time spent on swapping, service, overhead, and idling, to measure computer use.

NORAD Desk Top Exercises

The NORAD Desk Top Exercises are designed to present a realistic, continent-wide battle simulation to the North American Air Defense System's Combat Operations Center. They are also designed to actively exercise the entire NORAD system. Plans for the exercises are developed jointly by NORAD and SDC. Designers and planners at SDC, working closely with NORAD headquarters, formulate and produce a comprehensive as well as detailed description of the Desk Top problem, a set of simulation procedures and the requisite problem input tapes, films and other aids for the entire exercise. A unique simulation facility, which includes seven large-scale computer-based simulation models, is used in the production of the inputs. During the exercises, simulation is supervised by local military personnel. The course of the exercise depends on the real-time reactions and inputs of NORAD personnel. SDC representatives are available at each facility for aid and consultation and also contribute extensively to the debriefings which follow the exercise. The Desk Top Exercises have evolved with the NORAD system from the comparatively small, manual Desk Top I to the huge, largely computerized Desk Top IX.

Vehicular Traffic Model

The Vehicular Traffic Study Project at SDC has developed a digital computer simulation model of a portion of a freeway diamond interchange. The broad aim of the vehicular traffic study is to develop some much-needed basic knowledge that can be used to provide a tool for research on freeway diamond interchanges--research promoting improvement of the geometric design of the interchanges themselves and development of effective control devices regulating traffic flow through them. The method of the study is to simulate traffic flow in a diamond interchange between a freeway and an arterial street, and to validate this model by field data.

Becuase of the sheer size of the physical area that must be examined, the number of vehicles involved, and the complexity of the task itself, the study has been divided into four phases or modules.

- Merging of an on-ramp with freeway traffic;

- Merging of an on-ramp with freeway traffic and an off-ramp with arterial traffic;

- Processing of all arterial traffic;

- Simulation of the operation of the entire interchange by appropriate combination of modules 2 and 3 above.

Strategic Mobility Planning Model (MORG-1)

SDC assisted the National Military Command System Support Center in developing, designing, programming and implementing a strategic mobility planning model. MORG-1 provides rapid calculations of time-phased movement requirements for the delivery of forces and supplies into specific areas, with estimates of the availability dates and units necessary to meet those requirements.

On a request from the Secretary of Defense to assemble a plan for deploying a specified force, the user will go to MORG-1 for information on the kinds and amounts of supplies that must accompany the force, and on where the supplies must be at a given time. MORG-1 will also yield information on the rate of supply that must be maintained during the force's deployment.

Urban Planning Model

The Los Angeles Department of City Planning has initiated a program of mathematical model development. The models, once developed, will assist city planners in the understanding of urban processes, and will also enable them to make better selections from among alternative plans. SDC is assisting the Department in the development and implementation of a residential location model. Simultaneous with model design, the needed data are being gathered from a variety of sources and converted to a form required by the model.

National Policy Formulation

SDC has developed a simulation vehicle for research purposes consisting of a socio-economic model of the American society, simulated major interest groups within that society, and exercise procedures enabling these groups to make decisions on given public policy issues during specified future time periods. Some examples of the policy issues examined in this research project have been the raising of tax exemptions; the reduction of the work week; the increase of federal aid to education; and the negotiation of arms control agreements.

Simulation of Large Social Systems

This research project (known as Leviathan) involved a large-scale simulation that represents the significant activities, organization, and communication patterns of hundreds of people. Functional responsibilities were specified for important decision-makers, whose roles were enacted by live subjects in one of SDC's laboratories. The subjects intervened in the computerized simulation through appropriate input/output and display equipment.

Data Processing System Simulator (DPSS)

The DPSS was initially designed to meet the needs of analyzing and developing the data processing requirements of the Project 465L Strategic Air Command Control System. It has subsequently been generalized to permit its application to other systems in various stages of design and development. Results have shown the usefulness of the DPSS in Project 465L and, in a preliminary manner, its usefulness on the Space Surveillance Project and the New York State Identification and Intelligence System.

The Data Processing System Simulator is a general-purpose computer program that can be used for the evaluation of a proposed new design or a modification to an existing design of a data processing system prior to making equipment selections or performing any significant computer program design. The DPSS can also be used to provide guidance in the design and development of a data processing system during the detailed design stages.

The DPSS can be used to determine the sensitivity of a data processing system's performance to various system loading or design parameters. In addition, the total system design, including the software and equipment portions, can be subjected to a rigorous analysis and evaluation early in the design process.

The flexibility of the DPSS in terms of the variability of both the inputs to be tested and simulation program logic makes this tool useful in the early stages of establishing data processing system requirements. It is a powerful tool in performing system feasibility studies, simulating the operations and performance of a computer-based data processing system, and in evaluating equipment and data processing software combinations as a function of system operational requirements.