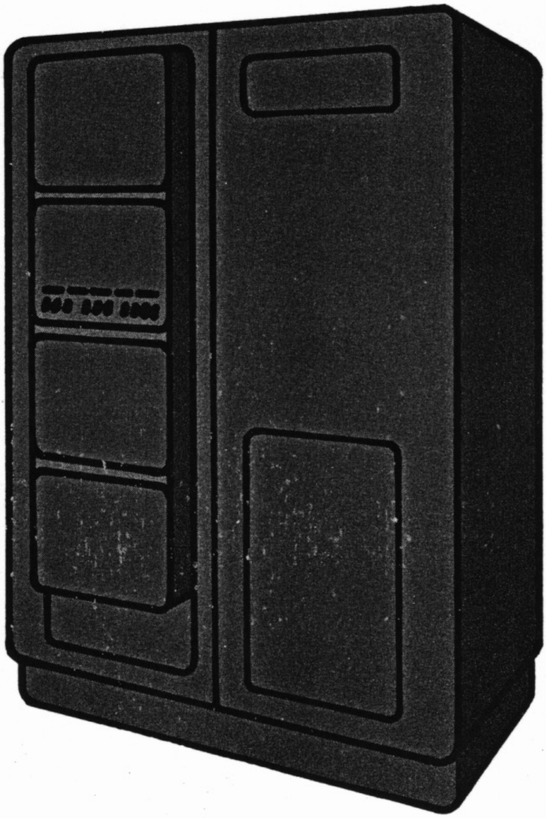
Bolt Beranek and Newman Inc.

BBN and Computers
A History



Preprint of an article to appear in the Encyclopedia of Computer Science and Technology

BBN and Computers - A History

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Encyclopedia of Computer Science and Technology

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Cambridge, Massachusetts

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I. INTRODUCTION

Bolt Beranek and Newman Inc. is a consulting and research and development company based in Cambridge, Massachusetts, with regional offices in six other major U.S. cities.

Founded in 1948, BBN was initially a partnership of Massachusetts Institute of Technology professors consulting in the areas of acoustics, noise control, and architectural services. Over the years, however, the scope of BBN services has widened and resulted in present capabilities which include computer science and systems, applied physics, oceanology, instrumentation, environmental systems, experimental psychology and education.

About half of BBN's professional activities are oriented toward computer science and technology, on projects ranging from artificial intelligence to computer network technology to medical computer systems for the research lab and the practitioner's office. Since its entry into the computer field, BBN has focused primarily on the field of man-machine interaction, and in so doing has made major contributions to technological progress in the areas of time-sharing, remote access, computer-assisted instruction, artificial intelligence, and the building of computer networks.

II. EARLY EFFORTS

BBN's earliest efforts in the computer field grew from the study of problems in man-machine relationships. During the late 1950's BBN embarked on several programs of research intended to make human use of machines more natural and more efficient. The mid-century exponential rise in the number and complexity of machines (and, concomitantly, the degree of man's dependence on technology) dictated close study of man's own capacity to derive those benefits which machines were intended to provide. A machine may operate at peak efficiency, yet its net effect be substantially less efficient if information concerning its function is not available or easily assimilable by its human controller. Thus, knowledge of human perceptions and behavior are as essential to the creation of an effective system as are metallurgy and electronics. Given the problem of making humans better controllers of machines, BBN entered the field of control theory, analyzing human perception and reaction factors in control situations and incorporating complementary behavior into machine design.

During this initial period of involvement, BBN intensified its efforts in the field of psychoacoustics (a pre-existing offshoot of BBN's major concern with physical acoustics) and began experiments which spanned the entire range of perceptual psychology, which results were fed back both into operator training programs and machine design. Products of this initial foray included a number of special-purpose computer displays, pilot-vehicle simulators, and analog-digital simulations of a variety of control situations.

III. MAJOR AREAS OF RESEARCH

Since that time, research into computers at BBN has essentially remained centered on the questions of man-machine interaction. Two generally distinct approaches have been followed, each having slightly differing emphasis on the man-computer problem. One approach attempts to increase both the accessibility of computers and the number of levels of possible human interaction. The second path has involved research into artificial intelligence--the attempt to facilitate human-computer interaction by organizaing machine processes to resemble more closely human processes of thought and behavior. This double-flanking movement, combined with ongoing research in behavioral and physical sciences, has yielded enormous benefits for the man-machine partnership in the form of individual devices, new languages and complete hardware and software systems.

A. Accessibility and Interaction

1. Time sharing

The pursuit of increased computer accessibility leads to consideration of two types of access: one involves the capability of many users to make use of a single machine; others involves the capability of a single user to call upon the resources of a large number of different machines (for reasons of specialization of function, language, or data base). During the 1960's BBN developed the means to facilitate both types of access. In 1962 BBN provided the first public demonstration of a time shared computer system, operating with three terminals on a PDP-1 (Fig. 1).

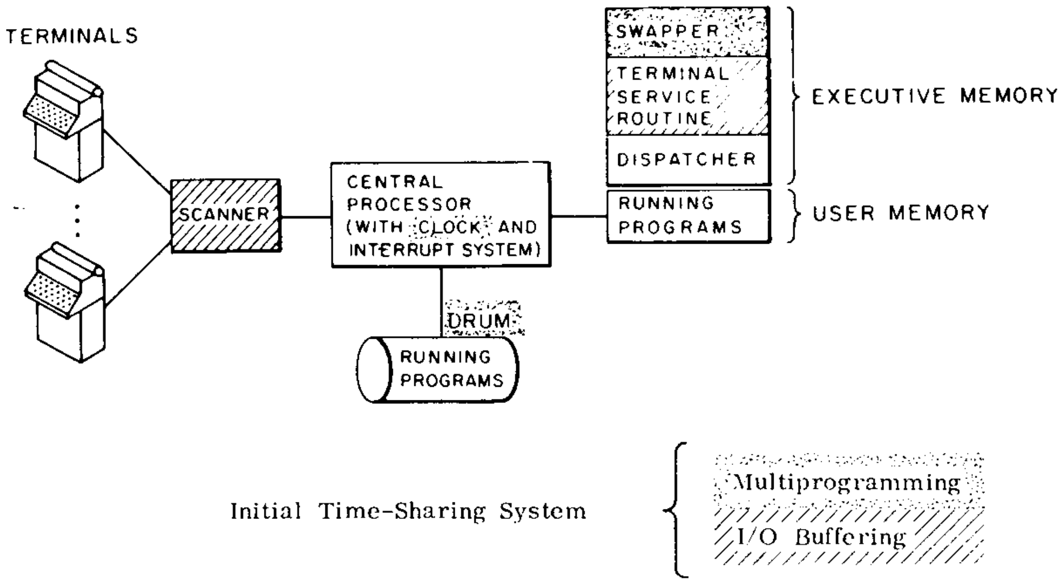


FIGURE 1 - BBN configured a DEC PDP-1 computer as shown to produce, in September 1962, the first public demonstration of time-sharing. A true time-sharing swapping system, this system permitted three users simultaneously to do machine-language programming and debugging. Over a decade later, the same basic organization is still being used in many time-sharing systems.

Concrete application of this major advance followed rapidly as BBN in 1962 undertook to design, develop, and implement a time-shared information system for the Massachusetts General Hospital under the sponsorship of the National Institutes of Health and the American Hospital Association (Figs. 2,3). The Hospital Computer Project, as it came to be known, continued for the next six years, and culminated in a system which accommodated 64 active terminals and provided storage, processing and retrieval of patient admission and clinical record files, laboratory results, and medication reporting. Other developments included aids for clinical research and nurse-scheduling, and certain specialized graphics devices.

As previously noted, improvements to the machine component of a man-machine system must be met with an increase in capability of the human element if the system is to be of real value. And so BBN responded to the proliferation of time-shared systems (and the yet greater resultant increase in the number of possible users) with the development in 1965 of the special-purpose time-sharing language, TELCOMP. Based upon Rand Corporation's JOSS, TELCOMP permitted users at remote terminals access to a central computer in a simple, English-algebraic language which could be learned by a non-specialist in a matter of hours. This on-line remote-access system provided considerable benefits to scientists and engineers, who were previously denied access for reasons of distance, finances, or lack of training. Later hardware and software developments gave TELCOMP users the capability for on-line storage and retrieval of information directly in the bulk memory of the central computer.

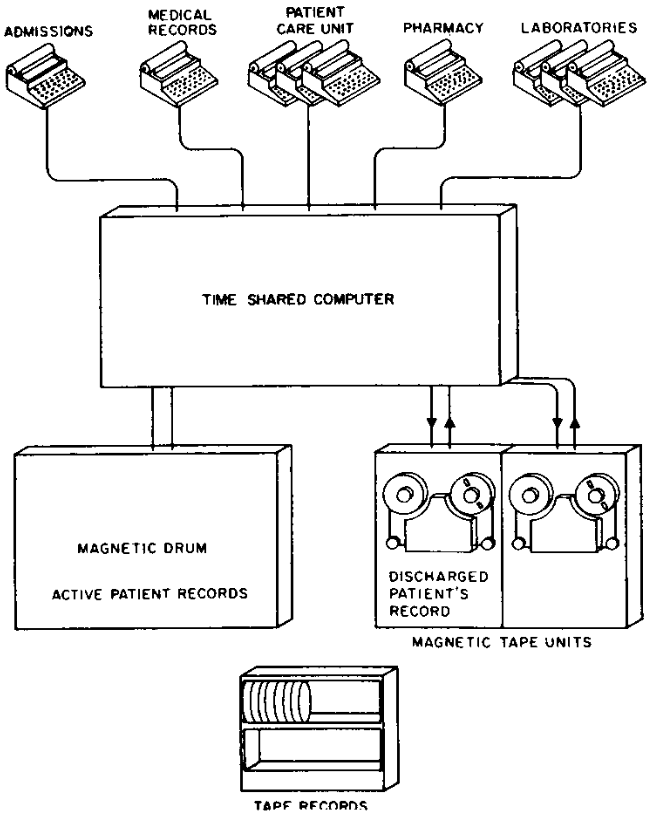


FIGURE 2 - The computer system shown is a prototype hospital information system developed by BBN and operated on a trial service basis in the Massachusetts General Hospital from 1966 to 1968. The programs stored in the central computer could manipulate medical-record data of any hierarchical level, could perform complex tasks of medication scheduling and charting, and could handle up to sixty-four terminals simultaneously entering or retrieving clinical information.

INFORMATION STORAGE AND RETRIEVAL SYSTEM

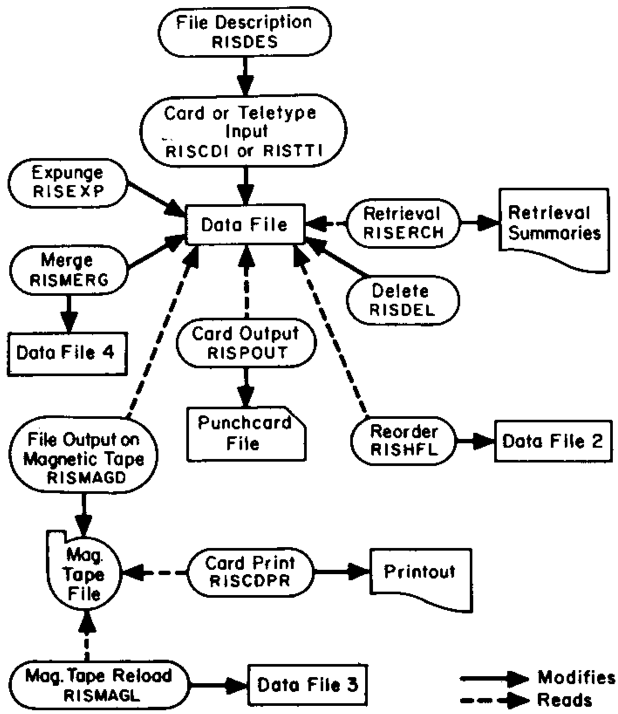


FIGURE 3 - This is a graphic representation of the interrelationship between the programs and the data of the Information Storage and Retrieval System developed by BBN in the mid-1960's for bio-medical researchers at the Massachusetts General Hospital. Unusual features of this data management system include interactive definition of file structures, a user-oriented syntax, description language to specify data formats, compatibility with standard punched-card files, a hierarchical indexing or file-inversion capability, and an ability for the user to generate a variety of retrieval requests simply by answering computer-posed questions.

In 1970 BBN furthered the efficiency of man-computer interaction in the realm of increased multi-user accessibility with the development of TENEX, a paged virtual memory operating system for the time-shared operation of the PDP-10 (Fig. 4). TENEX, providing each user with a 256K word virtual address space, simplifies the solution of problems requiring programs and data bases larger than the amount of available core memory. Creation and simultaneous operation of hierarchies of interdependent processes, real time response, expanded capabilities for system programming, and direct compatibility with DECSystem-10 code at the object code level are further advantages of the system. The TENEX system has won nationwide popularity, resulting in the existence of about a dozen TENEX systems throughout the U.S. in mid-1973, with more expected in the future.

2. The ARPA Network

Just prior to this development, BBN began working on ways to increase computer accessibility in the opposite direction, that is, to grant a single user access to a number of machines. The current product of this work is the ARPA Network, designed and developed under the sponsorship of the Advanced Research Projects Agency of the Defense Department (Figs. 5,6). The ARPA Network is a buffered store-and-forward data network that connects a set of geographically separated, heterogeneous, and autonomous computers, designated "Hosts," with the objective of facilitating interactive resource sharing between any set of these Hosts. The store-and-forward processing is accomplished by a set of identical small computers called Interface Message Processors (IMPs), and users with no Host computer are provided direct terminal access to the network by means of Terminal Interface Message Processors (TIPs) (Fig. 7). The internal operation of the IMP and TIP subnet is self-contained and essentially transparent to persons using the network. An

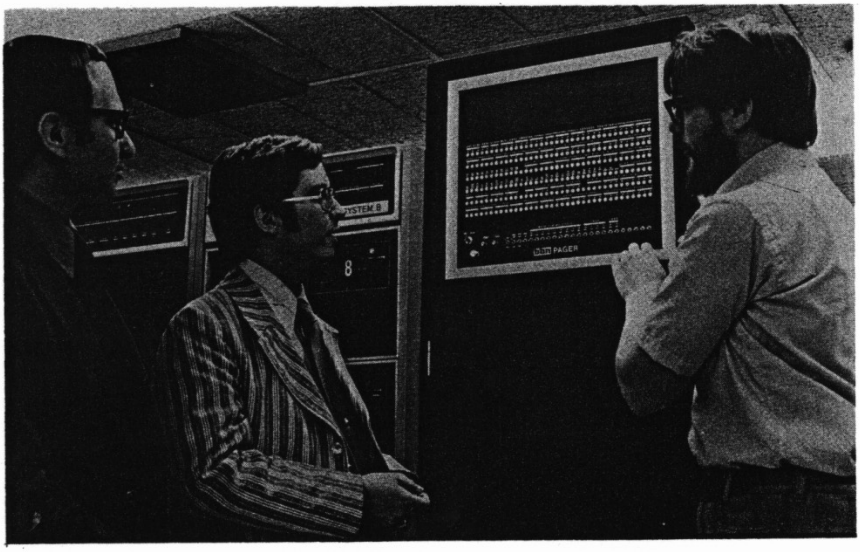
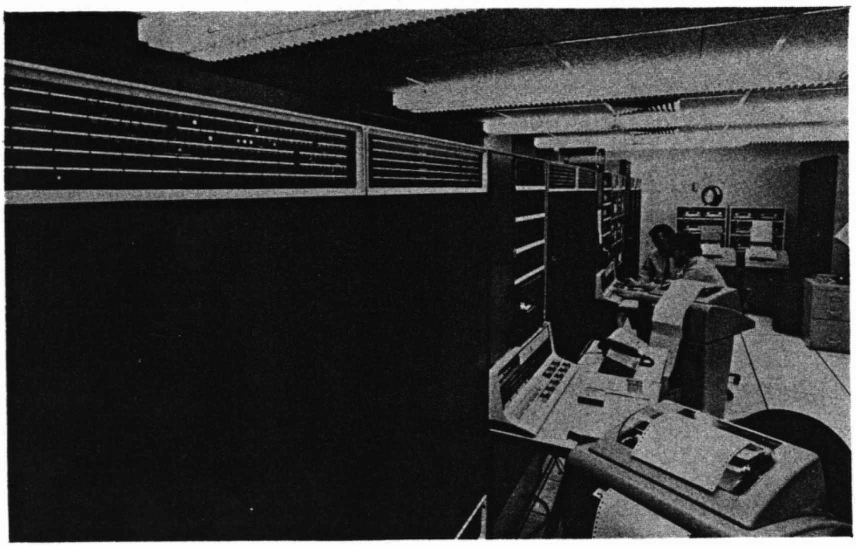


FIGURE 4 - BBN's specially-developed memory pager, for use with the DEC PDP-10, allows users to unite programs as if they had over 260,000 words of core memory even though only a small portion of their program need actually be in core. BBN also developed the time-sharing software for this system, which is called TENEX. The system has many special features, such as the ability to run multiple processes that share memory and a pseudo-interrupt capability that facilitates interprocess communication.



ARPA NETWORK GEOGRAPHICAL MAP, DECEMBER 1969

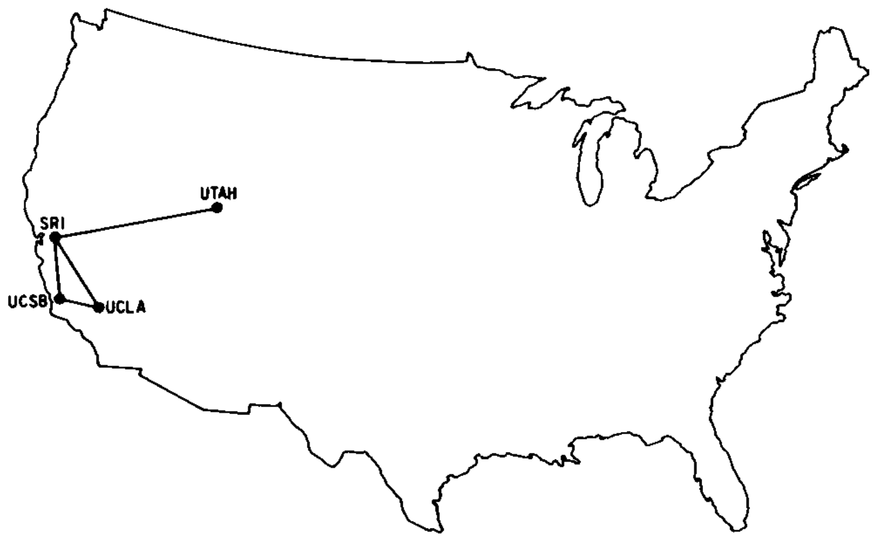
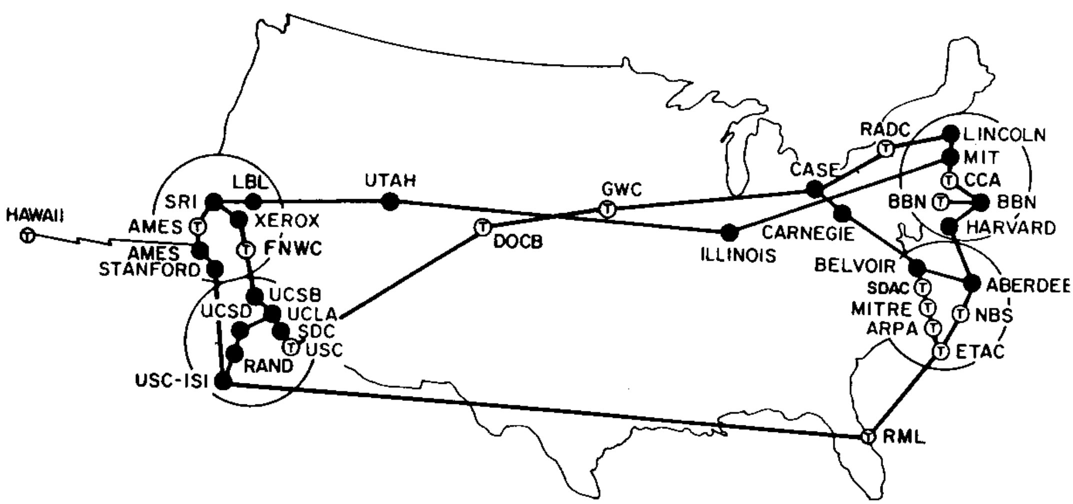


FIGURE 5 - a) The initial Advanced Research Projects Agency (ARPA) Network, above, connected four Interface Message Processors (IMPs), each of which allowed connection into the network of up to four Host computers.
b) The May 1973 network interconnects 36 sites, several by means of Terminal Interface Message Processors (TIPs), each of which allows direct access to the network by up to 63 terminals.

ARPA NETWORK GEOGRAPHICAL MAP, MAY 1973



ARPA NETWORK, LOGICAL MAP, MAY 1973

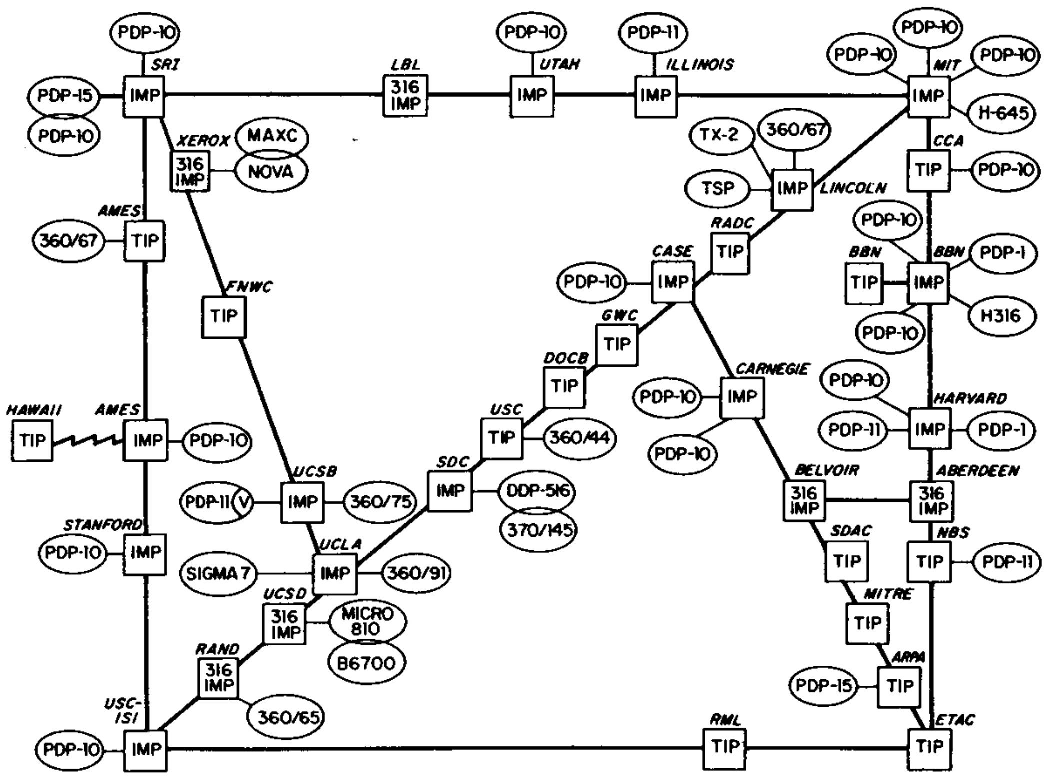


FIGURE 6 - Resources available to users of the Advanced Research Projects Agency (ARPA) Network include a wide varity of Host computer types (shown in ovals). A user may access any resource on the network from his own computer via Interface Message Processors (IMPs), themselves small computers based on Honeywell models 516 or 316, or directly from a terminal through an H316-based Terminal IMP (TIP). The IMP/TIP subnetwork communicates over leased 50-kilobit telephone lines (with the exception of a 230.4-kilobit link between the two Ames sites) plus a communications satellite link to Hawaii; an Atlantic satellite link will shortly extend the network to England and Norway. BBN is responsible for the design of the IMPs, the TIPs, the network as a whole, and the network's day-to-day operation.

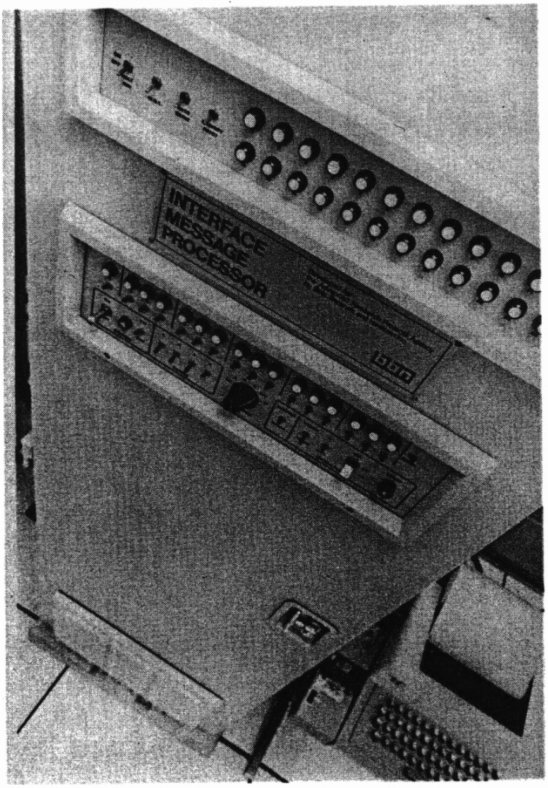
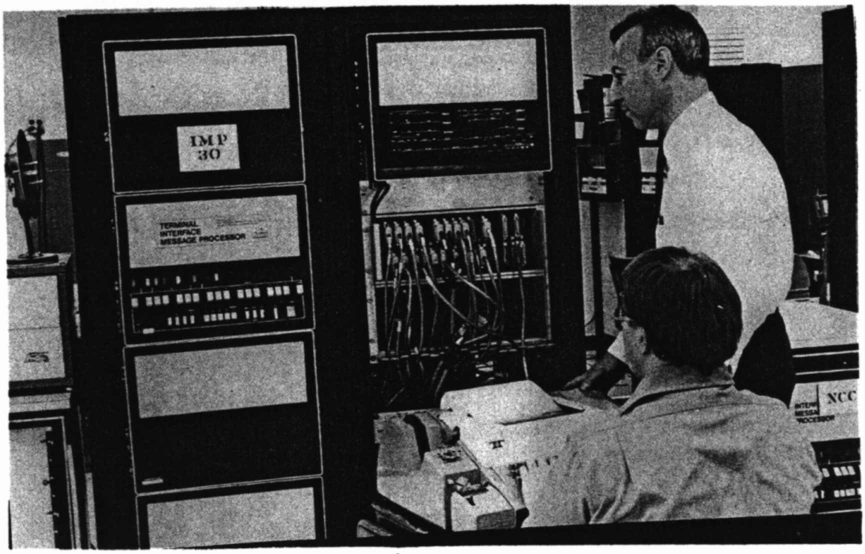


FIGURE 7 - The basic components of the IMP Subnet for the ARPA Network.

a) The Interface Message Processor (IMP).

b) The Terminal Interface Message Processor (TIP).



individual may access and use the resources of any of the Host computers as if the remote computer were an extension of the local Host. Developments underway in mid-1973 include a High Speed Modular IMP and implementation of network links via satellite to Hawaii and Europe.

3. Interaction via graphics

With computer accessibility being fostered by two different approaches (i.e., one seeking to increase the number of possible users through time-sharing, the other seeking to make more and different types of computers available), the overall problem of interaction is still only partially addressed. Once widened and simplified access is attained, an efficient interactive relationship depends upon the user's making best use of the accessed machine. Early in the 1960's BBN began discovering ways to increase the number of levels and types of interaction in the man-machine relationship. Working to extend levels of visual interaction with computers, BBN developed means for facilitating machine presentation of visual information, and for direct inputting of graphic information.

Among BBN's first accomplishments in this area was the GRAFACON digital tablet (based upon a development of the Rand Corporation), the first commercial device for direct inputting of graphical position information to a digital computer (Fig. 8). The GRAFACON, with its "writing tablet" offered significant improvement in naturalness of man-machine communication, particularly when used with various BBN-manufactured graphics devices such as the PLOTAMATIC x/y recorder and the TELEPUTER display terminal. Research into the field of interactive computer graphics also

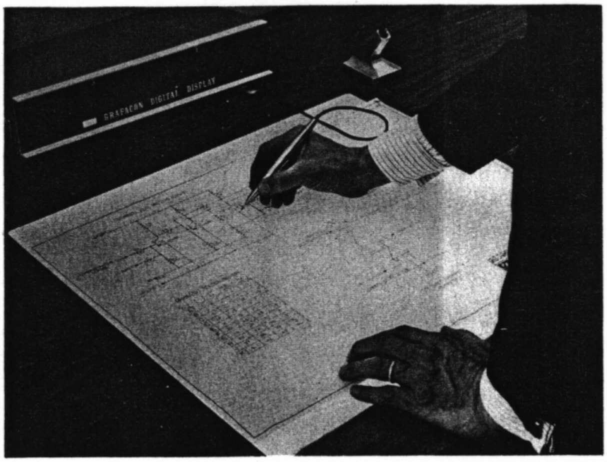
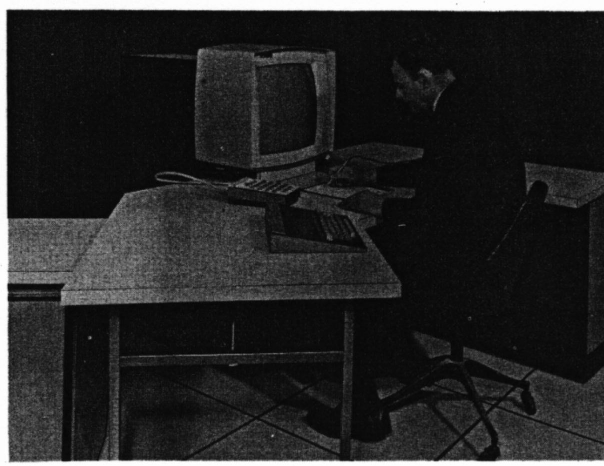
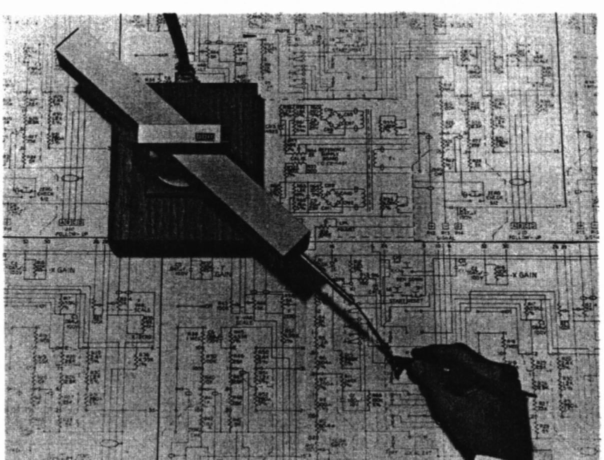


FIGURE 8 - Some BBN-developed computer graphics devices:

a) Inputting graphical data via the GRAFACON pen-and-tablet assembly (tablet is a fine wire grid, each line of which is excited with a 10-bit serial pulse train. An intersection is uniquely defined by a signal which the pen picks up capacitively. The digital display device gives decimal indications of pen position coordinates.



b) Operating the GRAFACON pen-and-tablet assembly in conjunction with an IBM 2250 CRT terminal.



c) Digitizing graphical information with the GRAFACON ρ-θ Transducer. The device has two analog voltage outputs proportional to the polar coordinates of the pen position.

found rapid application during this time in the form of complex control-situation simulations. Pilot-vehicle simulators were developed by BBN, drawing on advanced in the technology of visual displays, which also included diagnostic instructional monitors in instrument flying and in navigation (Fig. 9).

Later work in the software area has resulted in the design and implementation of general purpose graphics software for the Evans and Sutherland display processor; the design of graphics software which will convey detailed visual information to air-traffic controllers concerning the vectoring of aircraft in landing patterns; and the integration of displays of visual speech correlatives into a CAI system for second-language learning (Fig. 10).

4. Interaction via language

Throughout the history of BBN's involvement with computers, BBN has conducted continuous research at the most basic level of interaction, that of language, in order to make man-machine communication both simpler and more natural.

In the early-1960's BBN developed DECAL, and assembler-compiled hybrid which permitted the intermixing in a program of algebraic statements and explicit machine instructions. Shortly thereafter, BBN personnel began the continuing development of BBN-LISP. An adaptation and extension of LISP 1.5, BBN-LISP was first implemented on the SDS-940 and then on the PDP-10, and is now a major component of the TENEX system.

BBN-LISP facilitates use of TENEX's large memory capability, and possesses many useful interactive system features, such as: sophisticated debugging facilities, a LISP-oriented editor within the system, compatible compiler and interpreter, and the capability for mixing of machine code with LISP expressions via the

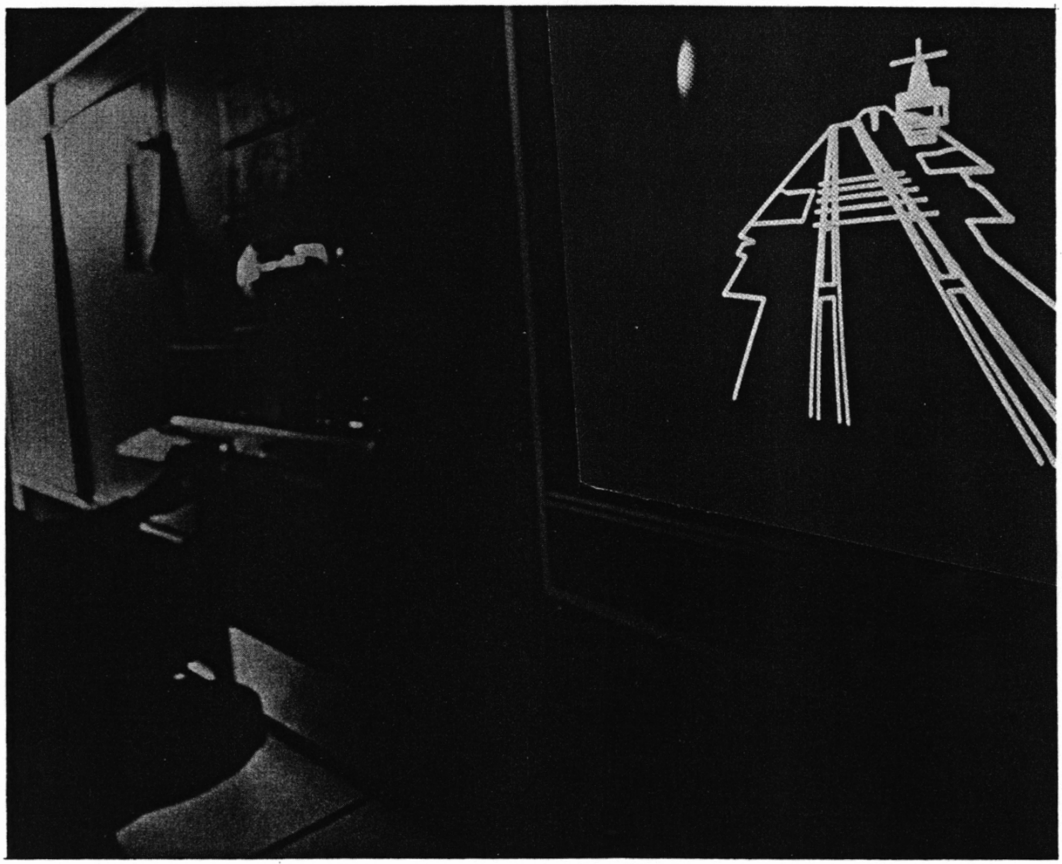


FIGURE 9 - One BBN endeavor in the area of interactive graphics is the development of graphic software for a system that can display moving pictures in three-dimensional perspective. The hardware for this system includes a special processor for rapidly calculating and presenting each successive frame of the moving picture. The system is being used for flight simulation; each time the pilot moves his controls, the system instantly alters the displayed picture in accordance with the visual change that would have accompanied a similar movement in actual flight. Here the system is being used to simulate landing on an aircraft carrier deck.

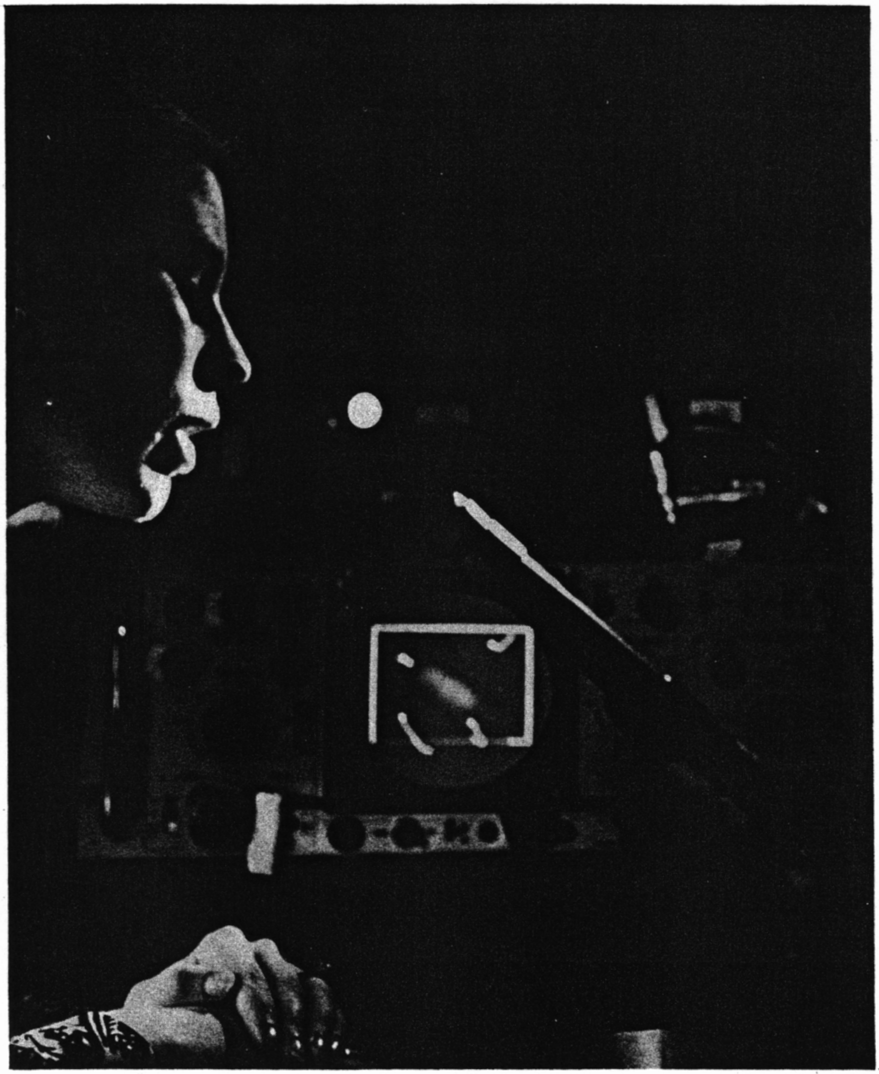


FIGURE 10 - BBN has explored the use of a computer-based instructional system to help students learn pronunciation of a foreign language. The system lets a student see as well as hear his errors, and for each error indicates the kind and the amount of adjustment he must make to achieve acceptable pronunciation. The computer analyzes certain acoustic properties of the student's utterances, and either represents them directly on a display scope or infers from them some anatomical concomitant, for example, the position and movement of the student's tongue.

compiler. One of the more recent additions to BBN-LISP is the "programmer's assistant", a subsystem which enables the user to treat it as an active intermediary, rather than a passive system which merely responds to each input and waits for the next. The "assistant" can remember the user's programming statements and can be instructed to repeat particular operations or sequences of operations, with possible modifications, or to undo effects of operations. Under development in mid-1973 is another subsystem which will permit use of ALGOL-like expressions (e.g., block declarations, infix operators, and if-then statements) within BBN-LISP. The major aim of work with BBN-LISP is to construct a programming environment which "cooperates" with the user in the development of his programs, and frees him to concentrate more fully on the conceptual difficulties and creative aspects of the problem under consideration.

In addition to the previously described TELCOMP, BBN has developed the related languages STRCOMP and RISCOMP, both JOSS-like conversational languages designed for complex text-manipulation and data-management, respectively. The languages LOGO and MENTOR were developed in the late 1960's for educational purposes, and are described in Section III.B.

BBN's most recent effort in computer language development is PARSEC, designed for use in the PROPHET System (see Section IV.). PARSEC is one of the first extensible languages to be used as the implementation language for a large, in-service applications system dealing with real-world problems. It allows the definition of new data types as composites of existing data types, and permits the description of syntax for new commands through transformations which reduce them to combinations of statements which are already defined. PARSEC integrates features drawn from a number of extensible language efforts, combined with the kind of service capabilities which are often omitted in development of new languages: full input/output commands, dynamic overlays, good error recovery, garbage collection, tracing and debugging aids, and a broad set of numeric and string manipulation system functions.

B. Artificial Intelligence and CAI

Natural communication with computers is a point of intersection with the other major line of research undertaken by BBN--artificial intelligence. Here BBN has attempted to facilitate human-computer interaction by organizing machine processes to resemble more closely human processes of thought and behavior. Expanding from its first ventures in psychoacoustics and control theory, the BBN Behavioral Sciences division has conducted research into several areas of human behavior, the findings of which have been applied to machine strategies. Studies of the structure of language in man have had their results applied to the design of more natural (i.e., human-like) language-processing schemes in machines. Similarly, inquiries into the nature of human control behavior, pattern recognition, and speech comprehension have yeilded new strategic knowledge which found rapid application to problems of machine sensor-information integration, automatic pattern recognition, and verbal command strategies for computers.

By integrating various human-modeled machine processes, BBN has been able to produce computer systems which perform complex human-type decision-making and monitoring functions, among them automated biology and psychology laboratories and computerized air-traffic control systems. An early development was a software system which allowed the machine to edit and simplify its own programs.

A particularly vivid example of this sort of adaptive research at BBN is in the area of semantic net theory. Curious as to the associative nature of the structure of meanings in the human mind, BBN researchers embarked on a series of experiments intended to, in effect, map human semantic organization. Taking differential response times of subjects adjudging the truth or falsity of conceptually related statements to be an indicator of the relative "semantic distance" between the implicit concepts, BBN researchers constructed an explanatory model of the apparent interlinked hierarchical semantic structure. Software configurations modeled along the selfsame lines as these perceived "semantic nets", and incorporating the appropriate syntactical strategies, produced programs capable of generating whole discourses of sentences from component morphemes, rather than regurgitating entire, prefabricated, specifically programmed responses.

Of particular significance in this area is the application of principles of artificial intelligence to Computer-Assisted Instruction. In 1964, BBN developed a "Socratic dialogue" program for CAI which enabled the machine "instructor" by inferential and deductive rules to pose questions to a student and to supply answers and clarifications (Fig. 11). The following year a new language, MENTOR, was developed, for use by educators in creating Socratic-type CAI programs for their students.

Another striking advance in the use of computers for teaching purposes came with BBN's development of SCHOLAR (Figs. 12, 13) a CAI program based on the formulation of semantic net theory noted above. SCHOLAR is capable of engaging the student in mixed-initiative dialogue, wherein the student may take the initiative in querying the computer or turn the initiative over to the machine, in which event the machine may opt to lecture or query the student. Based on cues from the student's response times and actual responses (and, of course, from his questions), the computer stages reviews and formulates quizzes, generating its "utterances" from scratch, i.e., basic morphemic constituents.

LOGO is an educational language devised by BBN researchers to teach school children techniques of problem-solving. In learning to use LOGO, a procedure-oriented extensible language, young students learn not only the basics of programming, but the basics of problem-directed thinking. A most popular application of LOGO is in the programming of Irving, a turtle-like robot, to run mazes, search for articles, and otherwise be an object of fascination (Fig. 14).

Other ventures in the use of computers as teaching machines include programs for speech aids to the deaf and for second-language learning, both of which involve, in part, rather ingenious matching tasks with CRT-displayed visual correlatives of speech patterns (Fig. 15).

A SOCRATIC SYSTEM PROTOCOL

PHYSICAL EXAM?

Fine. What in particular would you like to know?

CHEST EXAM?

It is common practice in the medical profession to begin an examination by checking the patient's general appearance.

GENERAL APPEARANCE?

Acutely prostrated, lying in bed on his right side. Looks acutely ill, sweaty, apprehensive, but alert. Paroxysmal cough, bringing up a little rusty streaked sputum. Breathing with difficulty.

EENT EXAM?

Check all the vital signs first!

PULLS?

Do you mean pulse?

YES.

100 a minute. Occasional extra systole.

LABORATORY REPORTS?

Fine. Which lab tests would you like to have done?

RBC?

A red count will be done. Results will be sent to you as soon as possible.

.....

Some of the first series of lab reports have just come in.
Urine exam: insufficient fluid for analysis.

RBC: 5 million.

WBC: 15500.

Differential: Shift to left.

When the other reports are in you'll be notified. Before proceeding with the reexamination it might be instructive to pause and consider the diagnostic implications of the information at hand. Perhaps you think it too early to arrive at any definitive conclusion. On the other hand, you may be prepared to make the diagnosis now. Are you?

NO.

Fine. Nevertheless, we've got a fair amount of information-at least enough to raise some, perhaps several, diagnostic possibilities. Have you any in mind?

YES.

Name one.

PULMONARY INFARCTION.

Fine. Pleural pain, dyspnea, fever and the physical exam signs and symptoms are certainly consistent with pulmonary infarction. Do you think shaking chills and the presence of rusty sputum further support this diagnosis?

NO.

Right. Though the white count is consistent, isn't it?

NO.

Wrong. The white count *is* consistent. This should further support your diagnosis. We've considered one possibility. Do you have another diagnosis in mind?

NO.

In that case I'd like to talk about viral pneumonia. The tachycardia, high WBC, elevated respiratory rate, shaking chills, bloody sputum and severe pleural pain all lend weight to that diagnosis-right?

APPENDICITIS.

Sounds good! But what about the history of cough and the chest signs? What evidence would help you establish this diagnosis?

EVIDENCE FROM ABDOMINAL EXAM.

Right! Go to it!

ABDOMINAL EXAM?

The heart exam should be done before this.

HEART EXAM?

Unchanged, except systolic murmur more prominent.

ABDOMINAL EXAM?

Pain localizing in lower right quadrant with continuing diffuse abdominal tenderness.

APPENDICITIS.

Appendicitis? Nonsense. By this time you should have your attention focussed on a different part of the patient's anatomy.

....

PNEUMOCCAL PNEUMONIA.

Are you absolutely sure?

YES.

You can't be until you have irrefutable evidence. What would help you nail down the diagnosis?

EVIDENCE FROM SPUTUM SMEAR AND CULTURE.

Good. Anything else?

NO.

I think you might also want evidence from x-ray findings. Go ahead and we'll see what happens.

....

FIGURE 11 - A socratic system protocol. The following is a series of excerpts taken from a transcript of inputs and outputs obtained on a Socratic System interaction in a medical diagnosis run. The sets of dots ..... indicate ommissions. The student inputs are expressed in capital letters and indented. The computer outputs are expressed in lower case, and are not indented.

```
-SCHOLAR)

++++++++++++++++++++++++++++++++++++++++++++++++++++++++

HELLO, MY NAME IS SCHOLAR. I WILL HELP YOU IN REVIEWING
THE GEOGRAPHY OF SOUTH AMERICA. THIS IS ABC REGIONAL
HIGH SCHOOL. TODAY IS 04/29/70.

WHEN YOU ARE READY TO START, TYPE READY --- REMEMBER
TO TERMINATE WITH AN ASTERISK * FOLLOWED BY A CARRIAGE
RETURN.

*READY*

PLEASE TYPE YOUR NAME --- MR., MISS, OR MRS. FOLLOWED
BY FIRST NAME, MIDDLE NAME OR MIDDLE INITIAL, AND LAST
NAME.

*MR. JAMES R. JONEES+S+ES*

NAME OF YOUR INSTRUCTOR, PLEASE:

*MR. BROWN*

LET'S BEGIN OUR DISCUSSION NOW, MR. JONES.

++++++++++++++++++++++++++++++++++++++++++++++++++++++++

SELECT AN ALTERNATIVE FROM THE LIST:

214000.
800300.
49883.
63690.

FOR THE QUESTION:

  APPROX WHAT IS THE AREA OF CHILE?

*800300*

YOUR ANSWER IS INCORRECT.
THE CORRECT ANSWER IS: 214000.

USE ONE OF THE FOLLOWING:

SUCRE
FRENCH
ARGENTINA
SPANISH

TO ANSWER THE QUESTION:

  WHAT IS THE LANGUAGE IN CHILE?

*
YOU ARE TAKING TOO MUCH TIME...

*SPANICH*

YOU SHOULD HAVE WRITTEN "SPANISH".

VERY GOOD.

PLEASE INDICATE IF THE FOLLOWING STATEMENT IS CORRECT
          OR INCORRECT:

THE AREA OF PARAGUAY IS APPROX 47432 SQUARE MILES.

*WHAT IS THE AREA OF BRAZIL?*

  THE AREA OF BRAZIL IS APPROX 3600000. SQUARE MILES.

NOW ANSWER THE QUESTION YOU DIDN'T ANSWER BEFORE.

*FALSE*

REPHRASE YOUR STATEMENT. I CAN'T UNDERSTAND IT.

*INCORRECT*

VERY GOOD.

THE AREA OF PARAGUAY IS APPROX 157000 SQUARE MILES.

  APPROX WHAT IS THE POPULATION IN BRAZIL?

*60000000.*

APPROXIMATELY TRUE, BUT A MORE EXACT VALUE IS 70000000.

*TELL ME SOMETHING ABOUT PERU.*

WAIT A MINUTE. I'M CHECKING MY FILES.

LET'S PROCEED NOW.

    PERU IS A COUNTRY.
    IT IS IN SOUTH AMERICA.
    THE POPULATION IS APPROX 7000000. PEOPLE.
    THE CAPITAL IS LIMA.

*Q/A*

DO YOU WANT TO CHANGE THE GENERAL MODE OF THE INTERACTION
    TO Q/A?
PLEASE ANSWER Y OR N.

*Y*

OK, MR. JONES. LET'S GO AHEAD.

*PLEASE, TELL ME MORE ABOUT PERU.*

    THE AREA OF PERU IS APPROX 480000. SQUARE MILES.
    THE LANGUAGE IS SPANISH.

*HOW MANY SQUARE MILES ARE THERE IN BRAZIL?*

  THE AREA IS APPROX 3600000. SQUARE MILES.

*WHAT IS THE PRINCIPAL RELIGION IN URUGUAY?*

  THE PRINCIPAL RELIGION IN URUGUAY IS CATHOLICISM.

*
WELL, HAVE YOU MADE UP YOUR MIND?

*COULD YOU PLEASE INDICATE THE PRINCIPAL RIVERS IN
ARGENTINA?*

I DON'T UNDERSTAND YOUR WORD "INDICATE". I'LL GIVE
      YOU ANOTHER CHANCE.

*THE PRINCIPAL RIVERS IN ARGENTINA ARE ---.*

  THE PRINCIPAL RIVERS IN ARGENTINA ARE THE RIO DE LA PLATA,
      THE PARANA, THE URUGUAY RIVER, THE SALADO, THE
      PARAGUAY RIVER, AND THE PILCOMAYO.

*MIXINIT*

DO YOU WANT TO CHANGE THE GENERAL MODE OF THE INTERACTION
    TO MIXINIT?
PLEASE ANSWER Y OR N.

*Y**

OK, MR. JONES. LET'S GO AHEAD.

WHERE IS BRAZIL?

PLEASE HURRY UP. I'M WAITING FOR YOUR STATEMENT.

*IN SOUTHAMERICA*

I BELIEVE YOU MEANT TO TYPE "SOUTH AMERICA".

THAT'S RIGHT.

IS IT CORRECT TO SAY THAT THE CITIES IN BRAZIL ARE
    SAO PAULO, RIO DE JANEIRO, BRAZILIA, PORTO ALEGRE,
    BAHIA, RECIFE, SANTOS, MANAOS, AND BELEM?

*YES*

THAT'S FINE.

THE CITIES IN BOLIVIA ARE ----.

*LA PAZ, SUCRE, BOGOTA, AND ACONCAGUA*

AT LAST! ANYWAY, LET US SEE WHAT YOU HAVE JUST WRITTEN.

HAVEN'T YOU INCORRECTLY USED "BOGOTA" AND "ACONCAGUA"?
ON THE OTHER HAND "LA PAZ" AND "SUCRE" IS CORRECT.

THE COMPLETE ANSWER ALSO INCLUDES POTOSI, COCHABAMBA,
                              AND SANTA CRUZ.

*WHAT IS CORDOBA?*

    CORDOBA IS A CITY.
    IT IS LOCATED IN ARGENTINA.
    THE POPULATION IS 700000. PEOPLE.

    . . . .
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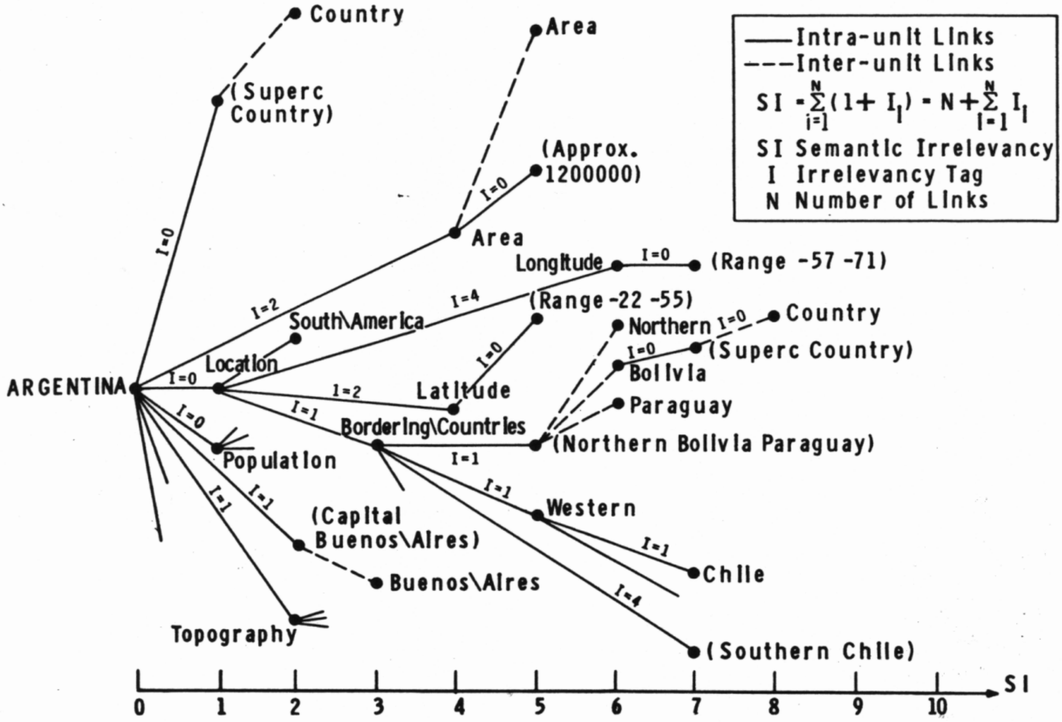

FIGURE 13 - SCHOLAR is information-structure-oriented, utilizing a data base of a complex but well-defined information structure in the form of a network of facts, concepts, and procedures. It is a semantic network in that its elements are units of information defining words and elements in the form of multi-level tree lists; the elements of those lists point in turn to their respective units, and so on. Pictured at left is a diagram of semantic structure for the network node 'ARGENTINA'.

FIGURE 12 - Here is an excerpt of a mixed-initiative CAI protocol using SCHOLAR; the subject matter in this case is South American geography. Not only does the computer have the capability to pose several types of questions (e.g., true-false, multiple-choice, WH-type, completion), but it can also answer these sorts of questions when the student takes the initiative.

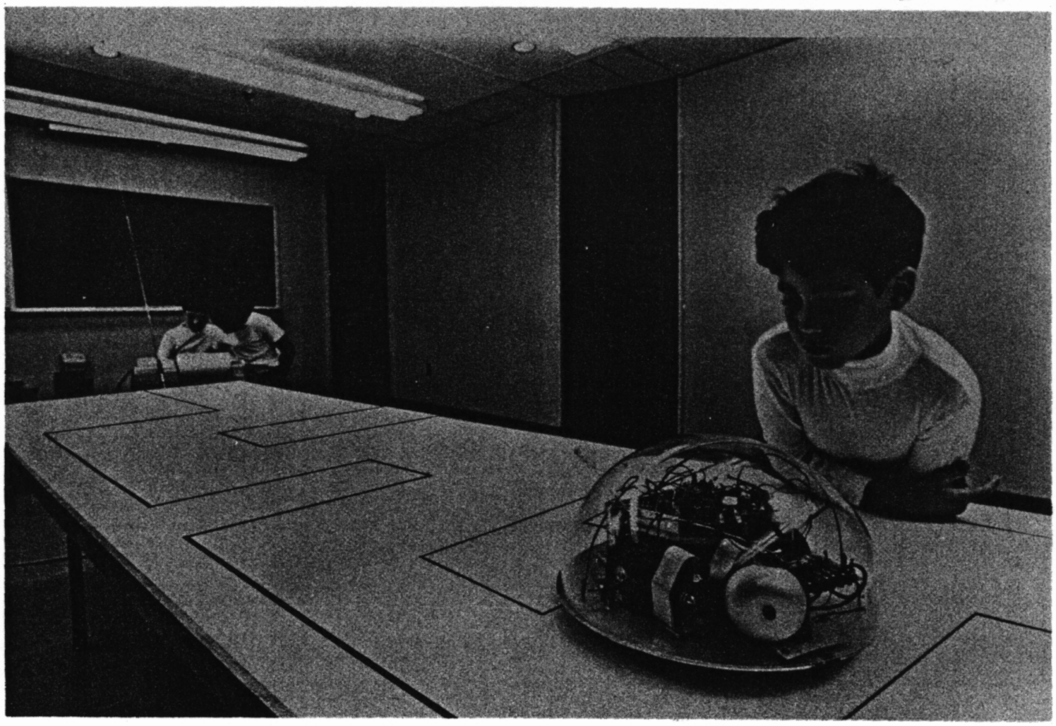

FIGURE 14 - Irving the Electronic Turtle with his young programmers. Using the BBN-developed LOGO programming language, children at a teletype terminal remotely control Irving. In setting up a program to solve a relatively complex problem--such as getting Irving through a maze--the child works out a sequence of elementary procedures; he can readily see the effect of errors in his procedures and try to fix them. An experimental approach to problem solving is thereby fostered; the child learns to describe and control processes while seeing them realized in a concrete fashion.

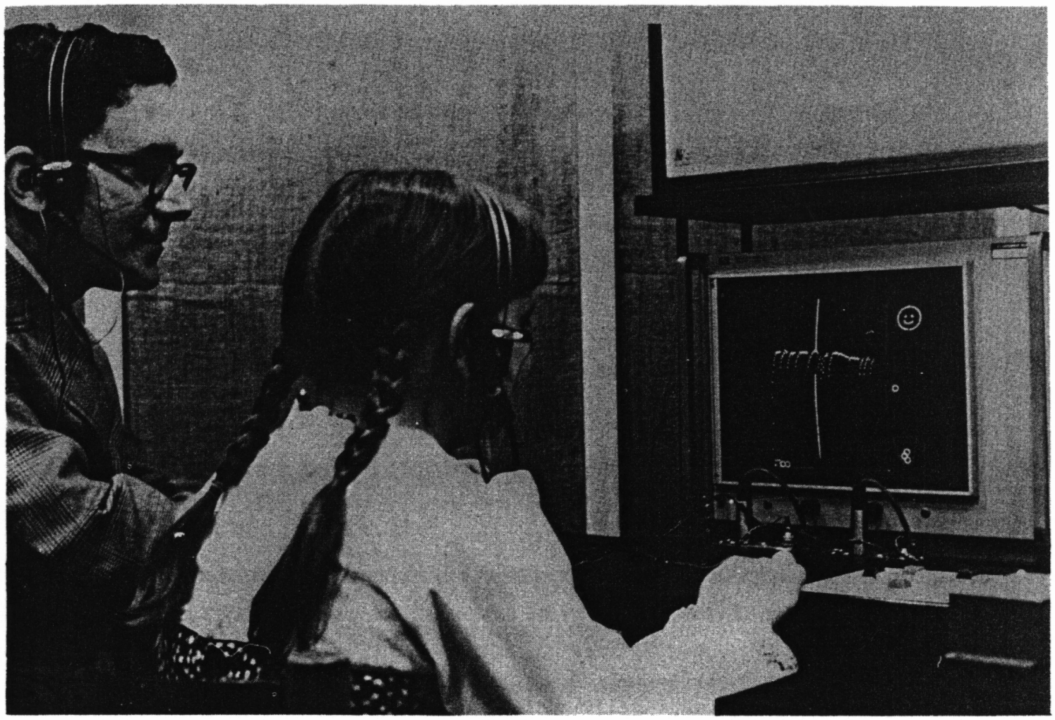

FIGURE 15 - BBN is currently working to provide computerized speech aids for the deaf. With the device pictured here, a deaf child can receive visual feedbacks of speech efforts. By using the correct pitch and volume, the child can put the ball through the gate and score a basket.