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ABSTRACT

The purposes of this study are to identify and define viable remote browsing techniques and the requirements for an interactive medical information system that would permit the use of such techniques. The main emphasis is in the areas of: (1) remote viewing of page material; and (2) remote interrogation of fact banks with question-answering abilities. After considering a variety of alternatives, a remote-viewing design approach was found that appears to be feasible, economical, and eminently well-suited for integration into the Biomedical Communications Network. In the areas of question-answering systems the development of deductive and language-processing capabilities was carried forward in the direction needed to support the requirements of a drug-effects information system. A small data base was constructed, and the formal ability of the system to carry out language analysis and deductions on this base was demonstrated. (Author/NH)

EDUCOM

Research Memorandum

Biomedical Communications Project

MEDICAL APPLICATIONS OF REMOTE ELECTRONIC BROWSING

RM–1169

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ABSTRACT

This study is part of an R&D effort aimed at the ultimate development of a Biomedical Communications Network. The purposes of this study have been to identify and define viable remote browsing techniques and the requirements for an interactive medical information system that would permit the use of such techniques.

The main emphasis of this study has been in the areas of: (1) remote viewing of page material; and (2) remote interrogation of fact banks with question-answering abilities. After considering a variety of alternatives, a remote-viewing design approach has been found that appears to be feasible, economical, and eminently well-suited for integration into the Biomedical Communications Network.

In the area of question-answering systems the development of deductive and language-processing capabilities has been carried forward in the direction needed to support the requirements of a drug-effects information system. A small data base has been constructed, and the formal ability of the system to carry out language analysis and deductions on this base has been demonstrated.

Various aspects of the problems involved in the development and demonstration of remote browsing capabilities have been analyzed, and development plans have been outlined for remote viewing and question-answering subsystems.

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1. INTRODUCTION

1.1 BACKGROUND

Since 31 May 1968, Stanford Research Institute has been studying, under EDUCOM contract, the medical applications of remote electronic browsing. This study is part of the larger R&D effort supported by the National Library of Medicine (NLM) in which several different contractors are involved. Complementary roles for the various contractors have been defined by NLM; SRI's role has been to identify and develop viable remote browsing techniques and the requirements for an interactive medical information system that would permit the use of such techniques.

The main emphasis of SRI's effort has been on two capabilities that are potentially of great importance in facilitating user interactions with medical libraries, information systems, and education systems as well, namely:

(1) Remote viewing of text, figure, or plate material; and
(2) Remote interrogation of fact banks [illegible] stion-answeri[illegible] abilities.

In addition to the work in these two areas, consideration has been given to more general aspects of remote browsing, and especially to the problem of integrating remote browsing capabilities into a practical medical information communication system.

Shortly after the inception of work on this contract, SRI was invited to meetings at the EDUCOM facility in Bethesda, and there briefed by EDUCOM and NLM on the plans and objectives of the NLM R&D effort. We were asked to make our own efforts consistent with these plans and objectives. Of critical importance from the point of view of the SRI project was the emergence of the Biomedical Communications Network (BCN) as a central concept in NLM planning. The SRI work has therefore not been simply a study of remote browsing techniques in the abstract, but rather a study of remote browsing techniques within the context of the Biomedical Communications Network, as defined to us by NLM and EDUCOM.

1.2 SUMMARY

1.2.1 Remote Browsing System Studies

A biomedical communication system serves to connect a variety of users with a variety of needs to a variety of storage nodes with a variety of informational and educational materials. Time is a fifth dimension in this problem, since the users, needs, nodes, and materials are all in a process of rapid transition.

A biomedical communication system is essentially a multipurpose system, with a large and changing variety of functions to perform. Such a system cannot be designed merely by conglomerating a number of specific function scenarios. Usually one item in such a system has the greatest economic cost and also the greatest longevity. This item becomes a central theme of the design, even though it may represent a means to a variety of ends, rather than an end in itself. In our case, this element is the Biomedical Communications Network (BCN).

The Biomedical Communications Network must be accommodated in a general sense to the conglomeration of specific functions it serves, but each specific function must finally be accommodated specifically to the Biomedical Communications Network. In particular, remote browsing techniques must be accommodated specifically to the BCN if they are to have real application and significance.

If one studies such a system by defining a variety of functional scenarios and propagating them through it, it quickly becomes clear that still further integration is needed. It will not be economically possible to create unique and separate system capabilities for the multitude of functions to be served by the system. It is necessary to find common functional elements in the various missions of the system, and to condense design and development effort on these common, generic functional elements.

A rough analogy can be drawn here with the design of Naval ship systems. The ship itself, although only a means to a variety of ends, is the central and basic element in the design. The functional elements of a wide variety of missions are condensed, for the most part, on to a relatively small number of generic functional subsystems, e.g.: propulsion, navigation, fire control, and surveillance.

Our analysis of the biomedical communication system leads us to conclude that the most important generic functional element capabilities of such a system are question-answering and remote viewing. These terms are used here in a general sense, and do not imply any given specific implementation. A user in seeking to fulfill almost any need will start out by asking questions of the system (and expecting reasonably intelligent answers) and will usually end up (given the capability) remotely viewing text, figures, plates, or other video material, including in some cases ordinary TV.

In summary, we conclude that the most central and basic element of a biomedical communication system is the BCN itself, and that two of the most important functional element capabilities of such a system are question-answering and remote viewing. These capabilities should be designed to be generic and should not be limited to one or even just a few of the BCN functions. However, in the development of these capabilities it will be desirable to concentrate on a limited field of application at the beginning, in order to minimize the cost of developing experimental data bases.

A very preliminary configuration analysis of a biomedical communication system leads us to believe that it has a strong possibility of becoming economically feasible within the next five years. Some other preliminary conclusions are as follows:

(1) Regional centers are likely to be the primary, but not necessarily the exclusive, source of remote-viewing materials and facts.

(2) At least for the near future, hospitals are likely to be the primary receiving points where these materials will be used, with other biomedically-oriented institutions also being terminals of the BCN.

(3) The most needed additional communication capability of Biomedical Communication Network is that of dedicated TV broadcast channels (dedicated to the BCN,

not to an individual user), and in the near future cables represent a preferred mode of transmission, at least for local distribution.

Main Results: We have achieved what appears to be a practical and effective integration between an assumed Biomedical Communication Network and a proposed remote viewing system. Both the network and the remote viewing system are generic in nature and capable of carrying out a wide variety of medical information and education functions.

The development of both the network and the proposed remote viewing system appears to be strongly supported by current technological trends. Beyond that, there is reason to believe that technological trends and competition will lead to rapid reduction in the operating costs of both the network and the remote viewing system in the next five to ten years.

While we have not demonstrated this with the same degree of certainty, we believe that the proposed remote viewing display console will also play a key role in the development of medical information systems with question-answering capabilities, since interactive access is a key element of such capabilities.

Scope of Report: In Sec. 2.1, we outline the elements of a remote browsing system and a remote browsing development program, based on the results of this study. The problems of evaluation and demonstration of such capabilities are also discussed. A development program is defined in terms of approximate schedules for prototype development and feasibility demonstration.

In Sec. 2.2, the analysis leading up to our present browsing system conclusions is summarized. This includes such aspects as types of users, types of uses, usage rates, typical scenarios, network design implications, network parameters, and possible network configurations and costs.

1.2.2 Remote Viewing Techniques Studies

The objective of remote viewing technology is to deliver pictures to a remote user, on demand, in a rapid and economical manner. The intent is to give him an equal or better capability than he would have where the materials are stored.

It is assumed that remote viewing starts with the address of the desired page or pages known. A complete remote viewing operation can then involve at least the following suboperations:

(1) Finding the document;
(2) Transporting the document;
(3) Finding the page;
(4) Scanning at the source;
(5) Transmitting to the user;
(6) Storing at the user's station;
(7) Display processing; and
(8) Displaying at the user's station.

There are at least several, and in some cases hundreds, of alternatives for each of these suboperations. The net result is a very complex matrix of possibilities. Furthermore, there is a considerable amount of interaction between the various elements of the process. In this context, a study of remote viewing becomes to some extent a search for the best route through a maze of alternatives.

In choosing an heuristic to guide this search, heavy emphasis was put on system integration of the remote viewing function into the BCN. This has led us to a preliminary design concept that differs somewhat from the concept that was uppermost in our minds at the beginning of this study. The present concept, however, is completely consistent with our design objectives, and appears to offer considerable promise.

Some of the main features of the proposed design concept are as follows:

(1) The material to be remotely viewed is assumed to exist primarily in the form of microfiche with a factor of reduction probably greater than 20 (in the interest of compact storage and economical handling).
(2) Remote viewing images will be transmitted via the preexisting TV broadcast channels of the BCN, with cables likely to be a major mode of transmission in the near future.

(3) Actual picture transmission will be by frame-addressed or line-addressed units of video, so that one channel can at one time serve many different users responsively. This concept could also allow the economical, and simultaneous, servicing of a variety of education functions via the same TV channel.

(4) The remote viewing display will have the capability for full frame storage, and will therefore not have to be refreshed via the remote channel.

(5) The display will also have a capability for handling alphanumeric and simple graphical information, and insofar as possible will be compatible with other functions of the BCN and other hospital information requirements.

(6) The initial display design will be aimed at achieving minimum cost to the user within the hospital or institutional (multiunit display system) environment. Further technological advances will be needed to make such displays economic at the doctor's office (widespread use of cable TV may be the required development).

Main Results: After considering a variety of alternatives, we have found a design approach that appears to be feasible, economical, and eminently well-suited for integration into the Biomedical Communication Network. This approach provides the least expensive means for delivering pictures electronically that we have been able to envision. The design approach also appears to be highly compatible with BCN requirements for remote interactive access to various data banks.

A key concept in this approach is the idea of line- or frame-addressed video information, transmitted via a TV broadcast channel to a specific user. The key element in the design is a remote viewing display console, with full-frame (or multiple-frame) storage capabilities. In regard to the physical storage part of the remote viewing problem, our analysis has led us to a strong emphasis on high-density microfiche as a preferred alternative.

Based on these recommendations and assumptions, it appears that the most important next step in the remote viewing area would be the design, development, and demonstration of a remote viewing display subsystem to refine and prove out the design concepts.

Scope of Report: Sec. 3.1 outlines the elements and preliminary design parameters of a proposed remote viewing display subsystem, based on the results of this study. A prototype development, evaluation, and demonstration plan is also outlined and discussed, including approximate schedules for the proposed program.

Sec. 3.2 summarizes the analysis leading up to our present remote viewing conclusions. This discussion covers all aspects of remote viewing and not just the display and transmission concepts. Aspects discussed include presentation techniques, display techniques, channel requirements, page storage and handling, book or document handling, and the economic factors associated with various alternatives.

1.2.3 Question-Answering Techniques Studies

The objective of question-answering technology is to deliver answers to a remote user, on demand, in a rapid and economical manner. The intent is to give him a capability somewhat comparable to what he would have if he were talking to a knowledgeable person at the information source. The question-answering (Q-A) system will be complementary to an intelligent user in the sense that it will have somewhat limited (but formally accurate) reasoning abilities and an extraordinary memory.

Question-answering technology has a number of major elements, among which are:

(1) Language translation and synthesis;
(2) Theorem-proving in the predicate calculus;
(3) Interactive accessing techniques;
(4) Memory organization and search strategies;
(5) Language formulation for a given application; and
(6) Data base encoding.

Much of our question-answering effort to date has been devoted to improvements in language-translation capabilities, deductive capabilities, memory organization, and system software. Language formulation and interactive access have been given less emphasis, and data base encoding has not yet proceeded very far.

A small data base (approximately 300 statements about 25 antihypertensive drugs) has been implemented, and has been used in question-answering demonstrations. The ability of this system to analyze a limited version of natural English, form nontrivial conclusions, and answer has been demonstrated.

Because of the small data base, this does not constitute a complete feasibility demonstration. Several factors remain to be assessed. Most important among these are:

(1) The economic parameters of a large-scale system, including say as many as 60,000 statements about 3000 drugs, in terms of memory requirements and processing times;

(2) The language definition and control problems associated with very-large-scale systems, as we move toward more and more sophisticated types of question-answering; and

(3) The possibilities for the practical evolution of an applied question-answering system, starting from present capabilities and moving forward with concurrent developments in the various functional element areas.

Of the above items, (1) and (3) are the most critical. If it appears that a full-scale system would be economically feasible and if a practical way can be found to start from present state of the information system art capabilities and evolve toward more sophisticated Q-A systems, most of the other problems will be solved along the way.

Some light may be shed on the economics of a large-scale system by investigating the parameters of the Relational Data File recently implemented at RAND. This system uses a predicate calculus representation, and has some similarity to the Q-A approach used by SRI. It now includes

70,000 factual statements, and was designed to have a capacity of 200,000 statements. However, this system has much less powerful deductive and language-interpretation capabilities than the SRI system.

In addition, we believe that we see the outlines of a practical way to modularize the various elements of an advanced information system with question-answering abilities and then to carry forward the development of these various modules concurrently, with acceptable levels of development. This concept is discussed in more detail in the body of the text.

<u>Main Results</u>. We have carried forward the development of deductive and language-processing capabilities in the direction needed to support the requirements of a drug-effects information system. A small data base has been constructed, and the formal ability of the system to carry out language analysis and deductions on this base has been demonstrated.

This in itself does not establish the utility and feasibility of a system based on this technology. An important missing ingredient is the economic cost of data basing, storage, search, and processing in a very large Q-A file. However, a study of the above-mentioned Relational Data File may possibly allow us to arrive at crude estimates of these economic factors without actually building our own large data base.

Another important question is how one might move in an evolutionary and practical manner from present information system capabilities towards the more advanced capabilities implied by Q-A techniques. Our studies have shed some light on this question, and we believe that the feasibility or unfeasibility of an applied Q-A system, on some limited subject field, could be estimated with tolerable confidence in the course of the proposed five-month follow-on study.

<u>Scope of Report</u>: Sec. 4.1 outlines and discusses the elements of an applied question-answering system. A strategy for the evolutionary development of such a system is also defined, together with an approximate schedule of development and demonstration.

Sec. 4.2 reviews the results of our technology studies and data base definition efforts and outlines the future direction of work in this area.

2. REMOTE BROWSING

2.1 CONCEPTS AND DEVELOPMENT PLAN

2.1.1 Elements of Remote Browsing Development Plan

Out of the system and technology analysis that is summarized in the other sections of this report a number of key elements of a remote browsing system have been identified and recommended for further development:

(1) A television broadcast network with special features;
(2) A remote viewing display console and scanner;
(3) A remote viewing demonstration system;
(4) Question-answering system techniques; and
(5) A question-answering demonstration system.

2.1.2 Special Television Broadcast Network

The remote browsing concepts that have developed out of this study assume the existence of a special television broadcast network. The most difficult requirement on this network is that it be able to serve economically a population of users with relatively low density. A key mechanism in seeking to meet this requirement is frame- or line-addressed TV.

Capabilities: Such a network will first of all have conventional TV broadcast capabilities. In addition, it will have addressed broadcast capabilities to support remote viewing. Ultimately, it may be desirable to develop addressed broadcast capabilities to support question answering, for reasons outlined later. The first terminal points of the network should be hospitals and the like, and the ultimate terminal points should be all potential users.

Requirements: This network must be economical for a low-density population of users. It needs relatively high signal-to-noise ratios to support the use of frame-addressed TV. Multichannel capacity is desirable to separate the various types of usage and allow more traffic. Medical aspects may require some privacy.

Cable TV appears to be ᵉ best suited form of transmission for these requirements. Furthermo the expected development of cable TV might to a considerable extent erwrite the development costs of the network. Cable TV also could prov a basis for reducing the unit cost of a terminal in a doctor's office y making it look like a terminal in a multiunit system.

Timing: A special n work is not needed in the early stages of remote browsing system dev lopment. Technical evaluation of a display console can be accomplish enti ely in the laboratory. Technical demonstration could use a limi ed network on an ad hoc basis. Even for operational demonstration it should be possible to use a network of limited physical scope.

Recommendation: For rem e browsing, network development is not needed at present. More detaile de initions of addressed broadcast TV modes should be developed an their compatibility implications analyzed. It is suggested that a va iety of possible applications of addressed broadcast TV be explored by those concerned with overall Biomedical Communication Networks design, since this technique appears to be at a very interesting point on the curve of capability versus cost.

2.1.3 Remote Viewing Display Console

Capabilities: A key element of our browsing system concept is a remote viewing display console. This console should ultimately have the following capabilities:

(1) Video page reception, storage, and display;
(2) Alphanumeric generation, display, and interaction;
(3) Keyboard and control bug inputs; and (perhaps)
(4) Hard copy output.

The console should be compatible with all BCN functions, and (if possible) with other hospital information functions as well.

Requirements: The display terminal mu be economical to operate at a low density of usage, since it must wait for the doctor, rather than vice versa. It must minimize the load on the TV broadcast line and the central computer. It must provide very fast response and adequate quality for reading medical materials. If possible, it should be compatible with color TV.

The design concept outlined in Sec. 3.1 is intended to meet these requirements, at least in a hospital (multiunit) environment. Within a cable TV network the same design might even meet these requirements in a doctor's office. The design is based on competitive technology whose costs appear to be in marked downward trends.

Timing: This console is a key item in the first stage, and all later stages, of remote browsing system development. Since the evaluation of a display has strong subjective components, it would be difficult to simulate this console. An actual console is also needed as a test bed for the evaluation of alternative control and display details.

Recommendation: It is recommended that the design and development of a prototype console with video display capabilities be undertaken immediately. Compatibility with alphanumeric display should be maintained, and such capability should be added in time to support the later stages of system demonstration.

2.1.4 Remote Viewing Demonstration System

Capabilities: The next step, beyond display design, in the development of remote browsing capabilities is a remote viewing demonstration system. This would involve a display a small TV network, a computer-based search capability, and a page data base. For a very limited technical demonstration, the search capability and data base could perhaps be borrowed from an existing system; for any kind of an operational evaluation it would probably be necessary to create a data base specifically for the evaluation.

Ways and Means: For purposes of demonstration, the subject matter of the data base should be relatively narrow and of high economic value. One especially interesting possibility is page material on drug effects and drug efficacy. This would parallel, and possibly later integrate with, our present efforts in the development of question-answering techniques. Useful results could probably be obtained with a data base of 10,000 pages, stored, for example, on a single Houston-Fearless carousel.

Timing: Present plans envision completion of console design, development, and technical evaluation in approximately 17 months. Technical demonstration on an *ad hoc* data base could begin almost immediately after that, and an operational evaluation on a pilot basis could be undertaken perhaps 6-7 months later. Preliminary efforts for these demonstrations and operational evaluations should begin about a year in advance.

Recommendation: It is recommended that the subject and user scope for a pilot demonstration of remote viewing be decided in the initial five-month phase of the planned follow-on study. Preliminary efforts for both technical and operational demonstrations should then be undertaken in parallel with the development of the display console.

2.1.5 Question-Answering Techniques and Systems

Information systems with the ability to answer a variety of questions in a variety of forms are a much-needed component of a medically oriented remote browsing development program. The trend in medical practice and education toward less memorization and more use of on-the-job information is very strong, and could be strongly supported by this type of remote browsing capability.

Capabilities: Some of the main elements of the capabilities needed for such systems are:

(1) Natural language interpretation and synthesis;
(2) Deductive and problem-solving abilities;
(3) Hardware and software for interactive access;
(4) Special memory and search organization; and
(5) Subject language development.

The first two of these capabilities are the most technically challenging and least well developed. It is therefore logical that they receive special emphasis in an R&D program, and they have been given particular emphasis in our program to date.

A Paradox: Since the language-processing and deductive components of question-answering information systems have the farthest way to go in achieving their ultimate development potential, one could argue that development efforts should be concentrated exclusively on these components until they have "caught up." This overlooks the very great difficulty of fully understanding how to proceed in the development of these components without an environment that includes the other components noted above.

This paradox would have a solution if one were able to define an evolutionary Q-A system design concept that was tolerant of various levels of language processing and deductive capabilities, from the present somewhat limited capabilities to the more sophisticated capabilities of the future. We believe that such a system can be defined, and the explication of this concept will be an important effort in the initial five-month phase of the proposed follow-on program. This problem is discussed further in Sec. 4.1.

Recommendations: It is recommended that the work in language processing and deductive techniques be carried forward at a somewhat greater level of effort than was possible in our present, very limited program. This will provide one important basis for an increasingly sophisticated capability in question answering. More detailed recommendations relative to work in the applied question-answering systems area are given in Sec. 4.1.

2.1.6 Evaluation of Remote Browsing Capabilities

One of the most difficult aspects of the development of remote browsing capabilities is the evaluation and demonstration of these capabilities. It is important not to underestimate the time, effort, and technical sophistication that will be needed to accomplish this part of the job. Evaluation of remote viewing capabilities will be difficult. Evaluation of question-answering capabilities will be still more difficult.

It is useful to distinguish, and keep separate, at least four main stages in this process:

(1) System test;

(2) Technical evaluation;

(3) Technical demonstration; and

(4) Operational evaluation.

Consider these stages and how they might apply to the evaluation of remote viewing and question-answering capabilities.

System Test: The purpose of system test, as defined here, is to demonstrate that the system performs physically as it was designed to perform. This should be established definitely and positively before proceeding with any further stages of the evaluation process.

System test in the first stages of a remote viewing evaluation program will involve only the scanning, control, and display elements of the system, since the other components of the system will be missing or simulated.

System test of an applied Q-A system should involve all the elements defined in Sec. 4.1, and should demonstrate that the hardware and software components of the system meet their design specifications.

Technical Evaluation: The purpose of technical evaluation is to assess performance against utilitarian criteria, but with a limited system in a limited and controlled environment. During this stage, alternative design approaches should be evaluated with respect to their utility and cost.

Technical evaluation of a remote viewing display system could be carried out entirely in the laboratory, since it is not difficult to simulate the TV network and its traffic load. A very limited page data base should be used, because of the cost of implementing a full-scale data base.

The evaluation would principally be concerned with the suitability of display and control features. Since measures of these features are largely subjective, psychometric experiments, with their inherent difficulties, are involved.

Technical evaluation of an applied Q-A system also can be carried out entirely in the laboratory. For economic reasons the fact data base should be limited, but not to less than one-tenth of what is considered a minimum operational data base. Controlled experiments should be undertaken to determine performance parameters and the effectiveness of various alternative design features and operating modes.

Technical Demonstration: The purpose of technical demonstration is to acquaint a selected audience with the capabilities achieved in the previous stages, as a prelude to an expansion to an operational pilot system. This is a means for generating a base of interest and for obtaining qualitative critical feedback. It does not generally add much to the technical development of the system, and in fact it may actually slow development by a diversion of manpower and facilities.

Technical demonstration of a remote viewing system might, for example, be accomplished by marrying the basic display to a preexisting page data base and search system. It might also be accomplished by making a movie of simulated operations.

Technical demonstration of an applied Q-A system could be accomplished by allowing selected users to operate the system through remote terminals, for a short period of time, and with close guidance to steer them through the limitations of the system.

Since technical demonstration is not based on even a limited operational capability, it is easy to draw invalid conclusions from such demonstrations, and different observers will often come to considerably different conclusions. Technical demonstration is undoubtedly needed, but it is a technique that should be used carefully and sparingly.

Operational Evaluation: The purpose of operational evaluation is to test a small but complete capability against utilitarian criteria and user reactions in a real environment. For practical and economic reasons it is important that both the data base and the user base be kept as limited as possible in the first pilot operations of remote browsing capabilities. Initial emphasis should also be on medical information with especially high economic value.

A drug efficacy and effects data base could be an appropriate area of initial application for both remote page viewing and remote question-answering capabilities. The two capabilities might, in fact, be complementary on such a data base. As a specific example that makes sense geographically, one could consider automating some of the functions of the Drug Information Center at Moffitt Hospital of the UC Medical Center.

An interesting point is whether the initial pilot system should be aimed at the service group, viz., the pharmacists and pharmacologists, or at the ultimate users, viz., the practicing MD's. Ultimately, the system could be aimed at both, with the service group being the principal operators of the system and the MD's the principal users. It is suggested that this question be examined carefully during the initial five-month phase of the planned follow-on effort, and that a decision be made at the end of this phase.

2.2 SYSTEM ANALYSIS

2.2.1 Categories of Users

Potential Users: It is difficult to estimate the total number of users who in future could benefit from the services of a Biomedical Communications Network, since these services would represent a radical advancement over anything now available. However, the number should include an appreciable fraction of the approximately 2.8 million persons in health occupations (1966 estimate).[1*]

While many of these people would not make direct use of the materials now held by the Library, they would become potential users when the BCN is able to provide them with educational or informational materials on an individual computer-aided information (CAI) basis through the same facilities as are used to give access to conventional library materials. This possibility of multiple use for the BCN is discussed briefly in the following section.

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* References are listed at the end of the report.

Active Users: Those who can make immediate and direct use of the NLM library materials are probably limited to the approximately 300,000 physicians, 70,000 medical research personnel, and 30,000 medical students estimated by Herner[2] to be the "core audience." Initially, it is assumed that the remote browsing service and any concomitant health education service would be made available only at certain locations. This would be mainly at hospitals and other principal biomedical facilities, such as universities and government laboratories, where these 400,000 potential users congregate habitually, at least during a portion of their working day. Potential locations at which remote browsing of NLM materials and CAI health education might be offered are the following (approximate number in parentheses):

- Hospitals (7,160)
- Clinics
- Schools of medicine (91), dentistry (49), nursing (1,200), optometry (10), pharmacy (73), podiatry (5), and veterinary medicine (18)
- Medical libraries (6,300)
- Drug laboratories
- Public Health Service installations
- Government regulatory agencies in the health field
- Government defense establishments concerned with CBR warfare
- Government contractors working in the biomedical field.

As more organizations become involved with public health matters there will be a corresponding rapid increase in the size of the "core audience." This will be particularly true if the BCN is well established when this demand manifests itself.

2.2.2 Categories of Uses of the BCN

User Purposes: The volume of traffic that users and potential users bring to the BCN will depend on the quality of the services that are offered, the cost of these services (direct economic and effort outlay by user), the nature of competing services, and the user's evaluation of the worth of availing himself of each service. Armed with his own incomplete knowledge of these factors, each user presents to the BCN a market for one or more of its services. His specific demands will be the result of trying to satisfy, usually one at a time, four informational purposes:

(1) Maintenance of current awareness in fields of knowledge with which he is familiar,

(2) Search for specific information needed to solve a definite problem in hand,

(3) Self-education in an area with which he has limited familiarity, and

(4) Preparation of educational materials for others, e.g., bibliographies.

<u>System Capabilities</u>: A wide variety of information access services could be offered by the BCN to help users meet the above information purposes. The major categories into which such services, provided at a remote location, fall are:

(1) Rapid, automatic search of indices or catalogs of library materials in the NLM to retrieve selected references.

(2) Rapid, automatic retrieval of NLM library materials or their surrogate and their transportation to an electronic scanning station.

(3) User-controlled viewing of the material at the scanner.

(4) Expeditious access to a hard copy of the viewed material.

(5) Fact retrieval in certain well-defined areas of knowledge, such as drug effects, in response to questions posed in a subset of English.

(6) Computer-aided instruction, on an individual basis, coupled with individual progress recording.

<u>Modes of Use</u> If these informational services have the appropriate characteristics, they can be used in several different ways and in a variety of combinations to satisfy all of the four basic purposes of the users. For instance, if the capability for automatic search of

the master index of all NLM materials is to be of use in satisfying the first, second, and fourth of these purposes, it must allow operation in the following modes:

(1) Automatic search, based on the user's profile of interest (on file with the BCN), of the index to or description of all current issues of those journals that the user desires to have monitored. The user must be able to control the number of articles to be drawn to his attention as a result of this search. These notifications might come to the user through his remote viewing terminal when he called for them. If he wanted to read a particular article he could then view it on his terminal display.

(2) Automatic search of the index or other description of all NLM library materials (journals and monographs) to obtain a limited number of references to probably the best sources of certain specific information, indicated in the search pattern entered by the user.

(3) Automatic search of the index or other description of all NLM library materials to obtain an exhaustive list of all references to works on a particular topic, subject to a set of constraints imposed by the user in framing his search pattern.

Various ways in which the other system capabilities might be implemented and might be combined by the user to continue the fulfillment of his information purposes are outlined in Sec. 2.2.4.

Educational Use of the BCN: Studies of the way in which physicians schedule their time indicate that they squeeze their educational reading into small, irregularly spaced slots between their multitude of other activities. All other health services personnel have the same type of problems: They must fit constantly needed education into their work periods in which they have some free time but during which they are always "on-call." As a consequence, any educational service for the health community that is to share the BCN facilities and that is to use the remote viewing terminals must have the following characteristics:

(1) It must offer to each user an individual service paced to his or her rate of learning. This would presumably be done in a CAI mode.

(2) It should allow each user to end an educational session abruptly when called to other duties and to pick it up again exactly where he left it merely by logging into the system anew.

(3) It must keep track of the user's educational progress in a variety of subjects learned as indicated in (2), above, so that formal recognition of this progress can be given.

(4) It should provide educational materials that include alphanumeric information and graphical images at or near the user's normal work station.

(5) It should operate compatibly with the remote browsing functions on both the TV broadcast facilities and the low-bandwidth control circuits of the BCN.

If educational services with the above general characteristics can be offered in parallel with the remote browsing and Q-A services, the potential users can include, in addition to the 400,000 persons in the "core audience," a major part of the 2.8 million in the health care field.

2.2.3 Estimates of Usage Rates

Competing Information Sources: In attempting to satisfy his four major informational purposes (current awareness, specific information, self-education, and information for others), each user has a variety of information sources to which he can turn. They compete with one another for his attention and patronage. This competition is on the basis of a complex of factors, not the least of which is his momentary evaluation of the worth of time and of the incremental value of the better information he may get from each source. Among the information sources that will compete with the remote browsing and Q-A services of the BCN are the following that are easily accessible to the potential user:

(1) The knowledge that he retains in his own head, or notes;
(2) Handbooks, standard texts, reviews, and data sheets from drug houses that he retains near his normal work station;
(3) The knowledge of his colleagues who are readily accessible to him;
(4) Current biomedical journals held by the user; and
(5) Standard library materials close at hand.

Within the BCN there will be a certain degree of competition between the remote viewing services (human-directed, machine-assisted information retrieval directly from the original library materials) and the Q-A services both in their retrieval of facts from tables and in their discovery of facts by inference. Is it quicker, more convenient, or more reliable for the user to look up and puzzle out the answer from a handbook or to get it from the Q-A subsystem directly?

Informational Activities of Physicians: Only a limited amount is known of the ways in which physicians satisfy their major informational purposes. Up to 1962 virtually no inquiry had been made into physicians' information needs. Herner[2] reports that a number of surveys indicate that the average practicing physician spends four to five hours each week reading current medical journals. Some of the information that the physician absorbs in this reading represents knowledge that he feels he must have at his finger tips, either to improve his moment-to-moment practice of medicine or to be aware of information pertinent to his work. However, if any of the information that he gains in this way and is forced to remember, could be made rapidly and easily accessible to him via the BCN remote browsing services, the use of these services might profitably displace some fraction (as yet unknown) of the 240-300 minutes he spends each week in reading current journals. This displaced fraction would not need to be very large before it would represent a considerable load on the remote browsing system.

Smith[3] has observed that the staff of 25 hospitals served on an interlibrary loan basis by the Wayne State University Medical Library make requests of their own hospital libraries that result in only eight interlibrary loan transactions per staff member per year. She also notes that only 11 percent of the hospital staff take advantage of the service. For interns at the same hospitals the figures are 10 loans per item per year with 30 percent participation. Her figures indicate that scientists in the academic community generate 134 requests on their libraries each year (Purdue University). If we take this request rate to pertain also to the 70,000 medical researchers noted earlier, if we assume that 37 percent of these will participate (50 requests per year), and if we assume that the BCN remote viewing services will be used at the same rate as interlibrary loan transactions are generated, we calculate that approximately 15,000 persons will use the viewing services each day.*

The foregoing figures merely give an indication of a probable lower limit in the demand for BCN remote browsing services. The very existence of these services could grossly affect the information-gathering habits of practicing physicians. If, on the average, each physician spent $\frac{1}{2}$ percent of his time per day using the BCN services the daily usage would jump from the assumed low of 15,000 to 150,000.

If each of the approximately 3 million health services personnel uses the BCN system for educational purposes for only one-half hour per year, 600 additional users will have to be accommodated on the system simultaneously at peak hours. This is about four times as many as are implied by the usage rate of 15,000 remote viewing per day.

<u>Distribution of Traffic</u>: Forbes and Bagg[4] give figures for the use of NLM materials by those having direct access to and by those distant from the library that indicate great differences in the use of the library by each group. Among the "outside" group 95 percent of the traffic is to journals and the remainder to monographs, while among the "insiders" the same ratio is 20/80. Orr[5] believes that 150 journals will answer 80 percent of the requests received by medical libraries. While most of those with whom the authors of this report spoke think that 90

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* Assumes 250 active days per year.

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percent of the remote viewing traffic can be accommodated by 10 percent or less of the total NLM collection, it remains to be shown exactly how this small percentage should be constituted once the monographs are available readily to outsiders.

2.2.4 Some Typical Use Scenarios

Conventional Selection Process: Unless a book, document, or journal is chosen for remote viewing at random or according to the user's memory, several aids inherent to a library system are normally consulted before the selection is made. Similarly, before a page of the book or journal is chosen for scanning, clues (tables of contents, indices, etc.) to the arrangement of the subject matter in the book are used.

Conventionally, the selection of a book for closer inspection is preceded by an examination of cards in the catalog of holdings. These cards are arranged lexically according to title, author, and broad subject categories. This arrangement can put the cards for books on unrelated topics in close proximity. However, the notation on each card of all the subject categories under which it has been cataloged is of some help in determining its contents and consequent interest to a user.

There are a number of ways in which a user may proceed in selecting for viewing the specific pages of those books that most probably contain the information he needs. For example, we can imagine four possible scenarios of his search, described as follows:

(1) Examination of the master index in digital form to locate the section of the card catalog to be searched. Inspection, in a serial fashion, of the cards, in digital form, in that section of the catalog to locate say, the ten most probable volumes. Call for the microform representation of these ten volumes in turn. Examination of the table of contents of each in turn to determine which ones are worth looking at further. For the probably useful volumes, search of the index for the page or pages to be scanned. Scan of the appropriate pages [illegible] subject

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headings and other clues as guides to the location of the segments to be read in full.

The above is a concise description of how a normal library search is conducted, except that rapid retrieval of a microform image of the volume has been substituted for physical retrieval of the volume from the shelf. This latter procedure has been concluded to take far too long to be practical for any but the rarely called for items and will, therefore, be eschewed in all scenarios.

(2) Same procedures as for (1) up to the point where the table of contents is to be examined. At this juncture the table of contents in digital form is inspected by the user on his display console. On the basis of this inspection, select only, say, three volumes for viewing out of the ten chosen as a result of consulting the card catalog. Once this selection has been made the previously followed procedures are pursued.

(3) Same procedures as (2) to the point where the book index is consulted. Examine book indices in digital form to select the actual pages to be scanned and read in the manner already described.

(4) Search query composed by the user of a logical combination of index or descriptor terms. An automatic search is then made to return to him the references to, say, the three most probably useful volumes. From that point the user proceeds as in (1).

An examination of the probable times needed to accomplish searches for information according to the above scenarios indicates that:

- Rapid retrieval of the most frequently called for volumes is required to cut the cost of the user and to prevent him from having to enter the queue for the system again when the volumes he wants are finally brought to the scanning station.

- Automatic search of an index to the collection that goes down to the level of the chapter of a book or to an individual journal article brings the greatest saving in time for the user.
- The other automated functions (digital access to table of contents and to the book index) bring only secondary savings in time.

2.2.5 Implications for Network Design

The figure of 15,000 usages of the BCN per day for remote viewing was based on the assumption that costs were comparable. Users would employ the network at least as often as they now appear to call on interlibrary loan services. Analysis indicates that it is quite possible that the response time for a user to get to exactly the piece of information he wants can be of the order of five minutes instead of several days for the interlibrary loan. Consequently, it seems not unreasonable to assume a several fold increase in the demand for the BCN remote browsing service. Consequently, a figure of 60,000 usages per day has now been chosen as a working figure. This corresponds to approximately 300 users on the average searching the master index simultaneously during a peak hour. At the same time 200 users will be in the remote viewing mode simultaneously (possibly 400 during a peak minute).

Using these figures, we can see[6] (Sec. 9 of Appendix 4.5) that more than one TV line or circuit will be needed. Calculations indicate that a minimum of three regional centers will be needed, in addition to the NLM center, to serve the whole country properly, and as many as ten might be desirable. The quoted usage rates figures indicate that if the users are to be served properly, each center must be capable of conducting a search of the master index every second during peak periods. This fact in itself seems to indicate the need for a separate computer, each equipped with a large amount of rapid access memory, at each center.

Rapid access must probably be provided to about 3 million pages of NLM library material to satisfy 90 percent of the inquiries. This volume of material, stored on conventional microfiche (24:1 reduction ratio), would, for example, occupy 50 Houston-Fearless automatic storage and retrieval units. However, the number of pages that may have to be viewed in a peak minute will call for 120 such units together with the associated scanning TV cameras for converting the optical images to electrical signals. This number may be reduced if a convenient way is found of removing the fiche from the retrieval unit so as to allow release of that unit to another user while the fiche is being viewed. However, the figure of 120 units has been used to provide a crude, but conservative, estimate of the costs involved and to show how each element of the system contributes to those costs. It is not implied that the system would necessarily employ this equipment and sharing technique.

2.2.6 Communication Network Parameters

As indicated in the SRI interim status report[6], (Table 3, Appendix 4.4) the average nationwide cost of linking a hospital to NLM or to one of the regional centers is expected even at present to be not more than $1,000 per month or approximately $45.00 per day. If only hospitals in the more densely populated areas of the country are served initially, the cost can possibly go as low as $27.00 per day, based on FCC Tariff No. 216 and the hospital distribution figures given in the SRI report referred to above. Widespread introduction of cable TV, in the next few years, could drastically lower these costs.

Each such separate TV broadcast circuit will support 250 users simultaneously in the remote viewing mode. One or several such separate circuits would originate at each regional center.

In addition to the TV broadcast network, the remote browsing system requires a voice-grade, duplex, data-transmission channel to each hospital for the exchange of control signals and digital information. This can be implemented by a direct dial-up connection from the hospital console. Alternatively, it can be provided by a leased line time-shared among groups of hospitals. Some combination of the two methods would probably be used in practice. The average load on this control circuit is likely to be quite low. However, it can also serve the needs of the Q-A subsystem and conceivably also those of CAI educational services with which remote browsing, hopefully, can share the TV networks. A cost of 5 percent that of the TV network has been assigned to this control network.

2.2.7 Network Configurations and System Costs

A nation-wide TV broadcast network, served solely from NLM and using several branches or main circuits, could possibly be implemented, but the peak load of 300 users simultaneously in the search mode would require over three automatic searches per second. This might be achieved by three separate computers that would split the load among themselves. However, there are considerable advantages to be gained from using a number of regional centers, each equipped with one computer and the microfiche retrieval and scanning gear for the most sought after material. NLM might also act as a regional center for the hospitals in the Washington area, but its primary role would be to make searches over the index to the little used portion of the NLM collection not held in the regional centers, to act as a backup.

Basic Costs: It is assumed that each center has the following complement of equipment at the costs given:

1 computer for searches	$1,500,000
Rapid access storage	1,000,000
120 microform storage and retrieval units	600,000
120 1000-line TV scanners	600,000
1 scan converter/TV interface	50,000

The viewing console at the hospital has been estimated to cost $20,000 (1975 costs) if only one unit is installed at each hospital. If ten units are installed, with nine used for the hospital information system, the unit cost will be $5,000, since character generator and disc storage can be shared among the ten.

Comparison of Costs of Major Modes of Operation: Five possible modes of operation will be costed on the basis of the use figures already given. These rough cost estimates show two important facts:

(1) The elements that contribute the greatest share to the total cost.

(2) The sensitivity of the cost per usage to the total browsing traffic.

Case 1: Assumptions: (a) remote browsing assumes the entire cost of the TV network, the regional computers, microfiche equipment, and the hospital console; (b) $8\frac{1}{2}$ uses per hospital per day on the average; (c) TV circuit costs $45 per hospital per day.

Cost per usage

Computer	$0.11
Memory	0.05
Scanner	0.09
Console	2.67
TV circuit	5.30
Control circuit (phone line)	0.75
	$8.97

Case 2: Assumptions: (A) hospital information system shares the cost of the consoles, (b) other assumptions as in Case 1.

Cost per usage

Computer	$0.11
Memory	0.05
Scanner	0.09
Console	0.10
TV circuit	5.30
Control circuit	0.75
	$6.40

Case 3: Assumptions: (a) hospital information system shares console costs; (b) education at CAI use of the TV circuits reduces their costs to 57 percent of former value; (c) all other assumptions as in Case 2.

Cost per usage

Computer	$0.11
Memory	0.05
Scanner	0.09
Console	0.10
TV circuit	3.02
Control circuit	0.75
	$4.12

Case 4: Assumptions: (a) remote browsing pays all costs; (b) hospitals in SMSA's in N.E. and Mid-Atlantic Census Divisions only served.*

Cost per usage

Computer	$0.11
Memory	0.05
Scanner	0.09
Console	0.69
TV circuit	0.46
Control circuit	0.19
	$1.59

Case 5: Assumptions: (a) hospital information system shares console costs; (b) educational usage of the TV circuits reduces their cost to 57 percent of present value.

Cost per usage

Computer	$0.11
Memory	0.05
Scanner	0.09
Console	0.10
TV circuit	0.26
Control circuit	0.19
	$0.80

* TV line cost $26.30/day; users per day = 18,000; users per hospital per day = 33 (average).

These figures make quite clear where the major costs lie and point to the importance of sharing the fixed costs at the hospital and especially those of the TV network among as large a number of users as possible. The figures cannot reliably be refined until the manner in which index searches are to be carried out is determined. Even under the favorable conditions assumed for Case 5, the dominant cost of the TV circuit is clear, but technological trends could markedly reduce TV channel costs over the next several years.

Nevertheless, a comparison of those costs with those experienced in borrowing books by interlibrary loan ($2.00 per book) shows that even in Case 1 costs are not out of line when one realizes that they yield rapid (five minute) access to exactly the information the physician needs. Three books from interlibrary loan may take several days to reach the physician, cost about $6.00 and not necessarily bring the needed information. The remote browsing service will fill an unmet need and should attract new customers.

3. REMOTE VIEWING

3.1 CONCEPTS AND DEVELOPMENT PLAN

3.1.1 Approach

As has been indicated earlier in this report, remote viewing is a particular part of the total remote browsing concept. It is a new element being proposed for reference retrieval and for the dissemination of educational materials. It provides facility for a doctor, after he has obtained a list of potentially pertinent references through a file search, to examine these for true pertinence. Since the doctor is presumed to be at a hospital distant from the library or regional center where the documents are held, he can only look at them through the medium of a television-like communication and display system.

In the initial approach to the remote viewing problem, it was hoped that a means could be found whereby remote viewing could be accomplished over narrow-bandwidth communication circuits. After careful study, it was concluded that any narrow-bandwidth system would almost certainly be economically and operationally unsatisfactory. A system using eye tracking, for example, might conceivably permit sending only moderate sized "windows" of high-resolution information in response to the user's eye motions, but these would have to be transmitted very rapidly if the user were not to see an intolerable time lag; eye tracking, then, appeared at best to be only one possible way of time sharing a wideband communication circuit among many users. Other time-sharing methods offered nearly equal capabilities, with better prospects of early implementation, once the decision had been made to go to time sharing of wide-bandwidth circuits. The effective bandwidth required per user can be relatively low, perhaps in the order of 16 kHz if 250 users share a 4-MHz circuit. Clearly, however, the selection of the optimum methodology is very sensitive to estimates of total amount of usage expected.

The question of whether the display can be of standard 525-line commercial television resolution, or whether it should instead use a higher resolution, was considered at some length. The conclusion, based on tests at SRI and other places, was that the resolution of 525-line commercial television would be marginal in many cases. If the material is columnar, however, and only a part of one column is presented on the screen at one time, better results can be expected; the 525-line resolution system is therefore not at present considered to be ruled out of consideration. The final decision can only be made on the basis of actual tests carried out with equipment that is or simulates the operational configuration contemplated. These tests must include techniques and equipment needed to move or zoom the camera field to a selected part of the page, since the facility with which a user can perform these operations will strongly affect user satisfaction with the system.

Reference is made to the memorandum to file dated 8 November 1968, entitled "Remote Viewing Technique, Electronic Browsing," by J. H. Jones. A proposed viewing system is discussed in some detail there, together with some of the major considerations that led to its selection. It involves use of 1000-line resolution pictures, time sharing of a 4-MHz communication circuit by up to 250 users, facilities for moving the camera field to selected parts of a page, and display refreshment using a local disc storage unit at the hospital. Two possible storage techniques are discussed, one digital and one analog, and it may be noted that the analog storage technique would be suitable for use with a 525-line commercial television resolution system.

3.1.2 Display and Time-Sharing Concepts

The crucial aspect of the display system is its operational suitability and the effect on system cost of measures taken to achieve operational suitability. The operational characteristics of the system under consideration will accordingly be reviewed briefly here.

In discussing the system, it will be assumed that the user has completed his search process, that the book or magazine chosen has been obtained from the stacks or microfiche files at NLM, that the desired page has been found, and that the material to be viewed is in front of a television camera at NLM. This defines the initiating instant; that is, the first instant when a video representation could be sent to the user. This initiating instant will hereafter be called <u>time zero</u> for the document page (as distinguished from a video frame) in question.

The user, sitting at a viewing console, sees the operation of the system as follows. First, after a delay of perhaps half a second after time zero, a coarse representation of the page appears on his screen. This is a presentation in too low a resolution for actual reading, but in enough resolution to show where lines of text, headings, graphs, pictures, or equations appear on the page. This image is painted onto the viewing screen in a thirtieth of a second. Within a tenth of a second after that presentation is completed, high-resolution scanning of the page begins. The coarse picture does not disappear; the detail is merely filled in on it by the high-resolution scan process. High-resolution begins at the top of the page, and progresses downward at a rate of roughly one-fiftieth of the display screen height per second. Thus, if ten inches of a document page were in the camera field, the high-resolution presentation would develop at the rate of a fifth of an inch of document page per second; if lines of text on the document were spaced six to the inch (a typical figure), the user would be able to read the material as it came into high resolution at a rate somewhat greater than a line of text per second. This is a relatively high reading speed for the average man.

A visible mark, or <u>cursor</u>, is presented on the left side of the viewing screen. The cursor automatically progresses downward with the high-resolution scan process, so that it always indicates the part of the document being brought into high resolution at the instant in question. The user has a <u>joystick</u> control that permits him to force the cursor to a new position--for example, to force it down the page in such a way as to skip some material. In this case, the high-resolution scanning process will continue at the same rate as before, but progressing downward now from the point to which the user directed the cursor, and leaving a part of the page in low resolution between the two high-resolution parts. The user may also, if he desires, force the cursor back up to resolve a portion he previously skipped. In short, the user may sit and read for the fifty seconds required to bring the whole page into high resolution, or he may take his cues from the coarse overview and scan the page at will by skipping to parts of greatest probable interest.

The resolution offered in the display will be approximately 1,000 lines by 1,000 picture elements per line. Depending on the material being viewed, this may not be sufficient to permit comfortable reading with the entire document page in the camera field. The user will therefore have means for selecting a portion of the page for enlarged viewing; he will select the desired portion on the basis of the coarse overview of the whole page. Details of the controls to be provided to him have not been finalized, but one may visualize a frame that he can adjust in size and push to the desired position, plus an implementation pushbutton that causes the selected area to be displayed to him and simultaneously causes the controllable frame to retract out of sight. The time at which he presses the implementation button becomes the new time zero for the selected page segment, and thereafter he sees the same sequence of events as was described heretofore for the whole page view. He again gets a coarse overview, after a short delay, followed immediately by a downward progressing high-resolution scan. He has the same cursor and cursor control facility as for the full page. Means would be provided for returning to the coarse overview of the full page, when he was ready to select a new part-page enlarged view.

The speeds indicated in the foregoing description are those that would be seen by a user when the system was heavily loaded (250 users sharing, with equal service to all, a standard 4-MHz TV channel). Provisions exist for providing two, three, or four times those speeds, or more, in off-peak hours when few users are requiring service. As presently envisioned, a computer controlling the whole system at NLM would allocate service among users, automatically providing better service when fewer users were active. However, priority schemes are also possible, whereby a user may call for greater speed if he is willing to pay a higher price. No hardware changes are required to increase the speed of service selectively or across the board; it is all under control of the NLM computer. The maximum possible speed of service would provide a selected

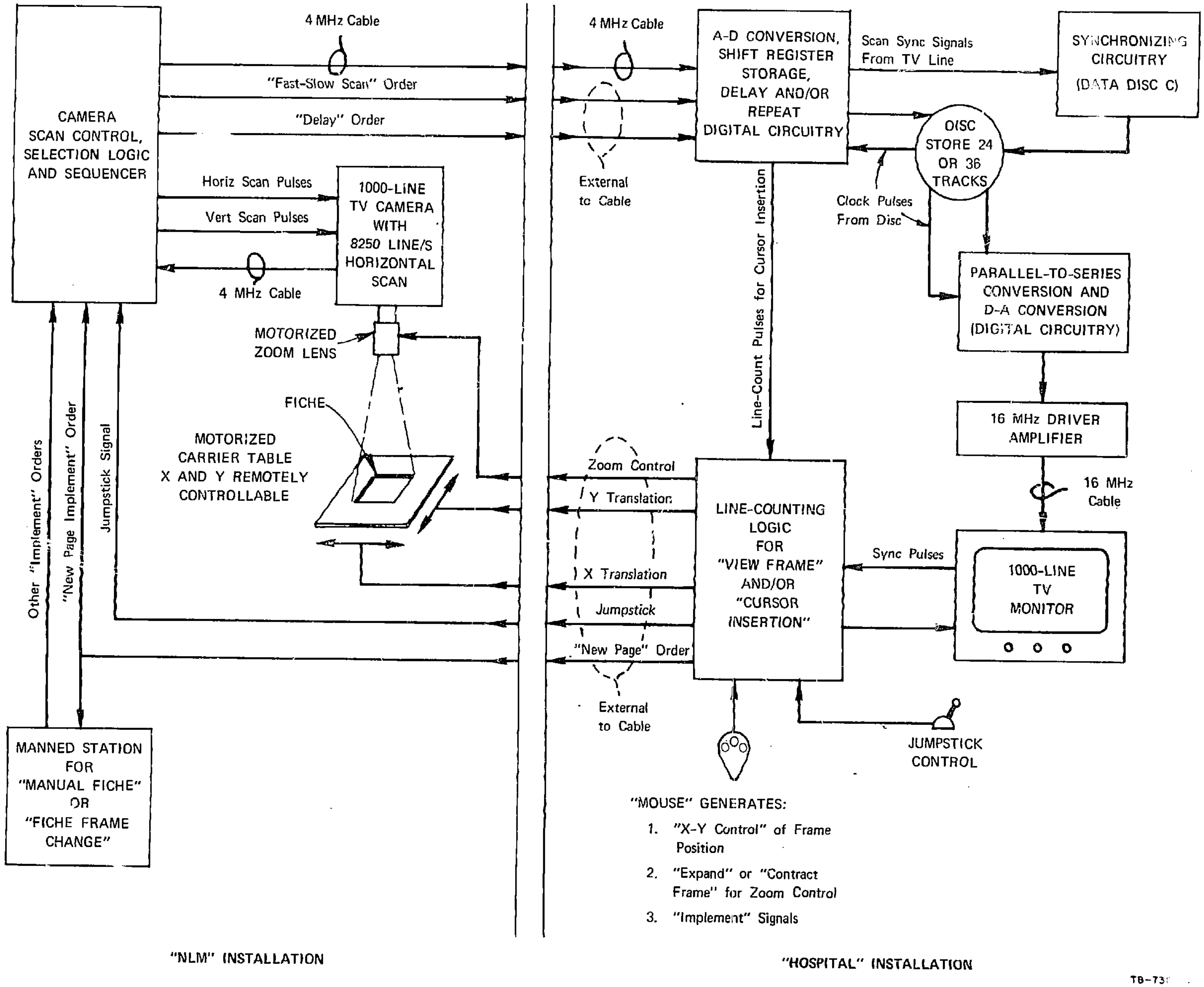

Figure 3.1.1 PROPOSED DEMONSTRATION VIEWING SUBSYSTEM

user with a complete high-resolution picture within roughly a quarter of a second after time zero.

3.1.3 Display Development Plan

It is planned that a test and demonstration complex of equipment will be developed and built to prove out the operational suitability of the system and to determine satisfactory values for required resolution, number of gray-scale levels, and related points. Both the analog and digital storage versions of the system will be implemented, most of the basic equipment being common to both. The memorandum mentioned in Sec. 3.1.2 explains the systems on which the demonstration equipment selection was based. The following additional comments apply to the equipment that will be procured and/or built for the demonstration complex. Figure 3.1.1 shows a block diagram of this equipment.

The TV camera, nominally of 1000-line resolution capability, will be scanned horizontally at a nominal rate of 8,250 lines per second for both the analog and digital storage demonstrations. Vertical scan will be at nominally 30 frames per second for the digital system and 7.5 frames per second for the analog. It is expected that additional interlace to divide each frame into two fields, as in conventional television, will be incorporated.

No line or frame addresses will be included in the transmitted picture signal, since there is only one addressee in this case. Auxiliary wires are used for the fast-slow scan order and delay order, where these are required.

The analog-to-digital converter will be capable of generating either two or three bits of gray-scale information (four or eight gray-scale levels). There will be a total of 6,000 bits of shift register storage, in two basic register sets of 3,000 bits each, segmented to permit several combinations. Specifically, tests will be made of configurations with 1000 clock pulses per scan line (visible part only) and two bits of gray-scale information per clock interval, or with 1500 clock pulses and two gray-scale bits per interval, or with 1000 clock pulses and three gray-scale bits per interval.

The disc store to be procured will probably be that offered by Data Disc, Incorporated, though SRI will undertake some further investigation of possible sources and offerings. A unit with 48 tracks and heads will be procured. At least four of the tracks will have heads and amplifiers suitable for analog recording; it should be noted, in this connection, that Data Disc's analog and digital heads are not identical and not functionally interchangeable. Up to 36 tracks may be used for storage of a picture. The remaining tracks may be used in the future for alphanumeric frame generation with character generation equipment offered by Data Disc, Incorporated; provision of this added capability, however, is not included in the tasks outlined here.

The <u>mouse</u> shown in the figure is a device perfected at SRI. It contains two orthogonally mounted friction wheels with attached potentiometers, for X and Y translation signal generation. It also carries three pushbutton switches. One of the switches will be used to signal "Implement." Another, as long as it is depressed, will cause the field of view of the camera to contract. The third, in similar fashion, will cause the camera field of view to expand. The line counting logic will cause a visible frame, showing the camera field of view in the size and position being selected by the user, to be superimposed on the displayed picture. (This superimposed frame representation is not recorded on the disc.) That same logic will generate the cursor described in the referenced memorandum.

For the analog storage version of the system, a modulator and a demodulator will be procured from Data Disc, Incorporated, together with two head switches for switching rapidly to any of four tracks. Logic to direct the switching between tracks will be built by SRI. The jumpstick control shown in the figure will, in the analog version, become the control that moves the quarter-picture window up and down the frame. The monitor will be modified for quarter-amplitude vertical scan and 8,250 line per second horizontal scan. The best way to show the view frame (to show the user the camera field he is selecting with the mouse) in the analog system has yet to be determined; at least three possibilities exist, however, and the best will be implemented. If time and funds permit, more than one possibility may be explored.

It is believed that, in both the digital and the analog systems, it will be possible within the proposed scope of time and money to demonstrate both a slow-scan mode and a mode in which a full high-resolution picture is delivered to the user in one T-frame time of 133 milliseconds (see the referenced memorandum). It is expected that, in the digital system, the coarse overview capability (with lines repeated to smear them vertically) will also be demonstrated. Though a coarse overview capability is theoretically possible with the analog system, no attempt to implement it in that system is proposed at this time. There will also be no control by the user, in the analog system, of the part of the frame being slow scanned; the slow scan will simply progress from top to bottom of the frame. It will be possible to demonstrate more than one speed of slow scan in the analog system, and two speed options may prove to be demonstrable in the digital system with the equipment proposed. (Detailed design has not yet been carried far enough to establish all of the limits on what may or may not feasibly be demonstrated with the proposed equipment complex.)

Transmission line noise will be introduced by simulation, and if feasible a loop of actual transmission cable should be leased to begin and end at the laboratory and provide a test with a real utility-provided circuit of some length. Random number delays will be imposed to simulate heavy traffic conditions.

3.1.4 Display Demonstration Planning

After initial tests are completed on a working complement of equipment, it will be appropriate to investigate and demonstrate operation in mo: and more nearly real-life environments. It has been suggested that a possible first step might be to transmit pictures over local broadcast television such as the Stanford Educational Television station. Experiments might also be carried out at that time on interpolating such picture transmissions into an on-going television program; it is doubtful that very many such transmissions could be interpolated without irritation to the television viewer, but the question of just how many should be investigated. The problem of noise in a broadcast television channel can also be expected to be more severe than in a cable system, and should be assessed.

A reasonable complete technical demonstration, including fiche retrieval and alphanumeric search operations in at least simulated form, would also be of value fairly early in the work. If costs prohibit creating a computer program and store of alphanumeric information that would be adequate for real operation, a scenario approach might be contemplated. This would permit a realistic demonstration of the principles involved, and might be recorded in a motion picture as a convenient means for briefing persons unfamiliar with the system.

A major effort should be initiated as soon as possible, however, aimed at a demonstration and test of the system in a real network with a real data base. This would involve implementing the alphanumeric display capability for the system, incorporating a computer and computer program, key punching an appropriate set of reference and retrieval information for each item in the data base, and implementing the full addressing and control network that is to be associated with the viewing channel proper. A major portion of the data base documents should be reduced to microfiche form, and a microfiche retrieval and positioning device should be procured and incorporated. Considerable cost would be involved, even if only a single viewing station were implemented, and a rather extensive preliminary effort of preparation would be required.

The first step in the work aimed at demonstration in a real system and environment must be a detailed investigation of the facility chosen as a test case. If, for example, the Drug Information Center in San Francisco is chosen, that entire operation must be studied in depth. Relations must be established with both supervisory and working level personnel of the selected facility, the work done must be analyzed, materials suitable for a remote viewing extension of the service must be chosen and analyzed for parameters implied in a remote viewing system, and the physical plant (room and door size, available power sources, and so on) must be surveyed in depth. Prospective users must be identified, locations appropriate to their needs must be found for display consoles and control elements, appropriate communications must be planned, and an initial educational effort must be planned and in part implemented. Permissions for the tests and for the use of facilities must be obtained from all organizations involved, and reimbursement must be arranged where required. Detailed estimates of costs for all phases of the proposed demonstration and test must be prepared, and responsibilities for all parts of the operation must be allocated. In short, a complete planning study must be carried out, or there will be little hope of carrying through a full-scale demonstration successfully.

3.1.5 Display Development and Demonstration Scheduling

As discussed in Sec. 2.1, the first five months of the implementation program should be devoted to finalizing the basic design of the remote viewing equipment to be built, to an extended remote browsing system study, and to selecting a suitable data base and organizational environment for ultimate real operational testing of a pilot system. Scheduling of efforts beyond that five-month period can at present be only tentative, since the results of studies performed then will determine what schedules are realistic.

Tentatively, it is judged that development, construction, and basic laboratory test and evaluation of the equipment described in Sec. 3.1.3 can be performed in the twelve months following the initial five-month study phase. That equipment complex does not include facilities for character generation and display of machine-originated alphanumeric material, nor does it include a keyboard at the display console. (This is because technical investigation of remote viewing equipment per se does not require the alphanumeric interaction capability, and because definition of such requirements for other aspects of the system will be completed only in subsequent program phases.)

In parallel with the initial hardware construction and test, system planning and study should be carried on aimed at preparing for technical demonstration with a scenario and simulated or skeleton data base. The technical demonstration, for which the required alphanumeric interactive capability might be simulated with teletype or existing cathode ray tube terminals, may be possible in the first six months following initial hardware work--that is, in the period from the seventeenth month to the twenty-third month after program initiation. This technical demonstration might be in motion picture form. During this technical demonstration period, further hardware construction should be carried on aimed at incorporating full alphanumeric interactive dialogue capability (character generation, keyboard, computer interface, and computer programs) in the remote viewing console.

Assuming successful completion of the preceding steps, and assuming that system planning and data base preparation had proceeded in parallel with the foregoing work, a complete but small-scale operational demonstration in some existing facility such as the Drug Information Center in San Francisco might be tentatively scheduled for the period from the twenty-second to the twenty-eighth month following program initiation. Details of such an operational demonstration will be finalized in earlier phases of the program.

Reference is made to SRI's Proposal for Research, SRI No. ESU 69-10, 24 January 1969, entitled "Design of a Remote Access Medical Information Retrieval System," for an estimate of the costs for the first five months of the program as outlined above, and for an estimate for planning purposes of the probable costs for the twelve-month period following the initial five-month period.

3.2 SYSTEM ANALYSIS

3.2.1 Objectives and Requirements

The objective of remote viewing technology is to deliver pictures to a remote user, on demand, in a rapid and economical manner. If this capability can be achieved it will represent a technological breakthrough since at present we are able to deliver pictures to a single individual (over distances in hundreds of miles) rapidly <u>or</u> economically, but not both.

Thinking in terms of ordinary TV techniques, a page of high-quality text material could be transmitted to an individual and refreshed at his display through a dedicated channel with, say, 30-MHz bandwidth.

But this would be prohibitively expensive.

On the other hand, the actual rate at which the individual's mind can absorb the information presented is five or six factors of ten less than the above figure. Between these two rates there is quite a bit of room for accommodation. We are looking for a scheme that gives the user much more information than he needs, while using much less channel capacity than the above.

What is needed is an ingenious system of packaging, handling, and storage of information, which at every stage in the process is particularly suited to this problem. Furthermore, the techniques used in the various stages of the process must be compatible with each other, and must provide the basis for a highly integrated design. We are looking for a breakthrough in system design more than in component design.

The elements of the viewing process are:

(1) Control by the user;
(2) Display at the user;
(3) Storage at the user;
(4) Transmission to the user;
(5) Scanning at the source;
(6) Page handling and storage; and
(7) Document, or information packet, handling and storage.

3.2.2 Control Techniques

Tracking: There are various schemes of tracking whereby the information transmitted might be more closely matched to the information wanted at a given instant of time. The three most obvious tracking techniques are eye-tracking, head-tracking, and hand-tracking. All three of these have been examined in considerable detail.

Eye-tracking is of special interest because it most fully defines the viewing situation, and allows the maximum possibility of bandwidth reduction. After a careful survey of the state of the art and key workers in this field, however, we concluded that for a considerable time into the future technically workable methods of eye-tracking would be too cumbersome to be acceptable by the average user. Head-tracking also appears to be quite cumbersome and offers little advantage over hand-tracking.

Other parts of our viewing system analysis complemented this line of thought by tending toward configurations that were readily compatible with hand-tracking inputs. Our present design approach uses a hand-tracking input.

Segmentation: Whatever control scheme is used feeds into a variety of possible picture segmentation schemes. Grossly, it seems desirable to allow X, Y, and zoom motions over a reasonable range. This is incorporated in the present design. It may also be desirable, or necessary from a practical point of view, to divide the picture into a number of major segments, for handling in transmission or on a limited-resolution display.

Within a given picture frame, further segmentation can increase the effective channel capacity, in terms of simultaneous users. Such segmentation tends to take the form of a movable aperture or slot. The moving aperture now seems overly complicated to us, and we have settled on a movable horizontal slot as the best compromise.

3.2.3 Display Techniques

Display Format: The remote viewing display must accomodate a wide variety of pictorial formats, including analog text, figures, photoplates, and computer-generated alphanumeric characters. A TV raster appeared to be the most practical way to handle this spectrum of formats. It also satisfies integration considerations.

Resolution: Display resolutions of 500 and 1000 lines have been considered. Both have advantages and disadvantages. The 500-line display is limited in resolution and therefore leads to more page segmentation. On the other hand it represents the minimum expense at the user terminal. It also is the most readily compatible with color. The 1000-line display reverses these pros and cons. It appears desirable to study both these alternatives in a prototype system, since final judgements of these factors are subjective.

Storage Means: One of the most effective ways to reduce the load on the transmission system is to store the picture being viewed at the user's terminal, or at least near to the user's terminal. Full-frame storage is therefore an essential feature of the desired display capability.

A variety of storage means have been considered for this application, including a large storage tube, a small storage tube with scan conversion, a plasma storage tube, a digital store with local picture generator, and synchronous magnetic disc. Most of these schemes were too expensive, lacking in resolution, or too developmental. Only the magnetic disc appeared to offer a practical way to achieve the desired storage capability in the near future.

Analog vs. Digital Storage: The disc allows analog or digital storage of picture information, or both. Both have advantages and disadvantages. Analog storage is somewhat simpler, more compact, not subject to quantizing loss, and more compatible with color. Digital storage lends itself to the synchronous time compression technique needed in a 1000-line display. We recommend that both be studied in a prototype.

3.2.4 Transmission Alternatives

At the extreme convenience end of the scale, one could consider picture transmission via a 30-MHz bandwidth line dedicated to an individual user. However, this is not a practical or an economic possibility.

At the other end of the scale, using the best that seems practical in picture segmentation techniques, we have been able to reduce the bandwidth required for a single user to that of a Telpak A line, or 50-kHz. This latter approach, however, would have several drawbacks.

In the first place, dial-up facilities of this type are not generally available, and the cost of a dedicated line would be excessive. More important, this approach would not integrate well into the Biomedical Communications Network, as it is now envisioned. Also there are no obvious major technological trends from which such an approach would benefit.

Addressed Broadcast TV: Once a decision has been made to provide full-frame storage at the user, then bandwidth-time product becomes the unit of commerce rather than bandwidth. This product is less expensive on wide bandwidth lines, and in fact is about 24 times less expensive on a conventional (4 MHz) TV line than on a (50 kHz) Telpak A line.

This would make a TV system, such as is planned for the Biomedical Communications Network, of considerable interest for remote viewing purposes, if we could in fact deliver to the individual user a unit of bandwidth-time product. A practical mechanism whereby this might be accomplished is addressed broadcast TV.

In this concept one transmits unrelated pictures via a broadcast system to many simultaneous users, the various pictures being segregated by frame or line addresses recognizable by the users' display terminals. This design concept integrates very well with the design decisions already discussed, and is the transmission mode suggested for further study.

3.2.5 Page Handling and Storage

That part of the remote viewing system so far defined is capable of delivering about five pages per second on a single TV broadcast channel. If the average user only reads half a page, then ten "pages" per second could be delivered, or 100 simultaneous users could be given a new page every 10 seconds. Technological trends are such that this capability could eventually become remarkably economical.

Within this context, page handling and storage must also be accomplished in a very rapid and economical manner if the whole system is to make sense. Unit storage of groups of pages in the form of microfiche appears to offer by far the most attractive approach. Even at conventional reductions of say 24:1 this approach is not excessively costly, and there is reason to believe that higher reductions, up to say 40:1, will be practical in the time scale of the envisioned development effort.

The great majority of inquiries to the whole NLM collection could probably be satisfied by a microfiche data base of less than 3 million pages. Furthermore, this need not be an archival system, and items of marginal quality for reproduction can simply be omitted. Inquiries that cannot be satisfied by the automated system could be satisfied in a completely conventional manner. The system costs indicated in Sec. 2.2 are believed to be conservative.

Mechanical page turning and book picking appear to be technologies of marginal utility within this context. In fact, it is clear that they should not be part of the fully automated system. They are far too slow and too expensive to be suitable for this system. In closed stacks, such as NLM's, an automatic book delivery system, for example the Randtriever, might be a useful supplement to the manual part of the system. But this is a state-of-the-art item and decision criteria are conventional. The remote viewing system design appears to have already outpaced the capabilities of any mechanical schemes for handling conventional book or page materials.

4. QUESTION ANSWERING

4.1 CONCEPTS AND DEVELOPMENT PLAN

4.1.1 Development Strategy for Complex Systems

A large information system with question-answering capabilities is a highly complex entity. Some of the difficulties we are faced with in the development of such a system were touched on in Sec. 2.1.5. There are, however, some general approaches that have proved useful in the development of complex systems.

Evolutionary Design: Although in the long run certain design ideas may have revolutionary implications, it is often possible to find a way for a design incorporating these ideas to move in an evolutionary manner from a position fairly near the present state of the art toward its ultimate objectives.

Modular Design: An important step in achieving an evolutionary development concept is to break the system apart into semi-independent modules whose development can then be carried forward in a leapfrog, rather than a lockstep, manner.

Redundant Modules: Development risk, and the degree of lockstep needed, can be reduced if the design and development plan includes some redundant, or at least partially redundant, modules. Partial redundancy is often more economic than total redundancy, since such modules can complement as well as substitute for each other.

Hybrid Design: A design that is multidimensional and that provides multidimensional benefits has a greater chance to survive the evolutionary process than one that is too unitary in nature. If progress is held up on one front it can advance on another. Some inherently hybrid elements of an applied Q-A system are: explicit vs. implicit facts; breadth vs. depth of fact base; existential vs. exhaustive answers; and character string vs. light button inputs.

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4.1.2 Components of an Applied Q-A System

What are the components, or modules, of an applied Q-A system and how do they relate to its design development?

Predicate Calculus: Perhaps the most essential feature of the type of question-answering system that we have been working on is that it requires a predicate calculus representation of its fact and theorem base. This is needed to allow the generation of answers implicit in the data base.

It also appears, however, that use of a predicate calculus representation is quite compatible with the problems of filing explicit data for fast on-line retrieval. If this is true, the possibilities for evolutionary design are very good.

Theorem Proving: The inferential capabilities of the system are based on theorem-proving and related logical techniques. It seems quite possible that these techniques can be introduced in an evolutionary manner. At the beginning there would be a certain ratio, in practical usage, between implicit information and explicit information. As time goes on this ratio would increase. Implicit information would tend to be more expensive and also more valuable than explicit informatio The user could be his own judge of how much machine time to spend in pursuing inferences.

Language Processing: The objective of language processing is to form a bridge between the user and the machine representation. Again it seems very plausible that this can be in an evolutionary manner. The user is not asking for a total English capability. All he is asking for is something that does not put too much burden of formal memorization on him. Within this general requirement there is certainly room for evolution.

Interactive Access: The burdens of "natural" language translation can be very much eased if full use is made of modern interactive access display systems. Free keyboard inputs can be supplemented with light buttons and standard forms. Fast feedback can be provided to check user agreement with the system's translation of his inputs. The display capabilities needed here probably can be integrated into a display of the type that we have proposed for remote viewing.

Memory Organization: A data base suitable for a modest-sized, but operational, system may have as many as 100,000 factual statements. The organization of this memory should be accommodated to the empirical nature of usage of the system, and should be capable of being reorganized adaptively to match changing usage patterns. The predicate calculus representation certainly should not hinder, and may help to make possible this type of accommodation.

Language Formulation: Language formulation is an important problem and component in the development of an applied Q-A system. The key to progress here would appear to be to keep the scope of early Q-A systems as narrow as possible, and to bring in real experts in the subject matter to assist in the formulation.

Data Base Encoding: Data base encoding is such a major factor in the cost of information system development that it should be considered a key module in the development program. Data base encoding should be an evolutionary process. This objective would be facilitated if the principal operators of the system were a service group. Questions that the system could not answer would be automatically referred to them, and then, if possible, the system would be updated to contain the answer, either explicitly or implicitly.

4.2 QUESTION-ANSWERING TECHNIQUES

One of our basic premises in this project is that the usefulness of a medical fact-retrieval system depends on its ability to communicate with doctors and drug information specialists in a language natural to them, and to make appropriate logical deductions. Therefore, we have directed much of our effort in the area of Q-A techniques toward the design of natural language communication capabilities and automatic theorem proving capabilities suitable for integration within a complete medical fact-retrieval system. In this section, we review our progress on these essential components of Q-A system development. The discussion will be divided into five parts: work on language-processing capabilities, the underlying deductive system, the memory organization in the computer, the drug effects data base, and some operational examples derived from a small demonstration system.

4.2.1 Language-Processing Capabilities

Because the inferential component of our fact-retrieval system assumes that the data base is represented in the predicate calculus, a logical language especially suited to deductive inferences, the natural language communication problem reduces to one of translating English statements and questions into the predicate calculus and back again. Therefore, the basic paradigm which we use is to:

(1) Translate English queries, requests, and so on, into a formal language based on the first-order predicate calculus;

(2) Perform any necessary deductive inferences based on the current set of axioms; and

(3) Generate an appropriate English reply sentence.

In the course of translating the source statement, the syntactic and semantic analysis routines may uncover an unclear portion of the input text. In such a case, the system assigns to the user a series of questions on the unclear portions. The character of those questions depends in part on the context of the conversation. The user's replies to these questions may be regarded as paraphrases of the unclear portions. The system then reanalyzes the text. If necessary, the system again assigns questions to the user, and in this manner establishes a dialogue between the user and the system. By means of the dialogue the user continually simplifies the formation of his query until it is completely understood by the system. The translation process is accomplished by means of two subanalyzers; a syntax analyzer and a semantic analyzer.

Syntax Analyzer: The syntax analyzer is based on the transformational grammar for a subset of English imperative, declarative, and interrogative sentences. The vocabulary is unrestricted insofar as adjectives and nouns are concerned, and in this sense it is similar to a transformational parser proposed by Thorn, et al.[7] The grammar consists of two subcomponents: a transformational component and a base component. The transformational component serves the purpose of decomposing complex sentences into their simpler kernel sentences so that parsing can be accomplished by the base component in a more efficient manner. The base component is derived from a simple phrase structure grammar written in Backus-Naur form.

The use of transformations in the syntax analyzer is currently restricted to string transformations that map terminal symbols into other terminals. The most conspicuous use of transformations in the current grammar is to recognize interrogative sentence forms either through subject predicate inversion or interrogative pronouns and map them into their corresponding declarative sentence forms. These transformed declarative sentences are then passed to the base component for complete analysis. In this manner, by adding a dozen transformations to the transformational component, we eliminate the need for practically doubling the size of the declarative base analyzer merely to handle interrogative sentences. Another simple but important use of transformations is in mapping plural noun and verb forms into their corresponding singular form to facilitate unique identification in the deep structure.

The base component of the grammar was taken essentially without change from the GRANIS system,[8,9] an earlier version of our system developed for application to graphical question-answering systems. Historically, this base component was implemented as a set of productions in Formula ALGOL. With small effort these productions were transliterated into LISP with their control programs for the sake of compatibility with the remainder of the system. In previous work, this base component was expanded by first adding new rules to the BNF grammar, applying the Early algorithm to the BNF grammar, and then post editing the resulting productions to obtain an efficient one-pass, syntax-directed recognizer for the BNF grammar.

In more recent work with medical-fact retrieval, however, it has been found to be more convenient to work directly with the productions themselves, abandoning the original BNF grammar. Thus, under the current strategy, the productions are treated as a separate programming language for grammar construction, and new productions are added directly to the recognizer as needed.

The form of the productions is as follows:

$$L1: \ \alpha \ \ /> \ \ \beta \ \ / \ \ \gamma \ \ * \ \ L2;$$

where L1 and L2 are labels, α and β are strings, the "> indicates a replacement operation, γ is a sequence of semantic productions, the " * " indicates a "read" operation taking the next word in the input string and placing it at the top of the syntactic stack, and the ";" is a punctuation mark delimiting the scope of the production. L1, "> ", β, γ, and " * " are optional characters, while both diagonal bars, α, L2, and ";" are mandatory for each production. Flow of control for the productions is defined as follows: If in the course of analysis control reaches the cluster of productions labeled L1 and the right-hand portion of the contents of the syntactic stack is an instance of the pattern string "α", then

(1) Replace that portion of the stack that was matched by "α" with "β" (which will in general depend on the portion of the stack matched, since free class variables become bound if the match is successful);
(2) Execute the sequence γ if present;
(3) If a " * " is indicated, then read a new word into the syntactic stack from the input string; and
(4) Go to the cluster of productions labeled L2.

Otherwise, if the stack fails to match the pattern string "α", control is passed to the next production in the sequence. Possible pattern elements for the pattern string α include terminal constants, class variables defined in terms of terminal constants or Boolean combinations of other classes, the pattern "$1", which can match a single arbitrary constituent, or the pattern "$", which may match an arbitrary number of arbitrary constituents much as in the COMIT language. The result of any successful match may cause extraction variables to be bound to the value of a match with a class variable, so that particular values of the stack may be referenced in the replacement portion. More explanation, together with examples of this process may be found in Ref. 8.

Transformational productions have the same form as base component productions except for the fact that the scanning for a match is from left to right across the entire sentence rather than from right to left across the syntactic stack. Any pattern element sequence can be quoted indicating that pattern matching is to be accomplished at the character level in a particular word rather than at the lexical level, and in this manner testing for plurals and standard suffixes or prefixes can be achieved.

Semantic Analyzer: Translation of a well-formed English source statement into an equivalent well-formed formula in the first-order predicate calculus is accomplished by means of a set of semantic productions interleaved with the syntactic productions. The semantic productions have an identical form and flow of control with the exception that the "*" operation is never used and they operate on a separate semantic stack. The method of integrating the syntactic and semantic analysis within a common production framework has been called Syntax-Directed Interpretation, and examples of this process can also be found in Ref. 8.

It is our belief that the above-mentioned techniques for natural language translation to the predicate calculus will be sufficiently general to accommodate any English dialect requirements peculiar to potential users from the medical profession.

4.2.2 Deductive Capabilities

In the past few years, a new approach has been developed for performing logical inference on a computer. This approach, introduced by Robinson,[10] applies a new inference rule called the "resolution principle to a classic first-order predicate calculus proof method called "Herbrand expansion".

Several computer implications of theorem provers based upon resolution now exist, and the performance of these systems generally dominates that of any other mechanical inference scheme. These systems are still only capable of very simple proofs (by a human logician's standards). (However, the combination of a shallow deductive system with a broad data base might still produce useful inferential fact retrieval.) The development of more efficient strategies for using the resolution principle, and of additional deductive principles that might be superimposed upon resolution, is one of our main concerns in this research.

Although the details of this work are highly technical, our results and current status can be summarized informally as follows:

(1) We are continuing to maintain and improve a resolution-based theorem-proving program (originally developed under other support).[11]

(2) We have invented, and built into our program, a bookkeeping procedure that prevents the system from wasting time exploring alternative, equivalent sequences for obtaining a single result (a major strategic problem in theorem proving) for the most important subclass of proofs.

(3) We have developed a notation called "elimination graphs," which reduces conceptual problems in designing theorem-proving strategies.

(4) We have extended some theoretical results, related to the "merge" principle, concerning the logical completeness of certain theorem-proving strategies. A brief technical summary of these results is contained in Ref. 13, which is available upon request from SRI. (The practical usefulness of these results remain to be tested.)

Our theorem-proving program is embedded in a question-answering program called QA3. This program is implemented in the LISP programming language on the time-shared SDS 940 computer in the Artificial Intelligence Group at SRI. Complete listings of the computer program which are rather large, can be obtained from SRI on request. A summary description of the QA3 system is contained in Ref. 14, also available upon request from SRI.

4.2.3 Memory Organization

Other theorem provers are oriented toward formal mathematics, and in a sense assume that they will be given only immediately relevant axioms when asked to find a proof for a theorem. For question answering, on the other hand, the system's memory will be filled with facts, most of which are not relevant for any one question. Therefore, a unique feature of QA3 is that it works with two memories, which can be thought of as immediate (for theorem proving) and long term (for fact storage). In order to facilitate future developments and experimentation, the following features have recently been added to QA3 (and are under further development):

(1) Flexible controls for specifying the transfer of facts between the two memories, and for tagging key facts.

(2) The ability to monitor many aspects of QA3's performance, and to obtain statistics concerning its operation.

(3) The ability to prepare sets of facts externally, and to add, delete, or edit them on command.

The present memory organization for our natural language fact-retrieval system stores data as a set of axioms. This choice is dictated by the inferential component, which requires axioms as the basis for automatic theorem proving. Various alternatives exist, however, for encoding the axioms in computer memory having varying degrees of storage efficiency and response time. Finding the optimal trade-off between the competing requirements of fast response time and small storage needs is an important issue for our studies, since our objective is to apply the techniques mentioned in the preceding sections to a relatively large data base of medical information.

Maron and Levine[12] have used the technique of replicating their data base several times (each time indexed by different parameters) thereby sacrificing memory storage for faster response time. In attempting to conserve computer memory, however, they have carefully packed their information into computer words, optimizing the number of bits needed to represent any fact. This approach or one similar to it is a possibility for some future version of our own system.

4.2.4 Answer Generation

A theorem-proving program is not normally intended to produce any information except whether an assertion is true or false. In question-answering applications, however, the theorem prover must not only assert the existence of an answer, but also constructively produce the answer. Although sufficient information is present in a proof by resolution to perform this answer construction, this information has not been extensively used or studied in the past. Recently we have established precisely what is the most general form such information can take and the procedures for building this information into an "answer" have been incorporated into QA3. This is described in detail in a new paper.[15]

In the process of applying QA3 to a new problem domain, we frequently discover ways to improve the performance of the overall system by modifying QA itself. For example, the process of answering a question about drugs frequently involves searching through small finite sets, e.g., the set of contraindications for a given drug. This kind of search process is awkward to express in the basic logical system; thus, a new feature was added to QA3: the ability to flag certain relations as requiring evaluation by special programs outside the logical system. This ability to escape from and reenter the theorem prover will be useful in a variety of question-answering applications.

The answer-generation capabilities of the QA3 theorem prover are illustrated with some artificial test data in Ref. 16, copies of which are available upon request from SRI. Since this test was run, these capabilities have been integrated with the drug system whose data base is described below; thus, we are now capable of performing similar logical inferences with meaningful drug facts.

4.2.5 Drug Data Base

To explore the feasibility of these techniques when applied to a medical fact file, a small data base has been constructed for 25 anti-hypertensive drugs described in the 1968 edition of the "Physician's Desk Reference" (PDR). The specific drugs used in this preliminary data base are shown in Table I. Ten common relations relevant to the description of drugs in the PDR are chemical name, action, indications, contraindications, warnings, side effects, precautions, dosage, how supplied, and drug house. In addition, the drugs were divided into categories according to their action. Various categories are Decarboxylase and Enzyme Inhibitors, Neuro Arteriole Blockers,Rauwolfia Preparations, Vasopressor Sedatives, Dycarboxylase inhibitors, diuretic combination, hormone steriods, laxatives, salt substitutes, hypnotic sedatives, tranquilizers, and exanthine preparations. In all, there are over 300 relations which comprise the data base, which is exhibited in Appendix A.

Table I

ANTIHYPERTENSIVE DRUGS

1. Aerolate
2. Aldactazide
3. Aldomet
4. Aldoril
5. Anhydron
6. Apresoline
7. Belbarb
8. Butiserpine
9. Capla
10. Dialose
11. Diasal
12. Diutensen
13. Eutonyl
14. Halabar
15. Harmonyl
16. Isemelin
17. Mebaral
18. Miltown
19. Neurosine
20. Normotensin
21. Prulet
22. Rauwiloid
23. Serpasil
24. Singoserp
25. Unitensen

4.2.6 A Demonstration System

To illustrate the use of the techniques described in the preceding sections together with the data base just mentioned, a demonstration system called ENGDRG was constructed. ENGDRG is now available by means of a Teletype link to any potential user around the country. On 13 December 1968, a demonstration was arranged for the Secretary of Health, Education, and Welfare, W. Cohen, as well as other key individuals within DHEW at the National Library of Medicine's Research Center in Bethesda, Maryland. The Teletype conversation that transpired will serve to indicate the general capabilities and power of ENGDRG.

Man: WHAT IS THE ACTION OF HALABAR?

System: THE ACTION OF HALABAR IS SEDATION.

Man: IS THERE AN ENZYME INHIBITOR?

System: YES, EUTONYL IS AN ENZYME INHIBITOR.

Man: WHAT DRUG HAS THE CHEMICAL NAME METHYLDOPATE-HYDROCHLORIDE?

System: THE CHEMICAL NAME OF ALDOMET IS METHYLDOPATE-HYDROCHLORIDE.

Man: SAM HAS MODERATE HYPERTENSION.

System: OK.

Man: SAM'S SYMPTOM IS CORONARY ARTERY DISEASE.

System: OK.

Man: CAN YOU SUGGEST A DRUG FOR SAM WHICH DOES NOT CAUSE HEADACHES?

System: YES, SINGOSERP.

Man: JACK HAS MODERATE HYPERTENSION.

System: OK.

Man: JACK'S SYMPTOM IS PRIOR TO SURGERY.

System: OK.

Man: CAN YOU SUGGEST A DRUG FOR JACK WHICH DOES NOT CAUSE HEADACHES?

System: YES, UNITENSEN.

The entire demonstration lasted no more than 20 minutes. In deducing the correct replies to the three questions about the hypothetical patients Sam and Jack, ENGDR had to inspect the data base to discover that of four possible drugs suitable for controlling moderate hypertension, (Aldomet, Apresoline, Singoserp, and Unitensen), two of them (Aldomet and Apresoline) had to be excluded because their potential side effects included headaches. For Sam, Unitensen was contraindicated because of his coronary artery disease, whereas for Jack, Singoserp was contraindicated because he was prior to surgery.

Appendix A

DRUG DATA BASE

LIST IN

LISTING ØF PREDICATE IN

1 (IN ALDØMET DECARBØXYLASE)

2 (IN ALDØMET INHIBITØR)

3 (IN EUTØNYL ENZYME)

4 (IN EUTØNYL INHIBITØR)

5 (IN APRESØLINE NEURØ#ARTERIØLE)

6 (IN APRESØLINE BLØCKER)

7 (IN ISMELIN NEURØ#ARTERIØLE)

8 (IN ISMELIN BLØCKER)

9 (IN HARMØNYL RAUWØLFIA)

10 (IN HARMØNYL PREPARATIØN)

11 (IN RAUWILØID RAUWØLFIA)

12 (IN RAUWILØID PREPARATIØN)

13 (IN SERPASIL RAUWØLFIA)

14 (IN SERPASIL PREPARATIØN)

15 (IN SINGØSERP RAUWØLFIA)

16 (IN SINGØSERP PREPARATIØN)

17 (IN BUTISERPINE RAUWØLFIA)

18 (IN BUTISERPINE PREPARATIØN)

19 (IN ALDØRIL DECARBØXYLASE)

20 (IN ALDØRIL INHIBITØR)

21 (IN ALDACTAZIDE DIURETIC)

22 (IN ALDACTAZIDE CØMBINATIØN)

23 (IN ANHYDRØN DIURETIC)

24 (IN ANHYDRØN CØMBINATIØN)

25 (IN DIUTENSEN DIURETIC)

26 (IN DIUTENSEN CØMBINATIØN)

27 (IN NØRMØTENSIN HØRMØNE)

28 (IN NØRMØTENSIN STERØID)

29 (IN DIALØSE LAXATIVE)

30 (IN PRULET LAXATIVE)

```
31  (IN DIASAL SALT)
32  (IN DIASAL SUBSTITUTE)
33  (IN BELBARB SEDATIVE)
34  (IN BELBARB HYPNØTIC)
35  (IN MEBARAL SEDATIVE)
36  (IN MEBARAL HYPNØTIC)
37  (IN NEURØSINE SEDATIVE)
38  (IN NEURØSINE HYPNØTIC)
39  (IN HALABAR TRANQUILIZER)
40  (IN MILTØWN TRANQUILIZER)
41  (IN CAPLA VASØPRESSØR)
42  (IN CAPLA SEDATIVE)
43  (IN AERØLATE XANTHINE)
44  (IN AERØLATE PREPARATIØN)
45  (IN UNITENSEN VASØPRESSØR)
46  (IN UNITENSEN SEDATIVE)
DØNE
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```
LIST CHEMICALNAME
LISTING ØF PREDICATE CHEMICALNAME
1   (CHEMICALNAME HARMØNYL DESERPIDINE)
2   (CHEMICALNAME ALDØMET METHYLDØPATEHYDRØCHLØRIDE)
3   (CHEMICALNAME APRESØLINE HYDRALAZINE#HYDRØCHLØRIDE)
4   (CHEMICALNAME EUTØNYL N#BENZYL#N#METHYL#2#PRØPYNYLAMINE#HYDRØCHLØRIDE
5   (CHEMICALNAME ISMELIN GUANETHIDINE#SULFATE)
6   (CHEMICALNAME RAUWILØID ALSERØXYLØN)
7   (CHEMICALNAME SERPASIL RESERPINE)
8   (CHEMICALNAME SINGØSERP SYRØSINGØPINE)
9   (CHEMICALNAME UNITENSEN CRYPTENAMINE)
10  (CHEMICALNAME BUTISERPINE SØDIUM#BUTABARBITAL#PLUS#RESERPINE)
11  (CHEMICALNAME ALDØRIL HYDRØCHLØRØTHIAZIDE#PLUS#METHYLDØPA)
12  (CHEMICALNAME ALDACTAZIDE SPIRØNØLACTØNE#PLUS#HYDRØCHLØRØTHIAZIDE)
13  (CHEMICALNAME ANHYDRØN CYCLØTHIAZIDE#PLUS#PØTASSIUM#CHLØRIDE)
14  (CHEMICALNAME DIUTENSEN CRYTENAMINE#PLUS#METHYCHLØTHIAZIDE)
15  (CHEMICALNAME NØRMØTENSIN ETHAVERINE#HYDRØCHLØRIDE)
16  (CHEMICALNAME DIALØSE DIØCTL#SØDIUM#SULFØSUCCINATE#PLUS#SØDIUM#CARB
17  (CHEMICALNAME PRULET ØXYPNENISATIN#ACETATE)
18  (CHEMICALNAME DIASAL GLUTAMIC#ACID#AND#PØTASSIUM#CHLØRIDE)
19  (CHEMICALNAME BELBARB PHENØBARBITAL)
20  (CHEMICAL..ME MEBARAL MEPHØBARBITAL)
21  (CHEMICALNAME NEURØSINE VARIØUS#BRØMIDES)
22  (CHEMICALNAME HALABAR MEPHENESIN#BUTABARBITAL)
23  (CHEMICALNAME MILTØWN MEPRØBAMATE)
24  (CHEMICALNAME CAPLA MEBUTAMATE)
25  (CHEMICALNAME AERØLATE THEØPHYLLINE)
DØNE
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```
LIST ACTIØN
LISTING ØF PREDICATE ACTIØN
1  (ACTIØN HARMØNYL HYPØTENSIVE#AND#TRANQUILIZING)
2  (ACTIØN ALDØMET REDUCE#BLØØD#PRESSURE)
3  (ACTIØN APRESØLINE REDUCE#BLØØD#PRESSURE)
4  (ACTIØN EUTØNYL LØWERS#SYSTØLIC#AND#DIASTØLIC#BLØØD#PRESSURE)
5  (ACTIØN ISMELIN PØTENT#ANTIHYPERTENSIVE#AGENT)
6  (ACTIØN RAUWILØID ANTIHYPERTENSIVE)
7  (ACTIØN SERPASIL ANTIHYPERTENSIVE#AND#CALMING#AGENT)
8  (ACTIØN SINGØSERP LØWER#BLØØD#PRESSURE)
9  (ACTIØN UNITENSEN CENTRALLY#MEDIATED#ARTERIØLAR#DILATIØN)
10  (ACTIØN BUTISERPINE INTERMEDIATE#DAYTIME#SEDATIVE)
11  (ACTIØN ALDØRIL REDUCE#BLØØD#PRESSURE)
12  (ACTIØN ALDACTAZIDE REDUCE#BLØØD#PRESSURE)
13  (ACTIØN ANHYDRØN DIURETIC#ANTIHYPERTENSIVE)
14  (ACTIØN DIUTENSEN ARTERIØLAR#DILATIØN)
15  (ACTIØN NØRMØTENSIN LØWERS#BLØØD#PRESSURE)
16  (ACTIØN DIALØSE PURGATIVE)
17  (ACTIØN PRULET LAXATIVE)
18  (ACTIØN DIASAL SALT#SUBSTITUTE)
19  (ACTIØN BELBARB ANTISPASMØDIC)
20  (ACTIØN MEBARAL ANTICØNVULSANT)
21  (ACTIØN NEURØSINE SØPØRIFIC)
22  (ACTIØN HALABAR SEDATIØN)
23  (ACTIØN MILTØWN ANTICØNVULSIVE)
24  (ACTIØN CAPLA CENTRAL)
25  (ACTIØN AERØLATE BØWEL#ABSØRPTIØN)
DØNE
```

LIST INDICATIØN

LISTING ØF PREDICATE INDICATIØN

1 (INDICATIØN SERPASIL HYPERTENSIVE#EMERGENICES)

2 (INDICATIØN ANHYDRØN HYPERTENSIØN)

3 (INDICATIØN NØRMØTENSIN HYPERTENSIØN)

4 (INDICATIØN DIASAL HYPERTENSIØN)

5 (INDICATIØN BELBARB HYPERTENSIØN)

6 (INDICATIØN MEBARAL HYPERTENSIØN)

7 (INDICATIØN NEURØSINE HYPERTENSIØN)

8 (INDICATIØN HALABAR HYPERTENSIØN)

9 (INDICATIØN MILTØWN HYPERTENSIØN)

10 (INDICATIØN CAPLA HYPERTENSIØN)

11 (INDICATIØN ISMELIN HYPERTENSIØN)

12 (INDICATIØN EUTØNYL HYPERTENSIØN)

13 (INDICATIØN ALDACTAZIDE HYPERTENSIØN)

14 (INDICATIØN DIUTENSIN HYPERTENSIØN)

15 (INDICATIØN DIALØSE HYPERTENSIØN)

16 (INDICATIØN PRULET HYPERTENSIØN)

17 (INDICATIØN AERØLATE HYPERTENSIØN)

DØNE

```
LIST INDICATIØN1
LISTING ØF PREDICATE INDICATIØN1
1   (INDICATIØN1 HARMØNYL HYPERTENSIØN MILD)
2   (INDICATIØN1 ALDØMET HYPERTENSIØN MØDERATE)
3   (INDICATIØN1 ALDØMET HYPERTENSIØN SEVERE)
4   (INDICATIØN1 APRESØLINE HYPERTENSIØN MØDERATE)
5   (INDICATIØN1 APRESØLINE HYPERTENSIØN SEVERE)
6   (INDICATIØN1 RAUWILØID HYPERTENSIØN MILD)
7   (INDICATIØN1 SINGØSERP HYPERTENSIØN MILD)
8   (INDICATIØN1 SINGØSERP HYPERTENSIØN MØDERATE)
9   (INDICATIØN1 UNITENSEN HYPERTENSIØN MILD)
10   (INDICATIØN1 UNITENSEN HYPERTENSIØN MØDERATE)
11   (INDICATIØN1 UNITENSEN HYPERTENSIØN SEVERE)
12   (INDICATIØN1 BUTISERPINE HYPERTENSIØN MILD)
13   (INDICATIØN1 BUTISERPINE HYPERTENSIØN MØDERATE)
14   (INDICATIØN1 ALDØRIL HYPERTENSIØN MØDERATE)
15   (INDICATIØN1 ALDØRIL HYPERTENSIØN SEVERE)
DØNE
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```
LIST CØNTRAINDICATIØN
LISTING ØF PREDICATE CØNTRAINDICATIØN
1   (CØNTRAINDICATIØN HARMØNYL (L MENTAL#DEPRESSIØN))
2   (CØNTRAINDICATIØN ALDØMET (L HEPATITIS ACTIVE#CIRRHØSIS))
3   (CØNTRAINDICATIØN APRESØLINE (L CØRØNARY#ARTERY#DISEASE))
4   (CØNTRAINDICATIØN ISMELIN (L PHEØCHRØMØCYTØMA))
5   (CØNTRAINDICATIØN RAUWILØID (L NØNE))
6   (CØNTRAINDICATIØN SERPASIL (L AØRTIC#INSUFFICIENCY))
7   (CØNTRAINDICATIØN SINGØSERP (L PRIØR#TØ#SURGERY))
8   (CØNTRAINDICATIØN UNITENSEN (L CØRØNARY#ARTERY#ØCCLUSIØN RECENT#CERE
ØSIS))
9   (CØNTRAINDICATIØN BUTISERPINE (L PØRPHYRIA PEPTIC#ULCER DEPRESSIØN))
10   (CØNTRAINDICATIØN ALDØRIL (L HEPATITIS ACTIVE#CIRRHØSIS))
11   (CØNTRAINDICATIØN ALDACTAZINE (L ANURIA))
12   (CØNTRAINDICATIØN ANHYDRØN (L HEPATIC#DISEASE))
13   (CØNTRAINDICATIØN DIUTENSEN (L PEPTIC#ULCER))
14   (CØNTRAINDICATIØN NØRMØTENSIN (L NØNE))
15   (CØNTRAINDICATIØN DIALØSE (L NØNE))
16   (CØNTRAINDICATIØN PRULET (L NAUSEA VØMITING))
17   (CØNTRAINDICATIØN DIASAL (L RENAL#DISØRDERS))
18   (CØNTRAINDICATIØN BELBARB (L GLAUCØMA))
19   (CØNTRAINDICATIØN MEBARAL (L NEPHRITIS))
20   (CØNTRAINDICATIØN NEURØSINE (L NEPHRITIS))
21   (CØNTRAINDICATIØN HALABAR (L NØNE))
22   (CØNTRAINDICATIØN CAPLA (L ANURIA))
23   (CØNTRAINDICATIØN AERØLATE (L NØNE))
24   (CØNTRAINDICATIØN MILTØWN (L ALLERGY#TØ#MEPRØBAMATE))
DØNE
```

LIST PRECAUTIØN

LISTING ØF PREDICATE PRECAUTIØN

1 (PRECAUTIØN HARMØNYL PEPTIC#ULCER)

2 (PRECAUTIØN ALDØMET FEWER#WHITE#BLØØD#CELLS)

3 (PRECAUTIØN APRESØLINE ARTHRITIS#LIKE#SYNDRØME)

4 (PRECAUTIØN EUTØNYL CHEESE#AND#ALCØHØLIC#BEVERAGES)

5 (PRECAUTIØN ISMELIN RENAL#ØR#CØRØNARY#DISEASE)

6 (PRECAUTIØN RAUWILØID PARANØID#DEPRESSIØN)

7 (PRECAUTIØN SERPASIL SEVERE#MENTAL#DEPRESSIØN)

8 (PRECAUTIØN SINGØSERP PEPTIC#ULCER)

9 (PRECAUTIØN UNITENSEN PØTENT#HYPØTENSIVE#AND#ØCCASSIØNALLY#BRADYCRØT

10 (PRECAUTIØN BUTISERPINE HEPATIC#DISEASE)

11 (PRECAUTIØN ALDØRIL EXCESSIVE#VØMITING)

12 (PRECAUTIØN ALDACTAZIDE PREGNANCY)

13 (PRECAUTIØN ANHYDRØN PREGNANCY)

14 (PRECAUTIØN DIUTENSEN PREGNANCY)

15 (PRECAUTIØN NØRMØTENSIN CARDIAC#DISEASES)

16 (PRECAUTIØN DIALØSE NØNE)

17 (PRECAUTIØN PRULET NØNE)

18 (PRECAUTIØN DIASAL NØNE)

19 (PRECAUTIØN BE[illegible] SENSI[illegible]Y#TØ#BARBITUATES)

20 (PRECAUTIØN MEBARAL PULMØNARY#DISEASE)

21 (PRECAUTIØN NEURØSINE CARDIAC#PATIENTS)

22 (PRECAUTIØN HALABAR SEVERE#HEPATIC#ØR#RENAL#DISEASE)

23 (PRECAUTIØN MILTØWN SUPERVISE#DØSAGES#CAREFULLY)

24 (PRECAUTIØN CAPLA DRØWSINESS)

25 (PRECAUTIØN AERØLATE NØNE)

DØNE

```
LIST SIDEEFFECT
LISTING ØF PREDICATE SIDEEFFECT
1   (SIDEEFFECT HARMØNYL LETHARGY#DIARRHEA#NAUSEA#ETC#)
2   (SIDEEFFECT ALDØMET HEADACHE#ASTHENIA#ØR#WEAKNESS)
3   (SIDEEFFECT APRESØLINE HEADACHE#DIZZINESS#PALPITATIØN#TACHYCARDICA)
4   (SIDEEFFECT EUTØNYL DIZZINESS#WEAKNESS#PALPITATIØN#ØR#FAINTING)
5   (SIDEEFFECT ISMELIN DIZZINESS#WEAKNESS#ØR#LASSITUDE)
6   (SIDEEFFECT RAUWILØID MENTAL#DEPRESSIØN)
7   (SIDEEFFECT SERPASIL LASSITUDE#DRØWSINESS)
8   (SIDEEFFECT SINGØSERP NASAL#CØNGESTIØN)
9   (SIDEEFFECT UNITENSEN NAUSEA#VØMITING#ANØREXIA)
10  (SIDEEFFECT BUTISERPINE SKIN#RASH#HANGØVER#SYSTEMIC#DISTURBANCES)
11  (SIDEEFFECT ALDØRIL SEDATIØN#WEAKNESS)
12  (SIDEEFFECT ALDACTAZIDE GASTRØINTESTINAL#INTØLERANCE)
13  (SIDEEFFECT ANHYDRØN WEAKNESS#AND#LETHARGY)
14  (SIDEEFFECT DIUTENSEN NAUSEA#AND#VØMITING)
15  (SIDEEFFECT NØRMØTENSIN NØNE)
16  (SIDEEFFECT DIALØSE NØNE)
    (SIDEEFFECT PRULET NØNE)
18  (SIDEEFFECT DIASAL NØNE)
19  (SIDEEFFECT BELBARB BLURRED#VISIØN)
20  (SIDEEFFECT MEBARAL DRØWSINESS#VERTIGØ)
21  (SIDEEFFECT NEURØSINE VØMITING)
22  (SIDEEFFECT HALABAR DRØWSINESS)
23  (SIDEEFFECT MILTØWN DRØWSINESS)
24  (SIDEEFFECT CAPLA DIZZINESS#ØR#WEAKNESS)
25  (SIDEEFFECT AERØLATE NAUSEA)
DØNE
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```
LIST WARNING

LISTING ØF PREDICATE WARNING

1   (WARNING HARMØNYL ALCØHØL#BARBITUATES#ØR#NARCØTICS)
2   (WARNING ALDØMET ABNØRMAL#LIVER#FUNCTIØN)
3   (WARNING APRESØLINE ALCØHØL#ØR#BARBITUATES)
4   (WARNING EUTØNYL MØNØAMINE#ØXIDASE#INHIBITØR)
5   (WARNING ISMELIN FAINTING#SPELLS#DIZZINESS#ØR#WEAKNESS)
6   (WARNING RAUWILØID PEPTIC#ULCER)
7   (WARNING SERPASIL GASTRIC#SECRETIØN#ØF#HYDRØCHLØRIC#ACID)
8   (WARNING SINGØSERP ANESTHESIA)
9   (WARNING UNITENSEN USE#IN#PREGNANCY)
10  (WARNING BUTISERPINE MAY#BE#HABIT#FØRMING)
11  (WARNING ALDØRIL IMPAIRED#RENAL#FUNCTIØN)
12  (WARNING ALDACTAZIDE SMALL#BØWEL#LESIØNS)
13  (WARNING ANHYDRØN HYPØKALEMIA)
14  (WARNING DIUTENSEN SMALL#BØWEL#LESIØNS)
15  (WARNING NØRMØTENSIN NØNE)
16  (WARNING DIALØSE NØNE)
17  (WARNING PRULET APPENDICITIS)
18  (WARNING DIASAL ØLIGURIA)
19  (WARNING BELBARB MAY#BE#HABIT#FØRMING)
20  (WARNING MEBARAL MAY#BE#HABIT#FØRMING)
21  (WARNING NEURØSINE MENTAL#DISTURBANCES)
22  (WARNING HALABAR MAY#BE#HABIT#FØRMING)
23  (WARNING MILTØWN MAY#BE#HABIT#FØRMING)
24  (WARNING CAPLA SMALL#BØWEL#LESIØNS)
25  (WARNING AERØLATE NØNE)
DØNE
```

```
LIST DØSAGE
LISTING ØF PREDICATE DØSAGE
1  (DØSAGE HARMØNYL #25MG#3#ØR#4#TIMES#DAILY)
2  (DØSAGE ALDØMET 250#TØ#500#MG)
3  (DØSAGE APRESØLINE 10#MG#4#TIMES#DAILY)
4  (DØSAGE EUTØNYL 25#TØ#50#MG)
5  (DØSAGE ISMELIN 10#MG)
6  (DØSAGE RAUWILØID TWØ#TABLETS#AT#BEDTIME)
7  (DØSAGE SERPASIL TWØ#ØNEQUARTER#MG#TABLETS#DAILY)
8  (DØSAGE SINGØSERP 1#TØ#2#TABLETS#DAILY)
9  (DØSAGE UNITENSEN 2#TABLETS#DAILY)
10 (DØSAGE BUTISERPINE ØNE#TØ#FØUR#TABLETS#DAILY)
11 (DØSAGE ALDØRIL ØNE#TABLET#2#ØR#3#TIMES#DAILY)
12 (DØSAGE ALDACTAZIDE ØNE#TABLET#4#TIMES#DAILY)
13 (DØSAGE ANHYDRØN ØNE#TABLET#PER#DAY)
14 (DØSAGE DIUTENSEN TWØ#TABLETS#PER#DAY)
15 (DØSAGE NØRMØTENSIN 1#TABLET#2#TØ#4#TIMES#PER#DAY)
16 (DØSAGE DIALØSE 1#CAPSULE#3#TIMES#DAILY)
17 (DØSAGE PRULET 1#TØ#3#TABLETS#AT#BEDTIME)
18 (DØSAGE DIASAL LIKE#SALT)
19 (DØSAGE BELBARB ØNE#TABLET#3#TØ#4#TIMES#DAILY)
20 (DØSAGE HALABAR ØNE#TABLET#2#TØ#3#TIMES#DAILY)
21 (DØSAGE MILTØWN 1#TØ#2#400#MG#TABLETS#3#TIMES#DAILY)
22 (DØSAGE CAPLA 1#TABLET#3#ØR#4#TIMES#DAILY)
23 (DØSAGE AERØLATE ØNE#CAPSULE#EVERY#12#HØURS)
24 (DØSAGE MEBARAL 400#TØ#600#MG#DAILY)
25 (DØSAGE NEURØSINE 1#TØ#2#TEASPØØNS#DAILY)
DØNE
```

LIST SUPPLIED

LISTING ØF PREDICATE SUPPLIED

1 (SUPPLIED HARMØNYL TABLETS#BØTTLES#ØF#100#500#1000)

2 (SUPPLIED ALDØMET BØTTLES#ØF#1000)

3 (SUPPLIED APRESØLINE 100#500#1000#TABLETS)

4 (SUPPLIED EUTØNYL 10#25#AND#50#MG#FILMTAB#TABLETS#IN#BØTTLES#100#AND#
0)

5 (SUPPLIED ISMELIN TABLETS#10#MG#BØTTLES#100#AND#1000)

6 (SUPPLIED RAUWILØID BØTTLES#ØF#60#AND#1000#TABLETS)

7 (SUPPLIED SERPASIL BØTTLES#ØF#100#500#1000#AND#5000)

8 (SUPPLIED SINGØSERP TABLETS#ØF#1#MG#BØTTLES#ØF#100#AND#1000)

9 (SUPPLIED UNITENSEN TABLETS#BØTTLES#ØF#100#500#AND#1000)

10 (SUPPLIED BUTISERPINE TABLETS#BØTTLES#ØF#100)

11 (SUPPLIED ALDØRIL BØTTLES#ØF#100#AND#1000)

12 (SUPPLIED ALDACTAZIDE BØTTLES#ØF#100#AND#500)

13 (SUPPLIED ANHYDRØN BØTTLES#ØF#100#AND#1000)

14 (SUPPLIED DIUTENSEN BØTTLES#ØF#100#500#AND#1000)

15 (SUPPLIED NØRMØTENSIN BØTTLES#ØF#30#100#500#AND#1000)

16 (SUPPLIED DIALØSE BØTTLES#ØF#36#100#AND#500)

17 (SUPPLIED PRULET PACKAGE#ØF#24#TABLETS)

18 (SUPPLIED DIASAL 2#ØZ#SHAKER)

19 (SUPPLIED BELBARB BØTTLES#ØF#100#500#AND#1000)

20 (SUPPLIED NEURØSINE BØTTLES#ØF#4#ØR#8#FLD#ØZ)

21 (SUPPLIED HALABAR UNKNØWN)

22 (SUPPLIED MILTØWN 200#400#MG#TABLETS)

23 (SUPPLIED CAPLA 300#MG#TABLETS)

24 (SUPPLIED AERØLATE BØTTLES#ØF#100#AND#1000)

25 (SUPPLIED MEBARAL 32#50#100#200#MG#TABLETS)

DØNE

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```
LIST HØUSE
LISTING ØF PREDICATE HØUSE
1   (HØUSE HARMØNYL ABBØTT)
2   (HØUSE ALDØMET MERCK#SHARP#DØHME)
3   (HØUSE APRESØLINE CIBA)
4   (HØUSE EUTØNYL ABBØTT)
5   (HØUSE ISMELIN CIBA)
6   (HØUSE RAUWILØID RIKER)
7   (HØUSE SERPASIL CIBA)
8   (HØUSE SINGØSERP CIBA)
9   (HØUSE UNITENSEN NEISLER)
10  (HØUSE BUTISERPINE MCNEIL)
11  (HØUSE ALDØRIL MERCK#SHARP#DØHME)
12  (HØUSE ALDACTAZIDE SEARLE)
13  (HØUSE ANHYDRØN LILLY)
14  (HØUSE DIUTENSEN NEISLER)
15  (HØUSE NØRMØTENSIN MARCEN)
16  (HØUSE DIALØSE STUART)
17  (HØUSE PRULET MISSIØN)
18  (HØUSE DIASAL FØUGERA)
19  (HØUSE BELBARB ARNAR#STØNE)
20  (HØUSE MEBARAL WINTHRØP)
21  (HØUSE NEURØSINE DIØS)
22  (HØUSE HALABAR CARNRICK)
23  (HØUSE MILTØWN WALLACE)
24  (HØUSE CAPLA WALLACE)
25  (HØUSE AERØLATE FLEMING)
DØNE
```

```
LIST ILLNESS

LISTING ØF PREDICATE ILLNESS

1   (FA (DRUG PATIENT SYMPTØM DEGREE) (IF (AND (ILLNESS PATIENT
SYMPTØM DEGREE) (INDICATIØN1 DRUG SYMPTØM DEGREE)) (PØTENT DRUG
PATIENT)))

DØNE
```

```
LIST HAS#ANY

LISTING ØF PREDICATE HAS#ANY

1   (FA (DRUG PATIENT SYMPTØMS) (IF (AND (PØTENT DRUG PATIENT)
(CØNTRAINDICATIØN DRUG SYMPTØMS) (NØT (HAS#ANY PATIENT SYMPTØMS)))
(SUGGEST DRUG PATIENT)))

DØNE
```

```
LIST SUGGEST

LISTING ØF PREDICATE SUGGEST

1   (FA (DRUG PATIENT SYMPTØMS) (IF (AND (PØTENT DRUG PATIENT)
(CØNTRAINDICATIØN DRUG SYMPTØMS) (NØT (HAS#ANY PATIENT SYMPTØMS)))
(SUGGEST DRUG PATIENT)))

DØNE
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```
LIST PØTENT

LISTING ØF PREDICATE PØTENT

1   (FA (DRUG PATIENT SYMPTØM DEGREE) (IF (AND (ILLNESS PATIENT
SYMPTØM DEGREE) (INDICATIØN1 DRUG SYMPTØM DEGREE)) (PØTENT DRUG
PATIENT)))

2   (FA (DRUG PATIENT SYMPTØMS) (IF (AND (PØTENT DRUG PATIENT)
(CØNTRAINDICATIØN DRUG SYMPTØMS) (NØT (HAS#ANY PATIENT SYMPTØMS)))
(SUGGEST DRUG PATIENT)))

DØNE



LIST INDICATIØN

LISTING ØF PREDICATE INDICATIØN

1   (FA (X DRUG SYMPTØM) (IF (INDICATIØN DRUG SYMPTØM) (INDICATIØN1
DRUG SYMPTØM X)))

DØNE
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