NETWORK INFORMATION CENTER AND
COMPUTER AUGMENTED TEAM INTERACTION

Augmentation Research Center
Stanford Research Institute

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Abstract

During 1970 SRI's Augmentation Research Center took part in preliminary operation of the ARPA network, made several important improvements in the ARC operating system's efficiency and features for users, and began installation of a new computer.

Conversion from an XDS 940 to a DEC PDP-10, which was in process in February 1971, has delayed full operation on the ARPA network.

However, the network has been used both in software development and in trial runs of the Network Information Center. Initial software for the Network Information Center was completed and documents have been rapidly accumulating. Other new hardware includes UNIVAC drums and various remote terminals. New software includes redesign of the core of our NLS, development of higher level processes such as executable text, and ready use of content analysers in automated clerical procedures. New features for users include, among other things, an online journal comparable both to a daily periodical and to archival journals, and a calculator.
The research reported here is the product of conceptual, design, and development work by a large number of persons; the program has been active as a coordinated team effort since 1965.

1970's work involves the whole ARC staff:

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Network Information Center

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IV. SUMMARY

A. INTRODUCTION

1. This report covers the year 1970 of research in a continuous program at the Augmentation Research Center of the Information Science Laboratory of Stanford Research Institute, supported by ARPA under RADC contract F30602-70-C-0219.

2. The research reported is aimed at the development of online computer aids for augmenting the performance of individuals and teams engaged in intellectual work, and the development of the Network Information Center for the ARPA Computer Network. The report covers hardware and software development, applications in several areas, and a summary of plans for the continuation of the research during 1971.

B. HIGHLIGHTS OF THE CONTRACT YEAR

1. During 1970 we devoted our attention especially to our continuing effort to improve the efficiency of our online system and polish and strengthen its usefulness to systems programming, to working with the ARPA Network, and to augmentation of distributed teams. During the latter part of the year we were deeply involved with translating our software into forms compatible with a PDP-10 and with choosing and connecting its peripheral equipment.

2. We have named an important new group of tools for users developed in 1970 "Higher Level Processes". They are routines in which the basic user features of our online system are building blocks in construction of programs that carry out specific, rather complicated tasks such as changing the order of a citation index and at the same time the format of the citations. Important Higher Level Processes are the rewritten Content Analyzer, the Analyzer Formatter, the Collector Sorter, and Executable Text.

3. We added an arithmetic and algebraic calculator package to our online system.

4. We have recently been working more with the goal of augmenting teams performing work that is distributed in time, space, and discipline. By way of communication and archival and managerial record keeping, we added a mail system and a Journal system. Any user may write a mail message from his terminal to any other users. The message is automatically brought to the recipient's attention when
he logs in. Mail has been particularly useful to our people temporarily or permanently at a distance from the Center. Mail messages automatically become part of the Journal. The Journal is an online repository of the thoughts, records, baselines, and evolving designs of the group. In our community it serves the function that academic journals serve for communities defined by disciplines except that publication takes about a day. Recent entries in the journal are held on disc and magnetic tape, older entries on paper and magnetic tape. Online is an index to the complete journal, including various retrieving aids such as sorting by title words.

5. Our participation in the ARPA Network included: using University of Utah's PDP-10 via the Network to aid in our transfer to a new PDP-10, and development of the Network Information Center (NIC). In using the Net to re-program our PDP-10 we typically sent blocks to UTAH that consisted of relocatable binary data produced by compilers executing in our XD3 9k0 and producing code for the 10. The data was stored on a disc at Utah by the network control program so that someone here could reconnect and call on the Utah loader for the transmitted file. We found this service so useful that we added multiplexing at this end so that three of our programmers could use the Utah system at once. The link to Utah operated daily from August 1970 through January 1971 and constituted the most substantial data transmission over the Net to that date.

6. At AHC we established a collection of documents that form the basis of the Network Information Center, established online techniques for handling the documents, and most important, began working dialog with the other centers. The combination of our reference data storage techniques with our programming allows retrieving documents according to a variety of attributes and combinations thereof. E.g., year of publication combined with author, or sponsoring institution. We organized with the other sites on the Network to establish Station Agents to handle their interaction with the Network Information Center and supplied the Station Agents with a catalog of their collection and other working materials. To stimulate dialog, pending full operation by connected computers, we set up a central telephone exchange and a system for circulating documents and memos by U.S. Mail through the NIC, including an intra-Net document numbering system.

7. In the Spring of 1970 we decided that DEC's PDP-10 with associated software and paging box from Utah might be a way
to increase the number of consoles and displays available to us, to strengthen our system in other ways, and to insure a system that could be expanded further with ease. In June after investigating several competing machines, we ordered a PDP-10 which was delivered in September. Our 940 was removed February 1, 1971. Associated equipment for the PDP-10 includes 128K of 1.0-microsecond core and the U/MAN Paging Box. After studying the various alternatives, we retained from the 940 system a 32K-word Ampex external core, UNIVAC drums as a swapping device, and a Bryant disc for mass storage. A drum/disc interface, an interface for the external core system, and an I/O control box were built locally to our specifications.

8. Re-programming for the 10 has created the necessity and opportunity for thorough-going revision of our software. Our online system which had been written in a special language, SPL, has been rewritten in L10, a language much more machine independent and more flexible in application. Our NLS has been rationalized to allow more routines to call on other routines. Display routines have been changed to allow division into up to eight areas which the user can load and exit independently. Many other features such as Mail, Journal, calculator have been substantially improved in the transfer.

C. PLANS FOR 1971

1. Early in 1971 we will complete transfer to the PDP-10, develop further and operate the Network Information Center, give more powerful tools to the users of our Dialog Support System, expand our Baseline Planning system, and make a variety of specific operational improvements.

2. We have established a three-step schedule of increasing interactive support to the other members of the AKA network. Uncertainties in the capacity of our new computer system when it is finally tuned, and in the load interactive service over the net will place on us make it difficult to estimate the number of users we will support at exact dates. We are proceeding with the following general plan:

In stage 0, beginning in mid June, we will offer experimental access to the NIC to a limited number of West Coast sites and to RADC and will offer a two-day course at SHI in our typewriter terminal online language which has been rewritten to provide users with more of the power of NLS.
In stage 1, beginning in mid August, we will offer further instruction, and an operational access to NLS to 4-6 simultaneous users.

In stage 2, beginning in October, we will offer message delivery online to remote sites, a deferred execution system for offline preparation of files for NLS use, and access to more users.

4. We will improve our Dialog Support System by further automation of entry of items into the Journal and of study of the documents in the Journal.

A command language in which the Journal may interrogate the user for information necessary to identification and automated retrieval of the document will make entry simpler and more effective.

Devices such as automatic construction of links between documents and generation of sets of documents, along with set manipulation commands, will facilitate study.

5. We will manage our daily activities more and more by means of our Baseline Planning system and develop new subsystems within it to, for example, filter out and record various useful views of the organized planning of the whole group.

6. Modular programming will make it much easier to transfer all or part of NLS to users outside of AKC. Design and implementation of a preliminary system will take place in 1971.

6. We have detailed plans for a variety of improvements in our NLS and Executive, most of which directly support NIC operations.
V. ARPA NETWORK PARTICIPATION

A. THE NETWORK INFORMATION CENTER.

I. Goals, strategy, and philosophy

We see NIC's primary role in the network experiment as support for network participants: tools, techniques, and services of computer, storage, and people. We aim eventually to provide highly interactive information services that will be valuable to a dynamic clientele and we hope to facilitate highly responsive dialog between and with them. But basically we can only serve as a supporting agent toward these ends. Emergence of a significant dialog will require active network participation both among the nodes and with NIC as it learns how to serve their information needs.

Some of the services we will provide are:

- Collection and storage of a wide range of network-relevant reference information (in the NIC Master Collection).
- Online service over this collection for querying, browsing, and retrieving -- designed to serve a range of terminals (typewriters to CRTs).
- A coordinated set of offline reference materials (indexes, etc.).
- A communication service in which there will be direct, interactive, and sophisticated handling of messages -- their composition, delivery, verification, storage, and retrieval (they become part of the master collection).
- A natural means for linking messages to each other and to any other items in our collection, to produce an organically developing network of dialog items whose search, study, and integrative manipulation will be supported by our computer aids as a basic NIC service.

We have been heavily involved in preparing ourselves toward these ends, both in range of services and in capacity to handle customers. It is quite evident that these ends will be reached only by steady evolution, throughout the range of site facilities,
2. Starting up

For some time, we were concerned with the question: How could we launch a new, experimental service for a clientele that we didn't see or hear, where the service was to be designed for a degree of computerized communication that hadn't yet emerged, but where it was disturbingly apparent that the proper performance of our declared function could significantly accelerate that emergence? What was needed badly in order that we at NIC could produce some service, and also, we thought, in order that the network could become alive was for a sizable amount of stimulating and visible dialog to take place. To this end, we decided to dedicate most of our NIC service energy over the past several months toward stimulating and supporting such visible dialog -- which is the reason for the "Network Dialog System" development.

To provide a useful initial service to the Network Community, and also to give our evolutionary process a starting place, we adopted the initial-stage design described below for visible dialog.

3. Dialog

By "visible dialog" we mean messages and memos that become a public record available to all potential Network participants, for later reference, citation, retrieval, or browsing; where people other than those involved in a given exchange are welcomed -- and helped -- to discover its existence and contribute questions and additions that in turn are incorporated as part of the recorded dialog. At first the media are whatever communication means can be best used at the moment -- mail, telephone, and the ARPANET as it becomes more and more functional.

To encourage communication initially, we are maintaining a NIC telephone system that provides toll-free service, especially for Station Agents and Liaison people although open to others. The system makes use of a commercial, after-hours answering service, and is responsive to special needs around the clock.

4. Station Agent and Liaison

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The Network Dialog System involves at least two specially assigned people at each site, who are as soon as possible to be provided with an online typewriter at a specially designed Reference and Communication Station. Besides the typewriter, the station is expected to include a telephone and certain hard-copy reference materials supplied by NIC.

The Station Agent helps the NIC with local services performed in our behalf, such as seeing that messages are delivered to local people, helping people learn how to use NIC services, updating locally held hard-copy NIC reference material (according to instructions and materials supplied by us), helping local users find needed information among the various hard-copy materials that will comprise an important part of our early services to each locale; and providing feedback to us about needs and possibilities for improving our services.

Each site also has a Liaison Contact available to the Agent for technical backup. He is usually a technically oriented person who is used to learning online techniques, who understands at least enough of the Network technology to interpret technical questions accurately and to pursue their answers intelligently. He is also expected to field technically oriented questions and requests from other Network sites.

In particular, the Station Agent will need a certain amount of consistent, supportive help in learning about technical details associated with some of these tasks -- we need each Liaison Contact to provide this (thus helping to form a working team, with whom we at NIC can work consistently, and about whom people at the site can feel comfortable in handling the reference and communication aspect of their total "Network interface"). Both people are becoming useful sources of Network folklore for people at the sites.

5. Manipulation

We are now set up to handle the transmission/distribution of such material as submitted to us, and to provide storage, indexing, retrieval and access to the accumulated material -- in hard-copy mailed media and/or by online access, whatever it takes to get things rolling. One-sentence messages, very informal memos, tentative plans, "CQ calls" seeking...
support or interaction, announcements of up-down-changes etc., arguments about how things should be done -- telephoned to us, mailed in long-hand or typescript, composed via Network access to our online editing system, sent or transmitted as a file composed on your editing system -- we are trying to handle them all.

After our transfer to the PDP-10 is completed, we will be ready to provide online interaction, in typewriter mode, for initial experimentation, for editing, for access to dialog material, etc. (holding off on more general access to reference material for the time being). Local Station Agents will be supplied with the reference information necessary to link to us and we will offer first to check them out and the Liaison men. They will (we hope) then check out other users.

6. NIC Station Collection

Physically, we have over 5,000 items, mainly external documents, in AKC's Master Collection. The NIC Collection is a subset of the Master Collection. We estimate that 500 to 800 of the items currently held will eventually prove relevant to the NIC clientele. At present some 500 of our most relevant documents have been replicated and a set installed at each station together with a computer-generated, hard copy shelf listing and index by number, author, and titleword.

We have isolated several hundred items that seem relevant now. These will be included soon in the NIC "Subcollection".

We are providing for steady addition from messages, memos, survey summaries, formal Network documentation, etc.

The most significant documents to the NIC Collection from volume and content relevance standpoints are those currently being added through dialog between network people and through collection and publishing of information describing network facilities, interests, and resources.

Catalogs and indexes
we have developed common conventions for catalog entries over the entire AHC (and therefore NIC) collection. Online entry formats are being converted from old formats to consistent more easily searched formats. All current NIC and AHC Journal collections are in the new catalog formats. All new entries take the new form. Each entry is stored now as one long string, within an NLS statement, with special strings of characters that separate and identify the different data elements.

9. CONNECTION TO THE ARPA NETWORK.

1. Our first hardware and software connection to the ARPA Network was completed in November of 1969 and is discussed in some detail in the references (ref.1). At the end of 1970 the hardware interface was still as described in that report and has been operating since that time with no difficulties.

2. The early software was definitely experimental. A preliminary network operating system was written which ran as a user program and allowed the login of one remote user over the Network and the simultaneous use of a remote facility by one local user.

3. Following this experimental system, work continued on a first-stage Network protocol operating at the monitor level.

Since there was no official Network protocol at that time, it was necessary to develop compatible protocol at at least two sites for debugging and experimental use of the facility. The University of Utah was chosen as the site for this activity, mainly because they were eager to cooperate in the experiment and personnel were available at ARC who were familiar with both the YLU operating system and the University of Utah's system.

Programs at both sites were written primarily by ARC personnel. (They included the monitor level coding required to operate the hardware and to allow programs logical access both to the Network and user level programs.)

The system when completed allowed a user at SRI to connect his teletype to Utah's time-sharing system with all the privileges and capabilities of a user locally connected at the University. Capabilities were also
provided for Utah use of the ARC facilities, although this feature was never thoroughly checked out.

1. When we determined to convert to a PDP-10 we decided to use the PDP-10 at Utah to aid the software conversion effort. This new application required some modification of the temporary UTAH/ARC protocol at both ends.

Programs were modified to allow transmission of files so that blocks of data could be sent to Utah. Typically we sent blocks to Utah that consisted of relocatable binary data produced by compilers executing on the 940 and producing code for the PDP-10. Data transmitted from ARC was stored on a disc at Utah by the Network control program so that the sender at ARC could subsequently invoke his network teletype connection and call the Utah loader to load the transmitted files. This arrangement gave the ARC programmer an extended debugging tool close at hand. We found this service so useful that multiplexing was added to both ends of the connection allowing three ARC users to work simultaneously with the Utah system. The link with Utah was in use daily from August 1970 to January 1971 for the modification and debugging of our NLS required to convert over to the PDP-10.

5. ARC personnel have participated in the Network Working Group, and we have followed closely the development of the official Network protocol. Implementation of this protocol in the 940 was planned in detail, but the anticipated transfer to the PDP-10 and the lack of other operating protocols on the Network, obviated the 940 version.
VI. CHANGING FROM AN XDS-940 TO A PDP-10

A. HARDWARE TRANSFER TO THE PDP-10

1. As the Augmentation Research Center has evolved more and more to an online community, the needs for computer service have steadily increased. Early in 1969 when experience showed that the 940 would support only about 6 display consoles, studies were undertaken on various approaches to increasing the service capacity. At that time the 940 still offered the only time-sharing system suitable for our needs and within our budget. The most reasonable approach to getting more service seemed to be the use of a small computer subsystem in conjunction with the 940. Work on this approach continued and in January of 1970 a small computer was selected for the development of an experimental front-end subsystem.

While the small computer approach was being pursued, we were also keeping up with developments in other computers and time-sharing software. In the Spring of 1970 it became apparent that the PDP-10 with the TENEX software system and associated paging hardware being developed by Bolt Beranek & Newman would be a major contribution to the field of research time-sharing.

When the PDP-10 became a real possibility we undertook a brief study of other available machines and associated time-sharing software. We considered in particular the XDS Sigma 7, the CDC 3300, and the Standard Computer IC-9000.

The last machine named would have been microprogrammed initially to emulate the 940 with an immediate increase in capacity due to the faster machine. Operations would have later been developed to more closely suit the needs of the ARC software system.

Of these machines the Sigma 7 and the CDC 3300 were quickly eliminated by lack of available time-sharing software. We seriously considered the IC-9000, but its uncertain development schedule and the unpredictable effort required for further development of the microcode ruled it out.

Investigation of price on the PDP-10 system, both from DEC and other sources, showed that it would be possible to replace the 940 with a significantly
larger PDP-10 system with a monthly lease slightly cheaper than that for the 940. Furthermore, the PDP-10 system would be much more open ended than the 940 system. Core memory could be expanded greatly, particularly through the BBN Paging Box. A wide range of peripherals is available and additional processors can be added. This expandability, together with the immediate increase in service capacity and slightly lower cost, seemed to justify the expense of converting software to the new system. An order was placed for the PDP-10 facility in June 1970 and the system was delivered in late September.

2. Figure 1 is a block diagram of the PDP-10 facility. It consists of the following major units:

The equipment leased from DEC includes the KA10 processor, 6 banks of MA10 memory (for a total of 128K), two mag tape units and controller, two DEC tape units and controller, and a teletype scanner for 24 teletype lines.

The BBN pager connects between the KA10 processor and the memories. In conjunction with a set of hardware modifications to the KA10, the pager changes the core memory mapping mechanism.

The UNIVAC drum system consists of four UNIVAC FH432 drums and a UNIVAC FH432/1702 controller. This system was our swapping medium on the XDS-940. It has a storage capacity of approximately 1 million 36-bit words. The drums turn at 7,200 rpm, with 20,480 words per track, providing a transfer rate of 250,000 words per second and an average access time (for each drum) of 4 milliseconds.

The Bryant disc system was also in use on the XDS 940. It consists of a Bryant model 4061-A24-16 Disc with 13 data surfaces and a Bryant controller.

The 24-bit Ampex Memory was in use on the 940 as an external memory system for display refreshing, network buffers, and line printer buffers. It was transferred to the PDP-10 system as an extra bank of directly addressable memory.

Other equipment shown in the facility was previously in operation with the 940 and was already connected to the 24-bit External Core Memory (ACM). It consists of the Network Information Center and Computer Augmented Team Interaction.
changing from an XDS-910 to a PDP-10

The following units that are described in more detail in the references (Ref. 2, 3): Two display systems for a total of 12 display consoles; input device controller for input from the 12 consoles; line printer controller; network interface; interface for a high-speed modem to drive the IMAC display.

The choices of equipment to make up the PDP-10 facility were governed primarily by the need to comply with the BBAN system to make maximum use of the TnNEX software and our desire to minimize the cost of transferring to the new facility by employing the existing equipment wherever possible.

Since the decision to transfer to a PDP-10 was based on the development of the TnNEX time-sharing system, paging hardware was essential to the system. BBAN developed a paging box and associated modifications to the PDP-10 processor in conjunction with the TnNEX development and was the only reasonable source for such hardware.

The amount of core ordered with the DAS system was determined by funds available for monthly lease and turned out to be 128K of 1.0-microsecond core.

For a swapping device, the obvious possibilities were the Bryant drum as used at BBAN, the UNIVAC drums already in use on the Ya0, and the swapping disc offered by DEC.

We ruled out the DEC disc because of its slower transfer rate, but gave considerable study to the Bryant drum and the UNIVAC drums. Speed was the major focus of the study.

The Bryant drum rotates at 1800 rpm and in transfer up to 16 512-word pages in 3h milliseconds (one revolution). The UNIVAC drums, on the other hand, rotate at 7200 rpm and each one can transfer 4 pages per revolution. But, since there are 4 drums running asynchronously, the average maximum transfer will be about 13 pages in 3h milliseconds.

These rates are maximum. The percentage of possible transfers which are actually used depends on the length of the drum queue and the distribution of requests.
Our studies showed that for about 20 items in the queue with a uniform distribution over pages of the drum, the Bryant is able to use about two-thirds of its possible transfer rate. The UNIVAC is able to give a higher actual transfer rate than the Bryant for queue lengths less than 20 because of the faster rotation and resulting lower latency.

In favor of the Bryant were lower cost and less software development because this drum is used by IBM in their MARK facility. In addition, changeover would be easier since the UNIVAC drums could be left on the 460 while getting the Bryant going on the PDP-10.

The UNIVAC drums appeared more reliable. There have been some bad experiences with head crashes on the Bryant drum, and with a single drum in the machine and few machines in the field a crash could mean being down for several months. (UNIVAC has many of these drums in the field, would be able to replace a bad unit in very short order, and the system could operate on three drums in the meantime.)

Reliability and speed, as well as a somewhat indefinite delivery schedule on the Bryant drum, led us to the decision to use the UNIVAC drums with the PDP-10 system.

In the case of mass storage medium, our possibilities were the existing Bryant disc, or the addition of disc packs, such as the DEC KPO2 disc drives, or the IBM 2314. Here investigation showed that the Bryant disc had been designed for easy modification to 36-bit mode, and that interface cost would not be too high. Since we already owned the Bryant disc, it was significantly cheaper to use it than to add any other storage medium.

4. Adapting the Special Equipment

Three interface units were required to connect the non-DEC equipment to the PDP-10. These were: (1) a drum-disc interface; (2) an interface for the 24-bit external core system; and (3) an I/O control box to convert the PDP-10 I/O commands to signals expected by the equipment that previously operated on the 460.
functions of these units are described in detail from
the programmer's viewpoint in the Appendices.

All these of these interface units were built to our
specifications by Cybernex, Inc. of Palo Alto,
California.

In the construction of these units, BKC logic cards
were used in some cases. In others cases it was
cheaper to make up special boards using integrated
circuit modules (dual-in-line packages). All panel
indicators are light-emitting diodes driven directly
from the logic circuits. All three units have fairly
extensive control panels with indicators for data and
major control signals plus switches for simulating
data and control signals. These panels made
debugging and maintenance much easier.

The Drum-Disc Interface:

This unit connects the Bryant Disc Controller and the
UNIVAC Drum Controller to a PDF-10 memory bus. Data
rates for these units allow both to share a common
memory bus. The drum has priority because its
transfer rate is higher, both devices may be
transferring data simultaneously and memory bus
multiplexing takes place cycle-by-cycle.

Control and interrupt signals for these units are
processed through the I/O Control Multiplexor to
avoid the necessity of connecting the I/O bus in
the drum-disc interface.

The Bryant Disc Controller contains facilities for
memory address and word-count registers and for
interpreting command tables in core. Therefore,
the portion of the interface handling this device
simply transforms PDF-10 memory bus signals into a
simulated XDS 940 memory connection.

The UNIVAC drum portion of the interface, however,
must provide word count and address registers and
otherwise perform the functions of a UNIVAC 1106
I/O channel, including the generation of function
words to the drum system in response to signals
from the I/O Control Multiplexor and the
interpreting of status words from the drum system
to generate status and interrupt signals.
The External Core Interface:

This unit connects the existing 24-bit core memory system to the PDP-10 processor memory bus. Viewed from the PDP-10, the External Core (ACOKE) system performs exactly as if it were part of the PDP-10 main memory, with the exception of the missing 12 higher-order bits in each data word. These bits will be ignored when writing and will be supplied as zeroes when reading. Differences in memory cycle times are not significant because the PDP-10 memory is asynchronous.

The XCOKE memory has no provision for a parity bit. The PDP-10 memory bus provides for this contingency through the ignore parity signal which is generated by the interface.

The XCOKE bank was implemented on the 940 with an 8 port access switch designed to have exactly the same interface characteristics as the executive controller used on the 940 memory port (Ref.2). This access switch was modified to provide high priority for one port to connect to the PDP-10 and the XCOKE interface unit was designed to convert PDP-10 memory bus signals to those required by the access switch interface.

Aside from coordinating the memory control signals on both sides, the principal function of the interface is to transform the negative logic pulse bus of the PDP-10 into the positive logic of the XCOKE system.

I/O Control Box

This unit processes I/O control signals for units connected to the 24-bit XCOKE memory system and for the drum-disc interface. It generates command signals in response to instructions from the PDP-10, provides status bits that may be read by the PDP-10, and processes interrupts to the PDP-10 with interrupt mask and priority selection features.

 Addition of the BBan Paging Box

The Pager connects the processor to the memory. In conjunction with modifications to the processor it changes the core memory mapping mechanism so that core memory is allocated and protected in 512-word pages.
The address space is mapped for executive mode as well as user mode. The paging mechanism may be bypassed either by a direct reset switch or by a PDP-10 instruction to permit running of standard DLE software.

To implement new instructions and to operate the Paging Box, fairly extensive modifications were required to the KAI0 processor.

BBN provided documentation for these modifications with the Paging Box. This documentation was very complete. It included logic diagrams for all portions of the processor affected and complete wire lists for additions and deletions. These changes involving approximately 700 wires (576 additions and 124 deletions) required approximately four man-weeks of ARC personnel time and were successfully completed in two weeks elapsed time.

In the course of checking out these modifications, only two minor errors were found in the BBN documentation, and the Paging Box functioned perfectly from the start, with no errors. This is highly commendable considering that AKC is the first customer for the TEN^X-Paging Box system.

6. Teletype Patching System

A teletype patching system was constructed by ARC personnel to provide flexible patching of teletype lines to various spots in the building, as well as to data sets. The patching facility includes local monitoring for maintenance and a variable character rate to accommodate a variety of terminals in use.

Four character rates, 10, 15, 30 and 60 cps, can be increased to a total of eight selectable character rates. Speed for a local terminal is determined by appropriate jumpers in the connector on the terminal. Over the telephone, speed is selected by dialing a digit after connection to the computer via the data set. The speed of the dial-up connection may be changed at any time simply by pulling the telephone dial an appropriate number of times to step through the available speeds.
NLS on the 940 was written in a machine-dependent language called MOL. The MOL compiler was written in a compiler writing language called TREE MeTA. MOL was a systems programming, high level language, specially written for the 940 and for writing NLS. The MOL (and also TREE MeTA) were written to operate under NLS as a sub-system. TREE MeTA is written in its own language, that is, it compiles itself. Parts of NLS were written in a language called SPL (special purpose language), which is also a MeTA generated language.

Changing from the 940 to the PDP-10 provided an opportunity to redesign NLS and other subsystems to a degree that the continuous press of other work did not allow us on the 940. The redesigning provided more flexibility and better service and made it possible to extend NLS much more than we could on the 940. No suitable programming language existed for the PDP-10 which could correspond to MOL. In addition, we had several ideas about combining SPL and MOL into one language.

The approach we decided on was basically to convert TREE MeTA to run on the PDP-10, design a new systems programming language, L10, and compile it on the PDP-10 with TREE MeTA. We decided that TREE MeTA was powerful and useful enough to warrant transferring to the PDP-10. In addition, the PDP-10 is a much more suitable machine for TREE MeTA. We also wished to make several additions and changes to TREE MeTA itself, which we could not do on the 940.

L10 was designed to take advantage of features that were available on the PDP-10 and not on the 940. The L10 language was specified in advance, and the NLS system was rewritten carefully (using the NLS system on the 940) starting about 8 months before it was actually compiled on the PDP-10.

The steps in converting TREE MeTA to the PDP-10, and getting L10 running on the PDP-10, were as follows:
First, it should be explained that TREE META is a program that compiles symbolic files which describe the syntax and code production rules for a language. The result is a binary file which is given to a loader. That binary file must be accompanied by a library of procedures -- which is common to all TREE-META-generated compilers.

We will use an upper case letter to represent a symbolic file, and a lower case letter to represent a binary file. Compilation will be written thus:

\[(p+1)(y) \rightarrow y\]

which reads: program p combined with program i (the library) compiles symbolic file y to produce binary file y.

The situation on the 940 was as follows:

The current TREE META symbols were called T2. The T2 compiler would compile MOL, the symbols for the current MUL compiler. The TREE META library was written in MOL and was called L. The current running TREE META was thus \(t2+1\) and MUL was \(m0l+1\). Notice that:

\[(t2+1)/(T2) \rightarrow t2\]
\[(t2+1)/(MUL) \rightarrow mol\]
\[(mol+1)/(L) \rightarrow l\]

The first step was to alter the library \(L\) to produce 36-bit binary files for the PDP-10 loader, rather than 24-bit binary files for the 940 DUT. We will call the new library L36:

\[(mol+1)/(L36) \rightarrow L36\]

We also altered T2 to produce 36-bit instructions, and to produce code to run with L36. The modified TREE META was called T2.5.

\[(t2+1)/(T2.5) \rightarrow t2.5\]

The next step was to write a compiler like L10, but one that would run on the 940 and produce binary loadable files for a PDP-10. It was written carefully to compile.

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a subset of LlO (because the 940 memory was smaller than the PDP-10). We called it L940:

\[
(t2.5+1/L940) \rightarrow 940
\]

The L940 compiler would compile L10 programs to load on a PDP-10, provided they used only the syntax included in L940. The library that would run with these META programs on the PDP-10 was then written in L940. We called it L10:

\[
(L940+L10)/(L940) \rightarrow L940
\]

this library could be loaded on a PDP-10

At the same time the real META for the PDP-10 was written in the T2.5 meta language and compiled on the 940. Call it T3:

\[
(t2.5+1/T3) \rightarrow T3
\]

This T3 was then ready to run on the 940 and produce PDP-10 code. In particular:

\[
(T3+L10)/(T3) \rightarrow T3L0
\]

which is ready to load on a PDP-10.

Also, L10 was written in the T3 language, including the full syntax this time, and using all of the new features in T3. It had to be compiled on a PDP-10 due to the restricted size of the 940:

\[
(T3L0+L10)/(L10) \rightarrow L10 \quad \text{(compilation on a PDP-10)}
\]

Running L10 on a PDP-10 is represented by \( (L10+L10) \).

Actually, it was somewhat more complicated than the description above because of these problems:

Symbolic programs on the 940 are 8-bit non-ASCII characters. On the PDP-10, characters are 7-bit ASCII. It was easier to introduce one extra step of MTA compilers to convert the literal strings inside the binary files than it would have been to write code to translate 8-bit, 3-character-per-24-bit-word text streams to 7-bit, 5-character-per-36-bit-word text streams, on a 940.
Some features we wished to include in the new TRex
MESA (T3) could not be reasonably compiled by the 940
MESA MESA, and an extra step was made to get to T3.

4. Method of debugging: the network

Arrangements were made to use the PDP-10 at the
University of Utah for debugging our compilers.

Programs were written on both ends to allow 940 users
to send files to Utah's file system, and to log in
and use the Utah system.

Programs (primarily L36 and T3) were checked out by
running them on the 940 and sending the binary results
to Utah and loading. Format errors and so on were found
by checking the binary image or the results of the
loading in Utah.

When programs could be successfully loaded in Utah,
symbolic test files were sent to Utah, and the compilers
were tested (110, T3). The results (PDP-10 binary
loadable files) were loaded in Utah and checked.

In any event, bugs were corrected in the symbolics on
the 940, and the necessary compilations were done again
and tested. And so on.

This work was primarily done during off hours in order
not to load our 940 too much, and in order to get
reasonable response from Utah.

The alternatives would have been to have both the 940
and our PDP-10 available to users for several months,
which would have been quite costly, or to use another
PDP-10, which would have involved at best carrying
magnetic tapes back and forth between computers. The
conversion would have taken perhaps three times as long.

The actual transfer to our PDP-10 was simple. Programs
were written to transfer files through ACOM (which is
part of the PDP-10 addressable memory). The PDP-10
loadable binary files, and symbolic files were sent
across to our PDP-10 and loaded.

C. NLS/TODAS TRANSFER.

1. The transfer to the PDP-10 demanded certain software
changes in our NLS and offered a particularly good
opportunity to make others. Here we list them. For the approximate baseline from which we here depart, see reference 1.

Reorganization of NLS:

The online system (NLS) has been modified so that the user specifies his terminal device and NLS provides the appropriate command parser and character definitions for that device. This modification subsumes the 940 NLS/TODAS subsystems. NLS was also reorganized to allow the user access to the typewriter-oriented and display-oriented command parsers for NLS and the parameter specification and executor for each command--this also makes possible separation of NLS command specification from the (core-NLS) file manipulation, with perhaps a network in between.

New Capabilities:

File System

The file system implemented in the PDP-10 NLS system functions as does that of the 940 NLS system, but allows more core space for file blocks, applies paging to those file blocks, and allows for more than one file.

In addition, the "working copy" of the 940 system has been replaced by a "partial copy" which contains only the blocks of the original file which have actually been changed by the user.

Also, only one user may now modify a source file at one time. The partial copies are retained until the user writes the change file onto a source file or explicitly deletes the partial copy.

As before we will have files, called "checkpoints", onto which copies of the partial copies are written for security and convenience. There will now be two checkpoints for each source file being modified. Those partial copy blocks which have changed since the second-to-the-last checkpoint are periodically copied to the oldest of two
Changing from an XDS-40 to a PDP-10 checkpoint files, the frequency depending on the user’s activity and a maximum amount of time between checkpoints.

Display Areas

Unlike the 940 NLS system, the TENEX NLS system allows the user to subdivide the text area of his screen into rectangular, non-overlapping display areas. We provide the user with commands to split extant display areas into two display areas, move the boundaries of display areas, and erase the display image from a single area. The user may display portions of several files in his display areas (maintaining separate view control parameters for each display area) and may freely edit across the display area boundaries. The user may also have a list of frozen statements (from any currently open file) associated with each display area.

Initially, a user with a typewriter-type terminal will continue to have only one file and one set of viewspecs.

New String Processing Routines

A new set of string manipulation routines was added, as well as new string constructs in the L-10 language which allow the use of string mechanism from a higher level.

Input Specification constructs in L-10

Constructs are being added to L-10 which make it easy for a user to specify personal commands. The same constructs will facilitate the description and implementation of the NLS command language.

Context Group

The user will be able to limit the sequence generator to a particular group within the file. This mechanism allows the user to restrict his activities to a portion of a file.

Modified or Deleted Capabilities:
Changing from an XDS-940 to a PDP-10

Structure Manipulation

These routines were modified to allow for cross-file editing.

Statement destruction

The routines that remove statements were modified to combine free space in the statement data blocks and so allow better use of this free space by the statement construction routines.

Statement construction

Statement construction routines were modified to make better use of the free space in a statement data block, to make use of the capability of L-10 to manipulate parts of a word (called fields), and to allow for string construction in string buffers as well as statements.

Text editing

These routines were modified to allow for editing of strings as well as statements.

Literal feedback

The literal feedback mechanism was completely rewritten to allow for multiple display areas.

Input feedback support

The input feedback support routines were modified to make use of fields in L-10, and to make the routines more consistent.

NLS input routines

Character input routines were reorganized with the more basic routines modified to account for the TENEX system.

Markers

Markers were called pointers on the Y20 system. A marker is a symbolic name which the user may attach to a particular character in a file. Use of markers was restricted to the file being

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displayed in the 9K0 system, but we modified the lookup routines to allow reference to all of the files which are currently open (this modification may not be used initially).

Calculator System

The calculator system was modified to make use of the double-word arithmetic instructions of the PDP-10.

Substitute

For the user, the editing command "substitute" operates as it always has, but internally it was completely rewritten and reorganized.

Output Processor

The output processor on the PDP-10 will be similar to the output processor (PASSH, which prepares files for printing and other graphic reproduction) now available on the 9K0 with the addition of new directives and a TREE-META-generated directive recognizer.

Insert Sequential

The insert sequential facility was expanded to incorporate the insert QED function of the 9K0 system. The change decreases command execution time considerably.

Content Analyzer-Analyzer Compiler

The analyzer compiler is replaced by the L-10 compiler, which now includes the capabilities of the L-10 analyzer compiler. The content analyzer also will make use of the L-10 compiler.

File Compactor

Used in the process of outputting a file, this facility was completely rewritten to make use of the multiple file capabilities of NLS/THLS.

File Input/Output

The Load File, Output File, Load (more recent, Network Information Center and Computer Augmented Team Interaction 29
Changing from an XDS-910 to a PL/10

Older) Checkpoint, Output checkpoint commands are either new or completely rewritten to account for the new file system. Automatic checkpointing has been added.

Initialization

Parameter specification

These routines were almost completely rewritten to take advantage of the added capabilities of L-10.

Sequence generator

The sequence generator was partially rewritten to make possible desirable changes in the sequence generator work area and to allow for the 'SEND' feature by making it a co-routine.

Frozen Statements

Frozen statements are handled as they were on the 910, except that frozen statements may be associated with each display area and that the frozen statement lists may contain statements from any file currently open.

Verify (cleanup)

A command to verify a file replaces a command to clean up a file. Verification is a fast read-only inspection of a user's file.

Bug Selection

The routines which use the position of the cursor to determine a location within a file being displayed (the bug selection routines) were modified to be compatible with multiple display areas.

Display Generation

The display image generator was entirely rewritten and recognized to allow for 1) control of the display by the Tektronix monitor, an IMLAC display-processor, or a host computer via the ARPA network, 2) multiple display areas,
Changing from an XDS-9a0 to a PDP-10

and eventual replacement by the portrayal generator.

It now creates a universal display image, device dependent secondary processors convert the universal display image to something compatible with the user's device.

Initialization routines were almost entirely rewritten to be compatible with the UNIX system.

Message Display

Modified to allow for addition of messages to extant messages on the screen and for multiple display areas.

String Routines

Extant string manipulation routines were rewritten to make use of the PDP-10's byte manipulation.

Text pointers

The use and implementation of the text pointers were changed to allow pointers to point to the gap between characters (interstitial) rather than to one of the characters. This greatly simplifies their use.

Text Editing

The basic text editing routines were rewritten to implement interstitial text pointers and be compatible with the L-lu language.

TNLS Input

The most basic routines were rewritten to be compatible with the UNIX system.

TNLS Command Specification

The TNLS command specification was partially rewritten and reorganized to allow for changes and reorganization of the support routines and to be more (structurally) similar to the NLS command specification.

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File Manipulation

The ring and data block manipulation, core page status table routines, and so forth, were extensively rewritten to take advantage of a more powerful file system.

Character Readout

The routines that read characters from strings were modified to use the capabilities of the L-10 language, the PDP-10's byte manipulation instructions, and to read characters from strings as well as statements.

NLS Command Specification Routines

The main NLS control routines--command language parser--were rewritten to conform to the replacement of the SPL language by L-10 and were reorganized to allow the user access to the parameter specification segment and the command executor segment of each command.

Data

The writeable data declarations are almost completely new. We now use local variables when appropriate and the renaming of unclear global variables.

Keyword System

The keyword system will be replaced later by a more powerful associative searching tool.

Trails System

The trails system will be replaced later by a more powerful associatives searching tool.

Tree Display

The principle of bootstrapping forced us to delete tree display from the system because it was little used.

Merge File (filtered copy)
A command similar to that available now on the 940 is provided in a cleaner and safer manner.

Don't Modify Working-Copy

A capability similar to that available now on the 940 is being provided in a cleaner and safer manner.

Collector-sorter

At the end of 1971 we had not as yet determined whether this feature will be provided as now available on the 940 or incorporated into NLS itself as a set of new commands.

Graphics Package

A new graphics system (also available to the calculator compiler) includes a new data structure, "boxes", "areas", and normal editing of labels.

Execute Text for Display Oriented NLS

An execute text command will be provided for NLS, if the programming and decreased efficiency is not too expensive.
VII. NEW FEATURES IN 1970

A. NEW TOOLS FOR USERS.

1. During 1970 we developed the following substantial new features for users:

Collector-Sorter

The Collector-Sorter is an NLS/TNLS subsystem which operates on a list of NLS files supplied by the user to extract statements that pass some user-specified content analysis program. The program may reformat the statements, and the Collector-Sorter may sort the collected statements with respect to specified "keys", which are appended to the statement by the content analysis program. It places the statements on the first level in a series of NLS files named *1, *2, ..., where * denotes a name given by the user.

Mail system

The Mail subsystem allows one to send messages to other users and simultaneously submit the messages to the Journal. The Mail is available as a normal subsystem, and also is automatically queried when a user enters NLS/TNLS. If the user has no messages pending, he goes directly into NLS/TNLS. Otherwise, he is informed of the pending messages and is left in the Mail subsystem, with termination taking him into NLS/TNLS. While in the Mail subsystem, the user may

- query the number of messages,
- query who sent the messages, when, and what the message journal numbers are,
- have the messages typed at his terminal or put into a file,
- have them simultaneously typed and deleted,
- delete any or all messages,
- and send messages to other users by either typing them at the time of sending or by naming a file from which the message(s) are retrieved.
Analyzer Compiler

The language which was developed for use in the specification of text entities and text editing algorithms was made available to the users. This language allows any user to develop very complicated personalized text editing. The Analyzer Compiler has been extensively used for the Network Information Center catalog management.

Executable Text in TNLS

The Execute Text command interprets an NLS statement as a string of input characters, just as though the user had typed them as command specification. A comment mode and a switch character, to switch from normal keyboard input to executable text input, are provided. This feature provided the first stage in the development of higher level capabilities in NLS/TNLS.

Calculator and Calculator Compiler

The new calculator and calculator compiler replaced and expanded the earlier calculator. This new NLS subsystem allows users to do simple arithmetic operations on numbers in NLS files as well as to write programs to do more complicated analysis. The algebraic (Tree beta produced) language provides constructs which elicit user responses, such as selection of a number in the file or the name of a procedure, variable, or calculator accumulator.

Cross reference facility

The cross-reference facility allows the system programmers to produce cross-reference listings for their NLS source files.

Execute Merge

The Execute Merge command allows the user to transfer all or part of one NLS file to another while retaining its hierarchic structure (when possible) and invoking various statement selection mechanisms such as level clipping or content analysis, if desired.

Substitute
The substitute command allows one to replace one set of text strings by another throughout a structural entity, invoking statement selection mechanisms if desired.

Transpose command

The transpose command allows one to interchange two entities (strings of characters, statements, or groups of statements) in an NLS file.

Bug selections in replace command

The replace command in NLS was expanded to allow optional selection of the replacement entity by means of the cursor.

Output processor directives

The Output Processor is an NLS file formatter, driven by embedded directives, for various output media, such as printer and microfilm. This NLS subsystem was expanded to incorporate several new directives (to simplify report production) and to initialize several directivees from the setting of the viewspecs at the time the output request was made. This report was produced using these new directives and the output processor.

Quickprint

quickprint gives the user a very quick print out of all or part of an NLS file. Unlike the output processor, quickprint ignores embedded directives and formats strictly according to the viewspecs at the beginning of the quickprint. Statement selection mechanisms such as content analysis can also be used.

Character translation in TODAS

An expanded set of viewchange commands implemented user control of character set translation as described above. In addition, it allows the user to define various shift characters, set the number of rows and columns to print on a page, set the page size, set tab stops, and save his definition in a file.

Jump to Content and Jump to Name

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The Jump to Content command scans statements for the string which was entered or selected by the user. If found, this statement becomes the new display-start statement, that is, the statement to which the current Statement Pointer (CSP) points (note that the content analyzer may remove this statement from the display image). The qualifiers 'First' and 'Next' specify that the scan should begin at the origin or at the statement following the current display-start statement, respectively. These qualifiers also may be used with the Jump to Name command.

Insert/Output Sequential

These commands convert NLS (random) files to sequential files and vice versa.

Execute TNLS/NLS

Allows the user to freely move from NLS to TNLS if he is at a display terminal.

New Viewspeacs

Two new statement selection viewspeacs were added:

1) Plex only: restricts the sequence generator to the plex of the source of the display-start statement

2) Content Analysis Fail: allows the sequence generator to select only those statements which fail to pass the current content pattern.

Reset File

Allows the user to discard his current file and revert to a null file.

In addition to the above, we wrote new user's guides for NLS/TNLS, the output processor, and the calculator.

As NLS has evolved, it has become apparent that a rational approach is needed to formulate it so as to be usable from a large diversity of terminals. It further became apparent that it would be desirable for a large number of diverse processes to have access to the NLS file
and text manipulation machinery, we have developed a new concept of the NLS program structure to provide these capabilities.

In this concept, a central collection of NLS routines serves as a library for all of the basic functions of NLS. Included among these basic functions are file handling, structure manipulation, text editing, and other functions which are useful for NLS programs. There is then a collection of processors or front ends, which are free to call on any of the routines in the Core NLS library. We call this library "Core NLS". As this model is evolved, the processors which call directly on the Core NLS routines become in fact trees of processors, with the following conventions:

The lowest node in the tree is that node which calls only on Core NLS routines. Any higher node may invoke any of the Core NLS functions, in addition to any higher level functions that are provided by nodes lower than itself, and in the same lineage. All terminal nodes on a tree are, in the terminology used above, processors for the NLS system.

These processors may now share common libraries, which are represented by lower nodes on the tree, e.g., all processors which deal with a certain type of display could share the library necessary for driving that display. Transportation between terminal nodes on the tree allows a processor at one terminal node to pass control to a processor at another node (e.g., as TNLS may be called from NLS).

There are two forms of calls: one is actually a branch, or a non-returning call, and the other corresponds to a procedure call in ALGOL. In this second case, parameters may be passed from the first processor to the one being called, and a processor may return a value. A stack is used to keep track of the return information and parameters. The stack allows recursion in the calls.

NLS (as a user system), TNLS, the Calculator, and the Collector/Sorter are examples of processors using Core NLS.

Further development of the model will turn the tree into a network of nodes where each node may serve a
processor function and a library function. As a processor, each node may perform a specific (set) of tasks which may or may not interact with a user. As a library, any node may be invoked by any other node, and then perform either a specially defined library function, or the function it would normally perform as a processor.

We are now making the necessary changes in the NLS System; the final reorganization in net form should be complete in June 1971.

C. NEW HARDWARE TOOLS

1. Three significant hardware changes in addition to the new computer during the past year were: (1) the addition of UNIVAC drums for a swapping medium, (2) the addition of several new types of typewriter terminals and (3) the addition of an IMLAC Display terminal.

2. UNIVAC Drums

In late 1969 we made a fairly extensive study of factors affecting response time in the 940 system. Based on this study the decision was made to replace the drums in use on the 940 with higher speed drums in the hopes of significantly improving response.

The drums were connected to the 940 through a second memory interface connection and an interface designed and built to ARC specifications.

The UNIVAC drums operated through a UNIVAC controller designed to operate with an 1105 system. The interface was therefore required to make the 940 look like an 1105 to the drum system.

In a manner similar to that used in many other 940 peripherals, a command table is stored in 940 core, giving all information relative to the transfer, including drum address, core address, word count, direction, and type of transfer required. The interface reads this command table and stored word count and core address in its own registers. The drum address and type of transfer requested are used to make up a 36-bit function word which is transmitted to the UNIVAC controller.
The interface also converts 940 positive logic to the negative logic of the UNIVAC system and performs 24-to-36 bit conversion by packing one and a half 940 words to each UNIVAC word.

Switch over to the UNIVAC drums led to a significant quickening of response. Although no actual measurements were made, our general feeling is that the predictions based on response studies were fairly accurate and that we got the improvement we expected.

Our experience with the UNIVAC drums' reliability has been very good, and UNIVAC maintenance and field services are excellent.

3. New Terminals

In the past year many new typewriter terminals for remote computer access have come on the market. These have been designed for many applications and use with many different systems, but very few met our requirements:

- Upper and lower case alphabet with a full complement of ASCII control codes;
- Full duplex operation;
- Character rate of at least 15 and preferably 30 characters per second;
- In addition to these specific features, we look for quiet, reliable, small, light terminals with reasonably good, neat quality and generally desirable appearance.

These features, particularly upper and lower case alphabet, eliminate most of the available terminals.

The terminals in use at ARC by the end of 1969 included Model 33 teletypes, Model 37 teletypes, G-E Termi-Nets 300's, and Executors. (ref.3)

Of these terminals, all are still in use with the exception of the G-E Termi-Nets. Maintenance problems and the generally low reliability of these terminals forced us to cancel our lease.

Of the others, the Model 33's are generally the

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stand-by for system use, monitoring teletypes, etc. because of their low cost and familiarity.

At the end of 1970 we were still using model 37 teletypes, but did not consider them desirable because they are large and noisy.

The executors are still highly satisfactory as portable terminals and have needed no maintenance whatsoever.

The only new terminal put into service in the last year is the Texas Instruments Model 72ü, five of these had been in service for approximately one month at the end of 1970, and so far our experience has been very good.

4. IMLAC display system

For some time we have hoped to incorporate a medium-speed remote display terminal as part of the facility and to experiment with using this terminal both as a high speed typewriter and as a modified display NLS terminal.

Early last year the IMLEC display system was introduced. It is attractive in price and seemed to have many of the features we were looking for in an experimental terminal.

The IMLEC is a small 16-bit machine with an arithmetic processor and a display processor operating from the same memory. The display processor drives a 9" by 11-inch display tube mounted in a separate unit. Input in the standard unit is from a keyboard that is read by the arithmetic processor and communication is through full duplex SIA interface.

For the IMLEC to operate as a remote NLS terminal it was necessary to add a mouse for display selection and keyset such as that used in the local display terminals. ARC personnel added them in a straight-forward manner.

Mouse coordinates (8-bit) for X and Y directions are ready by an I/O instruction into a single 16-bit IMLEC word. The second I/O instruction reads the state of the five keyset switches and the three mouse switches. Software in the IMLEC

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tracks the mouse position from the screen, interprets the mouse switches, and provides an algorithm for interpreting the five-finger keyset output as characters.

The IMLAC is currently operating at 2000 baud over a Bell System 201A data set at a remote location. The data set connects at the ANL end to a data set controller operating from the 21-bit external core system (see Figure 1).

D. HIGHER LEVEL PROCESSES

1. During the past year we have expended considerable resources in the development of tools for extending our higher-level process capabilities.

By "higher-level processes" we mean processes in which the basic user-features of our online systems (particularly NLS) are used as "building-blocks" in the construction of programs for carrying out specific, perhaps rather complicated tasks.

HLPs are in general used to automate text processing operations which, by virtue of frequent use, are too repetitive and time-consuming to do by hand.

One of the major users of these higher-level process (HLP) tools has been the Network Information Center, which has utilized many HLPs in managing, searching, and print-formatting the NIC collection catalog as well as in other task areas.

Four principal HLP tools are described below.

2. Content Analyzer

Introduction

The Content Analyzer (CA) feature of NLS permits the user to write, as part of any file statement, a string of text which specifies in a special language some pattern or content.

After the pattern has been compiled, whenever the content analyzer is turned on (through the use of a VIEWSPEC parameter) only statements that satisfy the content specification will be displayed.

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The pattern specified may be simple — e.g., a string of characters that may appear anywhere in a statement — or complex — e.g., a string, followed within a given number of words by another specified string, in statements created after a certain date by a certain author, and not containing some third specified string.

The language for specifying content patterns is simple and easy to use for simple cases, but powerful enough to be useful in more complex cases as well.

The Process of Searching a Statement

When the Content Analyzer is turned on, each statement in the file is searched, character by character, for the content specified in the pattern. Normally, the search begins with the first character, but it is possible to cause the search to proceed backwards from the end of the statement.

The CA uses a pointer to keep track of the search. The pointer always indicates which character is to be examined next, unless something in the pattern causes the pointer to be moved first.

At any given moment in the search process, the analyzer is searching for one of four types of content entity:

A literal string of characters, such as a "abcd" or "12-x" or "ed Mat" or "memory."

A string of "character-class variables" specifying, for example, "three digits, one after another," or "two letters, followed by any number of spaces, followed by three to five letters or digits."

The date associated with the statement. (This is not normally printed or displayed as part of the...
statement text, but every statement bears user-accessible data specifying the date on which it was created or most recently modified.

The initials associated with the statement. (As with the date, patterns may test the initials of the user by whom any statement was created or most recently modified.)

All of the more complex analysis is achieved by moving the pointer according to the logic of the pattern specification.

For example, if the analyzer is to start at a given point and find either String A or String B, it first looks for String A; if String A is not found, the pointer is returned to the starting point, and a search is made for String B.

3. Analyzer-Formatter

The Content Analyzer is an old NLS, having been an integral part of NLS for several years. During the past year an expanded version of the CA, called the Analyzer Formatter (AF), has been incorporated into NLS. The AF permits the use of more complicated filtering patterns and also provides capabilities for reformatting or "programmed editing" of text statements.

The Analyzer-Formatter is used in much the same way as the Content Analyzer, the major difference being that the AF has far more flexibility and power than the CA, and consequently, requires that a user master a more complicated language for specifying patterns.

whereas CA patterns are restricted to being short strings of text, AF patterns are specified in an algorithmic language that permits powerful tools such as conditional statements and subroutine calls to be used in describing how a statement is to be searched and altered by the Analyzer-Formatter.

In spite of this power, however, the AF is easy enough to use that sophisticated users frequently write AF programs for one-time use in editing specific NLS files.

The AF has been heavily used in the conversion of
catalog files from old formats into a single new format
and in processing the internal text codes into more
readable forms for human consumption.

The statements below are, respectively, the text for
a single catalog entry as it appears in a master
catalog file and the text produced by reformatting
selected parts of this entry for inclusion in a
"shelf-list" for online viewing and hardcopy
printing:

<Version 1>

Richard S. Marcus, Alan R. Benefield, and Peter Kugel
(Massachusetts Institute of Technology, Electronic
Systems Laboratory, Cambridge, Massachusetts)

[January 1971].

Describes decisions made in design of system/user
interface for Intrex, grounds for decisions, and
results obtained by experiments with users, finds
high degree of user acceptance as implemented.
Indicates desirable improvements.

<Version 2>

Richard S. Marcus, Alan R. Benefield, and Peter Kugel
(Massachusetts Institute of Technology, Electronic
Systems Laboratory, Cambridge, Massachusetts).

[January 1971].

Describes decisions made in design of system/user
interface for Intrex, grounds for decisions, and
results obtained by experiments with users, finds
high degree of user acceptance as implemented.
Indicates desirable improvements.
2. Collector-Sorter

The Collector-Sorter (CS) is a subsystem called from NLS that automates the process of collecting statements from one or more NLS files and sorting them into one or more new files.

The Collector-Sorter is usually used in conjunction with an Analyser-Formatter program, so that in the collection process statements may be arbitrarily reformatted by the AF program. The AF program can also be used to select from the text of each statement strings to be used as sort keys for that statement.

The Network Information Center has made heavy use of the CS in preparing hard-copy catalogs and shelf lists from the machine-readable master NIC catalog.

5. Executable Text

The Executable Text (ET) feature of TNLs is an early attempt to provide users with an easy-to-use procedural language for manipulating information contained in NLS files.

This feature permits users to request that some body of text within a file be interpreted as if it were the user's own keyboard input stream.

ET commands may be used to perform any NLS editing operations, including changing the ET "program" itself. They may also be used to perform file-manipulating operations, such as loading, updating, and printing, and it is possible for an ET program to link to another ET program in a different file.

Executable Text alone can be used to automate simple file editing operations, and in conjunction with the AF and CS it provides users with a powerful mechanism for writing programs to perform complex editing tasks as well as some forms of user-interaction.

2. DESIGN TEAM AUGMENTATION

1. The need

Arc has become more and more involved in augmentation of...
teams, and we are giving serious consideration to
improving intrateam communication with whatever mixture
of tools, conventions, and procedures will help.

If a team is solving a problem that extends over a
considerable time, the members will begin to need help
remembering some of the important communications --
i.e., some recording and recalling processes must be
invoked, and these processes become candidates for
augmentation.

To consider some of the different
conditions where such storage and recall may be useful,
suppose person A communicates with person B about item N
at Time T.

They may well be counted on to remember their
exchange during the problem-solving period, but
consider the case of person C who, it will turn out,
is going to need to know about this communication at
time TT:

Perhaps he was there at Time T out,
he was too heavily involved even to notice the
communication, and/or item N wasn't relevant to
his work at that moment and so wasn't implanted
for ready recall.

Perhaps A and B didn't anticipate his later need
and thus failed to invite him into their
interchange or inform him of its conclusion.

Perhaps, although persons A and B knew he would
later need the information, they didn't want to
interrupt their own working sequence with the
procedure of interrupting person C and getting him
involved.

Or, if the consequences of the interchange carry over
into a long-lasting series of other decisions, one or
both parties may fail to remember accurately, or may
remember differently because of different viewpoints,
and troublesome conflicts and waste of effort may
result. A single person will make a list of things
to do on a shopping trip because he's learned that
the confusion and pressure may make him forget
something important. It's obvious that to be
procurer for one of a mutually dependent
interdependent pair of lists would make it even more
important to use a record.
Further consider the effect if the complexity of the team's problem relative to human working capacity requires its partitioning into many parts where each part is independently attacked, but where among the parts there is considerable interdependence through interactions on mutual factors such as total resource, timing, weight, physical space, functional meshing.

Here, the communication between persons a and b may well be too complex for their own accurate recall. For example, their communication period resulted in scratch paper or a chalkboard covered with possibilities and the essence of the agreed-upon solution which has since disappeared.

We envision effectively augmenting our collaborative team by having an "intragroup documentation system", containing current and thoroughly used working records of the group's plans, designs, notes, etc. Therefore, we have begun to develop a system for entering and managing those records. The AKC Journal is this intragroup documentation system.

2. The AKC Journal

Our Journal is an open-ended information storage and retrieval system. It accommodates and retrieves whatever thoughts any member of the group feels worth keeping. All entries in our internal "mail" system automatically become part of the Journal. In addition, any online user may flag any file for transcription into the Journal within a day. In addition to NLS files, other hard copy including photographs, line drawings, and scratch notes can be logged into the Journal. In handling extra-computer copy the Journal draws on the techniques we are developing for NIC and KINS. In this section of this report, we concentrated on the Journal as recipient of NLS files.

We believe the Journal is the key to the development of our Dialogue Support System. We are encouraging members of the group to enter items freely, to err on the side of loquaciousness, even to enter information that will become useless. We hope to learn from such a flow how to winnow worthwhile information, to refine the techniques of query, analysis, and access that are necessary to proliferate all our augmentation research.

As each item (in this case, every NLS file) enters into

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the Journal it receives master Catalog Number (CNUM) and is catalogued. The CNUM is generated from the one master-collection sequence that AHC uses for all of its frozen-item storage: XDOC, NIC, Journal, KINS, and we assume, an increasing number of other special collections. The CNUM becomes the master identifier of the NLS file; it is printed in the upper right corner of each page of a printout of that file; it is the standard reference name to use in an NLS link; and it becomes the "file name" of that file within the storage and retrieval system of the Journal.

When the Journal System takes a file into custody, it guarantees retrieval of that file (by its CNUM) at any later time.

A Master Catalog holds descriptions of each item that is stored in AHC's Master Collection. The Master Catalog is composed of a set of NLS files in which each entry (describing one collection item) occupies one statement whose NLS name is 'M+CNUM -- '. For instance, the catalog entries are formatted in a special way to delimit the different data elements. For instance, for most items there is a "*al" preceding the first-author's name, and within this type of main field there often are flags such as "#2" or "#3" to delimit a particular subfield. The initials of the ARC author are stored after the data element code "#a6".

We don't really expect to use this format permanently for storing our catalog data. Within a year the size of the collection will make query and file management operations too inefficient and we will change it. A collector sorter and special reformatting programs will reduce the work of designing and changing the new format to several hours at the console.

The organization and formatting of the catalog files will evolve during the next year, but the user's concept of this function probably won't be affected.

Special data elements are under consideration for processing our NLS files into the journal. For
instance, it is likely that the catalog entry will involve a record of the whereabouts and the reference target of every cross-file link with the file. Such a notation would be an important aid in querying and is also the base for the "back-linking" we have been considering for so long.

Journal entries now also exist as a shelf of hard copies. For the shelf-stored copies we now have what we call "catalog-management processes", (Executable Text) programs to help manage and retrieve the information.

The catalog-management techniques that we have used were designed expressly to accommodate special collections. For example, a working subset of the Master Catalog holds the Catalog entries for the items that have been entered in the Journal. This subset is called the "Journal Catalog", and can be extracted automatically from the Master Catalog. Our initial shelving is by Catalog Number, so the shelf list is by CNUM.

Initial Journal catalog format:

\[(\text{M}1090) \ast a6 \text{VU} \ast a6 \text{Comments on W3U M97, Catalog Query System} \ast a6 10/22/70 \ast d7 09:54:23 \ast f3 :JRNLA \ast d2 J0U \ast d3 new * \] 7e2f2a

\[(\text{M}1099) \ast a6 \text{VU} \ast a6 \text{10ACQ} \ast a6 10/22/70 \ast d7 10:27:25 \ast f2 :10ACQ \ast d2 J0U \ast d3 new * \] 7e2f2b

\[(\text{M}520U) \ast a6 \text{VU} \ast a6 \text{New NLS Calculator} \ast d6 10/30/70 \ast d7 11:10:35 \ast f2 :CALDOC \ast d2 J0U \ast d3 new * \] 7e2f2c

\[(\text{M}521U) \ast a6 \text{MAIL} \ast a6 \text{MAIL FILE} \ast a6 11/01/70 \ast d7 10:55:22 \ast f2 :MAIL \ast d2 J0U \ast d3 new * \] 7e2f2d

\[(\text{M}520W) \ast a6 \text{VU} \ast a6 \text{Old but Relevant NIC Notes from Aug 70} \ast a6 10/29/70 \ast d7 09:11:26 \ast f3 :JRNLA \ast d2 J0U \ast d3 new * \] 7e2f2e

\[(\text{M}522W) \ast a6 \text{WU} \ast a6 \text{ENTRY TO NIC LIAISON LG} \ast \text{WU-USB} \ast a6 10/24/70 \ast d7 11:11:11 \ast f3 :LIAISON LG \ast d2 J0U \ast d3 new * \] 7e2f2f

\[(\text{M}522W) \ast a6 \text{WU} \ast a6 \text{ENTRY TO NIC LIAISON LG} \ast \text{WU-USB} \ast a6 10/30/70 \ast d7 11:11:11 \ast f3 :LIAISON LG \ast d2 J0U \ast d3 new * \] 7e2f2g

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We can automatically generate near-copy citation lists in various layouts by means of a library of reformatting programs. The Collector-Sorter processor is invoked in one set of executable text programs, to produce listings sorted on selected keys.

One such listing is the shelf list. A Shelf List for a given collection is a list of citations ordered in the way in which the collection items are physically "shelved" or otherwise stored.

Shelf List (by CNUM):

5206  DCE 11/04/70 Discussion Notes, DCE/JTM: Net access for NIC users
Source:  :JRNLA  Time: 1303:33

5209  DCE 11/02/70 Some NP Notes on Analyzer Formatter and Executable Text
Source:  :ETAF1  Time: 0919:42

5210  WIB 11/02/70 COMMENTS ON 5206 (PROPOSED EXECUTABLE TEXT FEATURES)
Source:  :MEMO  Time: 0919:00

5211  MAIL 11/06/70 MAIL FILE
Source:  :MAIL  Time: 1137:46

5212  WIB 11/03/70 ENTRY TO NIC LIAISON LOG = *LIBRAR
Source:  :LIAISON LOG  Time: 1108:07

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If the items are standing on the shelf arranged by catalog number, you would probably find one easily without looking at the Shelf List. But, if the item is gone, the Shelf List can verify that it should be there.

The items might very well be shelved according to a subject outline -- e.g., a set of user-reference volumes whose sections would each be a separate journal entry. Here the various sections would be updated independently, and their catalog numbers would bear no relation to their ordering within the binders. The Shelf List here would look like a Table of Contents.

An "Index" contains one-line citations ordered alphabetically or numerically on one or more of the terms found in the catalog entries, we automatically produce indices ordered on: Catalog Numbers; Author; and Keywords from the title (having an entry for each non-trivial title word).

Author index (by initials):

- LWP 12/09/70 Partial Description of the Universal
- CHL 09/11/70 New NLS features

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5244 CHI 12/10/70 NOTES ON CHANGES TO THE MLS SYSTEM

5103 DCE 06/03/70 Initial Journal System (limited version)

5219 DCE 11/06/70 Requirements for higher-level

Titlewort Index:

<table>
<thead>
<tr>
<th>Word</th>
<th>Num</th>
<th>Auth</th>
<th>Date</th>
<th>Title (front only)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACCESS</td>
<td>1032</td>
<td>WKE</td>
<td>07/10/70</td>
<td>NETWORK ACCESS TO SYSTEM</td>
</tr>
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<td>Access</td>
<td>1050</td>
<td>WKE</td>
<td>07/10/70</td>
<td>NETWORK ACCESS TO SYSTEM</td>
</tr>
<tr>
<td>Access</td>
<td>5205</td>
<td>DCE</td>
<td>11/02/70</td>
<td>DISCUSSION NOTES, WCB/JIM: NET</td>
</tr>
<tr>
<td>ACCESSION</td>
<td>4099</td>
<td>WSD</td>
<td>10/06/70</td>
<td>PROGRAM FOR PRODUCING A TITLE</td>
</tr>
<tr>
<td>Activity</td>
<td>5214</td>
<td>DCE</td>
<td>11/07/70</td>
<td>NOTES: DCE TALK WITH NUBIN RE.</td>
</tr>
<tr>
<td>Agency</td>
<td>4051</td>
<td>DCE</td>
<td>09/10/70</td>
<td>SETUP OF A NATIONAL</td>
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<tr>
<td>AGENTS</td>
<td>5615</td>
<td>JBN</td>
<td>12/15/70</td>
<td>TRANSMITTAL TO NIC STATION</td>
</tr>
<tr>
<td>Analyzer</td>
<td>5227</td>
<td>WLB</td>
<td>11/18/70</td>
<td>ANALYZER-FORMATTER PROGRAMS</td>
</tr>
<tr>
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<td>5209</td>
<td>DCE</td>
<td>11/02/70</td>
<td>SOME NP NOTES ON ANALYZER</td>
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</tr>
<tr>
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<td>5207</td>
<td>WLB</td>
<td>10/30/70</td>
<td>MEMO WE PALO ALTO ANSWERING SERVICE</td>
</tr>
</tbody>
</table>

We keep up-to-date copies of the shelf list, Author Index, and Title-word Index on the shelf beside the hard copies of the Journal.

We will soon begin to divide the journal into sub-collections, e.g., obsolete items; software documentation; baseline records; correspondence; etc.

We plan to make journal material ever easier to read online. By next fall we hope that any MLS user studying

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a journal item may jump from a link to any journal item that has been referenced within the past few days with the speed of disc access, and with a "worst case" time of less than five minutes for a file not used recently.

3. The baseline record:

The baseline record is a special sub-collection of the journal. It will consist of a series of files specially formatted to contain task and resource allocation information, including files of plans, specifications, analyses, designs, etc.

It will be composed of that portion of our current working records that represents our best definition of tasks we plan to perform in the future, how we are planning to do them, and what uses of resources (people, system service, materials) are expected.

We will keep some or all of the baseline record within a specially organized sub-collection of the journal, shelved separately, and we will use as a "shelf list" a topically organized table of contents. Sections of the baseline record that are superceded by new journal entries will be retired to obsolete status. Changes will be approved and recorded as in configuration management of hardware designs.
VIII. PLANS FOR 1971

A. NETWORK INFORMATION CENTER DEVELOPMENT AND OPERATION

1. Computer and Network Use

As necessary documentation becomes available, we will bring up the BBN Network Control Program (TCP) and Telnet. We will then perform some testing before we provide network service.

Initially, our local connect capacity allows for 12 displays and 24 typewriter terminals. With about 10 displays and 6 typewriter terminals running NLS, response is satisfactory, but marginal for display users. The delivery in June of new bryanta drums and measuring and tuning the new system should increase capacity and response. How much improvement to expect is not known.

The system processing required to support a network user is heavier than required to support a local typewriter user. Therefore we are not sure how many network users we will be able to support without degrading response seriously or requiring that we limit local loading by administrative restrictions. Our initial hope is that we can handle 6 network users by mid-summer with an optimistic expectation that we might be able to handle closer to 12.

As there is only limited interactive experience over the network, we do not know what its response characteristics will be like. We may find that the delays caused by two timesharing systems and the network transmission may allow us to support the higher number of network users without adding serious incremental response delays. The loading caused by parallel processes controlling intersite file transfers is also an unknown factor at this point.

We plan to increase our reference and communication service capacity by providing deferred execution facilities which will allow NLS compatible file preparation and editing offline or in local hosts; files so created may then be entered into NLS for further manipulation.

To prevent file capacity from being inadequate when needed, we are studying ways of using tape or facilities...
such as those at UCSB to give us an integrated auxiliary facility.

Our plans for providing online service to the network are briefly given below.

Stage 0 (Mid-June):

Stage 0 is to provide experimental access to the NIC for KADC and a limited number of west coast sites so that we can learn how to handle problems which may come up in actual network operation. These sites provide a variety of hosts and their location on the west coast simplifies communication during this initial trial period.

Stage 0 will allow access to the TENEX Executive, TNLS, an initial Network Dialog Support System – DSS (which will allow online creation and submission of messages and documents, with hardcopy mail delivery), and the first release of our TNLS users manual.

Initially, we will allow a maximum of two network users on at once.

There will be a two-day TNLs course at SRI in June for the initial sites.

Stage 2 (October):

Stage 2 is to provide access to the NIC from any site in the network having the appropriate access software.

Stage 1 will allow access to the DSS of Stage 0 with online access to documents and messages created online, online access to network related files such as the NIC Catalog, AMFA Network Resource Notbook, and other NIC documentation.

we expect to provide training to sites desiring access, we will allow as many network users simultaneous access as we can, depending on initial success with system tuning. A reasonable guess is 4-6 users.
Stage 2 will provide message delivery to files at remote sites (assuming protocols established by the Network working group have been implemented), an initial deferred execution mode allowing users to prepare files on their systems and then have them entered into TNL for further work, and improved query facilities of network online files.

We hope to have improved TeX-NLS performance so as to allow more network users simultaneous access than allowed in Stage 1.

2. Other Reference and Communication Activities

Mailing: We will continue to mail RFC's and other material going to liaison people as soon as we can get the material duplicated, which is usually within 24 to 48 hours after we receive it. We will mail material to station agents once each week, usually on Fridays. As online messages and documents are sent through the NIODSS, we will transmit copies to the addressees and to stations as appropriate.

Catalogs: We will continue to produce NIS catalog listings and indices, using improved techniques for their formatting and printing. We will also develop more automatic procedures for handling the production of the catalog and maintenance of the master catalog citation data. Early design work and the production of the first catalogs have given us additional understanding of the problems involved and ideas for meeting these needs. We plan to produce catalogs on a monthly basis.

B. DIALOG SUPPORT SYSTEM DEVELOPMENT

1. Automatic Journal Entry

After the transfer of NLS to the PUP-1U, our Journal entry and cataloging procedures will be made more automatic, and brought under direct user control from NLS.

Entry commands such as the following will be used:

- Execute Journal
- Interrogate (optional interactive input request mode)
Plans for 1971

Catalog entry, hardcopy formatting, and secure online filing of the document are included in this process.

Harcopy distribution will be used for all documents at first; optional online delivery to addressees or links (references) to the journal document files will follow soon thereafter.

2. We plan to make Journal material ever easier to read online. By next Fall we hope that any NLS user studying a Journal item may jump from a link to any Journal item that has been referenced within the past few days with the speed of disc access, and with a "worst case" time of less than five minutes for a file not used recently.

3. Further development and detailed design of other needed OSS features including work on backlinking, set generation and manipulation, and comment handling will continue.

C. BASELINE MANAGEMENT SYSTEM DEVELOPMENT:

1. The basic design and implementation of the ARC baseline management system will proceed with operational use of task planning procedures across various areas including development and operation in Service System, NLS, TENEX, Hardware, Dialog Support, File System, Management System, and Documentation activities.

2. Task planning data collection will continue, with
Improvement to be made in methods of file updating by those responsible for task management.

Key planning data elements include:

1. Requirements (what each task is supposed to produce)
2. Sponsors (other task(s) sponsoring conduct of each task)
3. Design details (or links to journal or other files)
4. Milestone points (as appropriate)
5. Estimated dates (start, completion, duration, milestones)
6. Estimated resource use (people, systems, other)
7. Sub-tasks (as appropriate)
8. Dependencies on or by other tasks (by time or design)

I. TRANSFER OF NLS

1. Transfer of existing NLS and TNLs features from the AHS 940 to the PDP-10 will be completed, with needed changes being made to those features where practical during the transfer process.

2. Key changes in TNLs will be made to give users more access to textual entities in viewing and editing operations. These will center about providing commands for specifying addresses more precisely and for movement of a control marker within a file to statements and within statements to character positions by character count, entity count, content, and other specifications.

3. TNLs changes will be made with the objective of giving network users access to NLS features and files in as useful a manner as possible, recognizing existing and future characteristics of the modes and terminals from which they will work.

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2. NEW FEATURES IN 1971

1. New NLS and executive features planned next are those most directly supporting NLS development and operation tasks.

2. Some Executive tasks are:

- Drum Diagnostics
- Bryant-UniVAC System
- Drum Comparisons
- Disc Diagnostics
- Disk Elevator Algorithm
- NET Link and Advise Studies
- Tertiary File Storage Study
- Increase Open Files Capacity
- Network File Transfer study
- Performance Measurements
- Study Capacity Increase Needs and Possibilities
- Background Process Development
- Reorganize ACORNE
- Old Scheduling Design

3. Some NLS tasks are:

- Cross File Editing
- Deferred execution
- Statement Address options
- Cross Reference
- Statement Property lists
- One Command Background
- Remote NLS Specifications
- Command backup
- Collector Sorter Improvements
- Fast Substitute
- Portrayal Generator
- Help Command
- Novice Mode

F. MODULAK PROGRAMMING

1. A fully-developed augmentation system of a few years hence will have a very large repertoire of commands, representing a rich vocabulary for eliciting help from the computer system. To experiment meaningfully with any one subset of commands, designed to support a special kind of intellectual task, the evaluation must rightfully be done within a working environment in which the subjects are...
doing all of their associated work in the way they would do it in the "complete workshop."

2. This means that to provide a progressive research environment in which rapid and significant evolution can take place, some sort of a "latest thing in complete workshops" must be maintained as a laboratory for each experimenter. To maintain this in separate installations is quite impractical.

3. The computer network offers an important hope here, in that it makes it possible for people at distributed locations to share a "latest thing in complete workshops" as an environment for their different, specific "tool-development experiments."

For several years AKO has been aiming toward an experimental future in which this was the way in which our work on augmentation systems would be done -- as part of a larger community in which many more people than we could marshal would be working on different fronts (and at different levels).

For instance, much of our motivation toward the Dialog support system has been to facilitate close collaboration between such distributed system-development participants.

4. Besides being able to sustain collaborative dialog, the participants would be much helped if each could view a relatively stable system as the background in which he experimented with a new tool, and if he could very rapidly and independently create and modify new tool features.

5. We are launching development of a Modular Programming System explicitly to serve this end. Design and implementation of a preliminary system will occur during 1971 with further stages of development to follow. When NLS has been modularized, it will be possible for instance to permit a worker at Utah to be given "custodianship" of a private subset of modules pertaining to the manipulation of one kind of graphic-data packet in our file data nodes.

He would be given his private copies of the source code files for these modules, and could add and/or modify them at will. His modules could be independently compiled by him at any time; and when he wishes to experiment with the resulting "new tool," his compiled modules could be linked into the rest of the NLS.
compiled-code module set at run time, perhaps in place of some modules that the standard version of NLS offers but that he is redoing.

To experiment with his tool, he could use it in the midst of processes, methods and information that are part of a busy (and evolving) working life in the whole workshop.

Each person could do his private development with minimal burden on the support system, and with maximum protection to the other workshop users.

The standard-NLS Module Set would be controlled and updated by a central community process, steadily integrating the improvements of the trial tools as they become thoroughly checked out.
II. GLOSSARY

ARC -- Acronym for Augmentation Research Center.

AKPA -- Acronym for the Advanced Research Projects Agency of the Office of the Secretary of Defense.

Augmentation -- In this report, extension, improvement, or amplification of human intellectual and organizational capabilities by means of close interaction with computer aids and by use of special procedural and organization techniques designed to support and exploit this interaction.

BoBAN -- Bolt Beranek and Newman. A commercial research and development organization under contract to ARPA for services to the ARPA Network, and under other contracts that lead to frequent interaction with ARC.

Bootstrapping -- A name for the research strategy of the ARC. By "bootstrapping" we mean taking advantage of the feedback in recursive development of systems. That is, we try to test ways of augmenting intelligence by their usefulness in developing new systems to augment intelligence.

branch -- In the NLS hierarchy of statements, a statement and all substatements that depend on it.

Center -- The same as ARC.

Console -- As used here, specifically a user's control console for the AKC's Online System (NLS). The consoles presently in use consist of a display screen, a keyboard, a "mouse", and a "keyset".

Current Statement -- In NLS, normally the last statement modified, executed, or reproduced by the user, and, hence the statement that starts the sequence of the sequence generator which generates the display image. Usually the statement at the top of the screen is the current statement, but content analysis or screen splitting may displace or obscure it.

Current Statement Pointer -- The internal symbol fixed on the current statement by NLS.

Dialog Support System (DSS) -- The system of files, programs, and procedures at AKC for storing, sorting and recovering the interchange of thoughts, plans, memos, technical documents, etc. that accompany our system development.
Display Start Statement -- The same as "current statement"

Executable text -- In NLS, a program or subroutine that is written in characters as all or part of a statement and that can be carried out by a simple command from the user.

File -- In NLS, this refers to a unified collection of information held in computer storage for use with the online system. A file may contain text (English or program code), numerical information, graphics, or any combination of these. Conceptually, a file corresponds roughly to a hard-copy document.

Field Operations -- In programming NLS, manipulations that involve the capacity of the Puk-lu's software to handle parts of words.

Frozen Statements -- In using NLS, statements added as is on the display while other parts of the file are composed or modified.

Higher Level Processes -- (HLP) Processes in which the basic user features of our online systems (particularly NLS and TNLS) are used as building-blocks in the construction of programs for carrying out specific, perhaps rather complicated tasks.

IMP -- Acronym for Interface Message Processors. Hardware devices that code and decode messages for transmission between the computers on the ARPA Network.

Intelect -- The human competence to make, sort, exchange, and apply to decision making knowledge.

Journal -- The open ended information storage and retrieval system that supports the Dialog Support System.

Keyset -- A device like a stenographic machine consisting of five keys to be struck with the left hand in commanding the online system.

List -- In the NLS hierarchy, the list of a given statement is the set of statements that are in the plex of the source of the given statement and are on the same level with it.

Markers -- A marker is a symbolic name which the user may attach to a particular character in a file. It is invisible on the screen, but visible to routines that search for it.
Mouse -- A device operated by the right hand in using the Online System. The mouse rolls freely on any flat surface, causing a cursor spot on the display screen to move correspondingly.

MIC -- Acronym for Network Information Center, MIC's key role in the ARPA computer network. The MIC is a computer-assisted reference and communication service for information pertaining to the network.

NLS -- Acronym for the AKU Online System.

Plex -- In the NLS hierarchy, the set of all statements that have a common source.

Online System -- This is AKU's principal and central development in the area of computer aids to the human intellect. As presently constituted, it is a time-shared multi-console system for the composition, study, and modification of files (see definition of "file"). Many details of the system are described in the body of this report.

Pointer -- An old name for marker.

KADC -- Acronym for Home Air Development Center.

Sequence Generator -- A routine that, when given the number that identifies a statement internally (the STID), will search through the file and find all the subsequent statements that observe the current viewspecs.

SI -- Acronym for Stanford Research Institute

STID -- Acronym for statement identifier. A number unique to each statement in a file and that remains with the data regardless of editing.

Source -- In the NLS hierarchy, the first sublist of a statement is the set of statements immediately below it, the second sublist is all statements one level below them, and so the nth sublist of statement "s" is the set of statements that are in the first sublist of the statements in the (n-1)th sublist of "s".

Statement -- The basic structural unit of a file. A statement consists of an arbitrary string of text, plus graphic information. A file consists of a number of statements in arranged an explicit hierarchical structure.
Textpointer -- In NLS as used on the Puv-1u, the fixation by NLS on a space between two characters which allows the users to be sure editing or execution of executable text will begin with the following character.

TNLS -- Acronym for Typewriter Online System. The system used in ARC from typewriter type terminals from early 1971 on. It differs from TOWAS internally in using core NLS with adaptive routines that are called automatically when the user names his terminal in logging in, and externally in a number of additional powerful editing commands.

TODAS -- Acronym for Typewriter Oriented Documentation Aid System. The version of NLS used from typewriter like terminals prior to 1971.

Tree Meta -- The compiler-compiler system of ARC, used to compile all the languages at ARC.
REFERENCES AND PUBLICATIONS

REFERENCES


ABC PUBLICATIONS


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Springfield, Virginia 22151; cost $3.00 per copy or 65 cents for microfilm.
APPENDIXES

A. APPENDIX A, I/O BOX

1. I/O CONTROL SYSTEM

2. General

The I/O control box connects onto the PDP-10 I/O system and is used to interface control signals and interrupt signals between various external devices and the PDP-10.

3. CONU To Devices

The PDP-10 controls external devices through the execution of a CONU instruction with device code 420.

The right half of the word has the following format.

```
18  21  32  33  3b
-- -- -- -- -- -- -- -- -- -- -- --
: ignore :
-- -- -- -- -- -- -- -- -- -- -- --
```

Sub-device bits

Order code

By setting bits 21 through 32, the order code can be transmitted to any number up to 12 external devices.

Bits 33 through 3b are decoded to generate one of eight commands that can be transmitted to the indicated devices.

Order code 0 has been reserved to represent a reset command.

In general only the first four order codes have been decoded in the hardware.

When the "HIST" switch on the PDP-10 console is pushed the order code 0 is transmitted to all 12 devices.

Bit assignment within this field as well as order functions are defined below.
<table>
<thead>
<tr>
<th>Code</th>
<th>Device</th>
<th>Order Code</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>32</td>
<td>Disc/Drum System</td>
<td>0</td>
<td>reset system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>reset drum</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>reset disc</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>start drum</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>go chain disc</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>go no-chain disc</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6</td>
<td>disconnect disc</td>
</tr>
<tr>
<td>31</td>
<td>Display System 1</td>
<td>0</td>
<td>reset</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>initiate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>pause</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>restart</td>
</tr>
<tr>
<td>30</td>
<td>Display System 2</td>
<td>0</td>
<td>reset</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>initiate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>pause</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>restart</td>
</tr>
<tr>
<td>29</td>
<td>L.D.C.</td>
<td>0</td>
<td>reset</td>
</tr>
<tr>
<td>28</td>
<td>Printer</td>
<td>0</td>
<td>reset</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>initiate</td>
</tr>
<tr>
<td>27</td>
<td>Network</td>
<td>0</td>
<td>reset</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>timer</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>receive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>menu</td>
</tr>
<tr>
<td>26</td>
<td>n.S Data Set</td>
<td>0</td>
<td>reset</td>
</tr>
<tr>
<td>25</td>
<td>Unused</td>
<td>1</td>
<td>initiate</td>
</tr>
<tr>
<td>24</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### a. CONI from Devices

The PDP-10 can sample the state of various external devices through the execution of a CONI instruction with device code of 420.

The right half of the word has the following format:

```
  10  
  :   lo  
  :   lo  
```

---

Complete flexibility is allowed in connecting any

---

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status condition of any device to some particular bit within this field.

Bit assignments within this field are defined below.

<table>
<thead>
<tr>
<th>Bit</th>
<th>Device and Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>35</td>
<td>Drum busy</td>
</tr>
<tr>
<td>34</td>
<td>Disc busy</td>
</tr>
<tr>
<td>33</td>
<td>Disc error</td>
</tr>
<tr>
<td>32</td>
<td>Display 1 busy</td>
</tr>
<tr>
<td>31</td>
<td>Display 1 error</td>
</tr>
<tr>
<td>30</td>
<td>Display 2 busy</td>
</tr>
<tr>
<td>29</td>
<td>Display 2 error</td>
</tr>
<tr>
<td>28</td>
<td>I.D.C. busy</td>
</tr>
<tr>
<td>27</td>
<td>I.D.C. error</td>
</tr>
<tr>
<td>26</td>
<td>Printer busy</td>
</tr>
<tr>
<td>25</td>
<td>Printer error</td>
</tr>
<tr>
<td>24</td>
<td>Network busy</td>
</tr>
<tr>
<td>23</td>
<td>Network error</td>
</tr>
<tr>
<td>22</td>
<td>H.S.D.S. busy</td>
</tr>
<tr>
<td>21</td>
<td>H.S.D.S. error</td>
</tr>
<tr>
<td>20</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td></td>
</tr>
</tbody>
</table>

5. Interrupt handling

The PDP-10 controls both the interrupt level and the masking of those devices from which it seeks interrupts. Control is executed through several CUNI and CONO instructions to the I/O control box.

Flag register

The flag register stores the bits which are trying to generate an interrupt to the PDP-10 system.

This register can be sampled by the execution of a CUNI instruction with a device code of 111.

Data will be presented with the following format.
Bits 16 through 29 are set when an interrupt has been requested from the appropriate device.

Devices are assigned to bit positions according to the following table.

<table>
<thead>
<tr>
<th>BIT</th>
<th>DEVICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>29</td>
<td>Bryant Disk: abnormal interrupt</td>
</tr>
<tr>
<td>28</td>
<td>Bryant Disk: normal interrupt</td>
</tr>
<tr>
<td>27</td>
<td>Display System 1</td>
</tr>
<tr>
<td>26</td>
<td>Display System 2</td>
</tr>
<tr>
<td>25</td>
<td>I.D.U.</td>
</tr>
<tr>
<td>24</td>
<td>Printer</td>
</tr>
<tr>
<td>23</td>
<td>Network = input</td>
</tr>
<tr>
<td>22</td>
<td>Network = output</td>
</tr>
<tr>
<td>21</td>
<td>H.S.W.S.</td>
</tr>
<tr>
<td>20</td>
<td>TV</td>
</tr>
<tr>
<td>19</td>
<td>XCUK failure</td>
</tr>
</tbody>
</table>

This register can be modified by the PUP-I/O through the execution of a CWNO instruction with a device code of 31.

The right half of the instruction has the following format.

```
10   29 30 31 32 33
-- -- -- -- -- -- -- -- -- -- -- --
: : : : : ignore :                
-- -- -- -- -- -- -- -- -- -- -- --
flags control                    
```

Bits 10 through 29 indicate the bits of the flag register to be effected.

If bit 30 is set, then the indicated bits of the flag register are to be set to zero.

If bit 31 is set, then the indicated bits of the flag register are to be set to one.
If bit 32 is set, then all the bits of the flag register are to be set to zero.

**Mask A register**

This register contains a 12 bit mask and a 3 bit interrupt level register. An interrupt is generated on the appropriate priority interrupt channel when one occurs both in the flag register and in the mask A register.

The source of an interrupt due to mask A can be determined through the execution of a COIN instruction with a device code of 400.

Data will be returned with the following format:

<table>
<thead>
<tr>
<th>10</th>
<th>29</th>
<th>35</th>
</tr>
</thead>
<tbody>
<tr>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>12 bits</td>
<td>ignore</td>
<td></td>
</tr>
</tbody>
</table>

Only if both a bit for mask A and the corresponding flag bit are set.

The mask A register can be modified through the execution of a COOU instruction with a device code of 400.

The right half of the instruction has the following format:

<table>
<thead>
<tr>
<th>10</th>
<th>29</th>
<th>30</th>
<th>31</th>
<th>32</th>
<th>33</th>
</tr>
</thead>
<tbody>
<tr>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

Bits 16 through 29 indicate the bits of mask A to be affected.

If bit 30 is set, then the indicated bits of the mask are to be set to zero.
If bit 31 is set, then the indicated bits of the mask are to be set to one.

If bit 32 is set, then the interrupt level register is to be updated with the contents of bits 31 through 32.

This register can be sampled through the execution of a DATAI instruction with a device code of 400.

Data is returned in the following format:

\[
\begin{array}{cccccccccccc}
& & & & & & & & & & & & \\
\text{mask A} & & & & & & & & & & & & \\
\text{priority} & & & & & & & & & & & & \\
\text{bits} 10 & 29 & 33 & 35 & & & & & & & & & & \\
\text{ignor} & & & & & & & & & & & & \\
\text{bits} 10 & 29 & 33 & 35 & & & & & & & & & & \\
\text{mask B} & & & & & & & & & & & & \\
\end{array}
\]

Bits 10 through 29 indicate the state of mask A, and bits 31 through 35 indicate the interrupt level set for mask A.

This register contains a 12-bit mask and a 3-bit interrupt level register. An interrupt is generated on the appropriate priority interrupt channel when a one occurs both in the flag register and in the mask B register.

The operation of this mask register is identical to that of the mask A register with the provision that the device code for the appropriate UNIV, CDNI, and DATAI instructions is 404.

UNIVAC Drum

Interrupts for the UNIVA drum are handled separately from the other devices to allow for a unique interrupt level for this device.

An interrupt is generated on the appropriate interrupt level if the drum flag is set.

The state of the drum flag bit can be sampled through the execution of a CDNI instruction with a device code of 400.
data is returned with the following format:

```
16 29 3b
::::: ignore ::::: ignore :::::
::::: ignore ::::: ignore :::::
```

Drum flag

Bit 29 is returned as a one if the drum flag bit is set.

```
1ae2a2
```

The drum flag and priority interrupt level can be modified through the execution of a \texttt{PUSH} instruction with device code \texttt{410}.

```
lae2a3
```

The right half of the instruction has the following format:

```
18 30 31 32 33 34
::::: ignore ::::: ignore :::::
```

control priority

```
lae2a1
```

Bit 30 will reset the drum flag.

```
lae2a2
```

Bit 31 will set the drum flag.

```
lae2a3
```

If bit 32 is set, the the priority interrupt level will be set to the value contained in bits 33 through 35.

```
lae2d
```

The drum interrupt level can be sampled through the execution of a \texttt{PULL} instruction with a device code of \texttt{410}.

```
lae2e
```

data is returned with the following format:

```
1b 33 3b
::::: ignore :::::
::::: ignore :::::
```

priority

```
lae2e1
```

bits 33 through 35 indicate the disc priority interrupt level.

```
lae2e2
```

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The urum interrupt can be turned off by setting the priority level to zero.
The subsystem described here consists of a high-speed UNIVAC drum units model Fh-432, and a UNIVAC drum control unit model 5012, connected to a PDP-10 memory bus through a special Disc-Drum Channel Logic unit.

The total storage available on the drum units is 1,040,576 words with an average access time of 4.3 milliseconds and a transfer rate of 240,000 words/second.

The Disc-Drum Channel Logic processes commands to the drum by reading a Unit Reference Cell (URC) in memory for instructions. In addition it allows the Bryant Disc controller to share access to memory through the same memory bus.

In addition to acting as a drum controller/interface, the Disc-Drum Channel Logic also connects the Bryant disc system with the PDP-10 memory. Memory access is multiplexed between the disc and drum a cycle at a time where the drum has high priority.

The Disc-Drum Channel Logic is connected to the PDP-10 memory through the high priority port of the UNIVAC MA-10 memory modules.

The drum URC is a fixed, three-word block of computer core memory.

URC 6a function word for drum
URC 1 65 word count and memory address
URC 2 66 status message

2. CONO, CONI, and Interrupt Instructions

Three CONO instructions are defined for the disc subsystem.

The CONO codes are (device code 420)

742200 000010 Reset disc/drum system
742200 000011 reset drum
742200 000013 Start drum

The CONO actions are:

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Appendix B, UNIVAC Drum System

Start Drum -- This CONU causes the controller to execute the command contained in the UKC.

Command processing consists of fetching the control words from memory, transmitting the function word to the drum, and managing the resulting data transfers between memory and drum.

A Start Drum CONU issued while the system is busy will be ignored.

Reset Drum -- This CONU immediately terminates any drum operation in process when the CONU is received, and returns the system to the disconnect state.

Reset disc/drum system -- This CONU immediately terminates any disc or drum operation and returns the entire disc/drum channel logic to the reset state.

One CONI condition is sensed.

The CONI device code is 420

<table>
<thead>
<tr>
<th>Bit 35</th>
<th>Set</th>
<th>Sense input</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>YYYYYYYYY</td>
</tr>
</tbody>
</table>

Drum Interrupt

An interrupt is generated on the appropriate interrupt level of the drum flag is set.

The drum flag and priority interrupt level can be modified through the execution of a CONU instruction with a device code of 410.

<table>
<thead>
<tr>
<th>Bit 30</th>
<th>Set</th>
<th>Reset the drum flag</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bit 31</th>
<th>Set</th>
<th>Set the drum flag</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

If bit 32 is set, the priority interrupt level will be set to the value contained in bits 33 through 35.
A more complete description of the CONI, CONI and interrupt capability for special hardware devices can be found in the \textit{I/O CONTHUT BOX} section of the appendix.

3. UHC Processing

During the command table processing sequence, the second word of the UHC will be fetched first.

The second word of the UHC has the following format.

\begin{verbatim}
 0 1/16
 1/16 1

Word Count Memory Address
\end{verbatim}

Bits 0 - 1/16 A positive word count including the value zero.

Bits 16-35 are an 18 bit address indicating the first word in FPB-10 memory for the current transfer. If this address is to be extended to 20 bits for use with the EAN paging box, the two additional bits are to be found in the first word of the UHC.

If either a zero word count or a memory parity error is detected while reading this word of the UHC, the status word will be written indicating such an error and the process terminated with no command sent to the drum.

After reading the first word of the UHC and finding a non-zero word count, the first word containing the drum command is read.
This word has the following format:

```
|   0   |   5   | 12  | 14  | 15  | 17  |
|------------------|
| Fun. Code | Ignore | 1oct Drum Unit |
```

Bits 0 - 5. This is a function code to be sent to the drum controller. Only 5 codes are acceptable and all others will result in terminating with an appropriate error bit in the channel status report. The allowed functions are described below.

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>02</td>
<td>Continuous write</td>
</tr>
<tr>
<td>03</td>
<td>Read Normal</td>
</tr>
<tr>
<td>04</td>
<td>Read Early</td>
</tr>
<tr>
<td>05</td>
<td>Read Late</td>
</tr>
<tr>
<td>06</td>
<td>Send Angular Address</td>
</tr>
</tbody>
</table>

Codes 02 and 03 are normally used to write and read with the drum.

Codes 04 and 05 are the same as the Continuous Read (02) function except that the drum read probes are shifted to read data pulses slightly earlier or later. These functions can be used to try to recover data following a parity error, or to aid online maintenance.

Code 06 is used to instruct the UNIVAC controller to send a status word containing the current angular address of the drum specified by the function word. This is a special command in as much as the channel logic ignores the word count field. (This field must be non-zero however so that the channel logic will read this word in the UNIVAC).

The Angular report is based on the selected Drum Unit. The remaining bits of the drum address (40-35) will be ignored.

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In most cases, the interrupt is returned within about 30 microseconds after the UONU is issued. If the "dead space" is under the read head when the function is in progress, up to 230 microseconds may elapse.

If this function word addresses an inoperable drum unit, the status word containing the Illegal Address (54) status code is returned.

The format of the angular position report is described under the status word.

Bits 12-14 This is an idenf field which must be set to either all one's or all zero's.

Bits 15-35 These bits represent the drum address as interpreted by the UNIVAC controller.

If the Channel Logic detects either an illegal command or a parity error the operation will be terminated with appropriate bits set in the Status word.

After processing the two words in the UKC, the Channel will then proceed to transfer data until the word count becomes zero. At this point a Control Code of 33 is generated and sent to the UNIVAC controller so as to conclude the current function and return the drum status to the Channel Logic. The drum status information is used by the Channel Logic in updating the status word in the UKC.

4. Status Report

Before setting the drum flag at the completion of a command, the third word in the UKC is updated by the Drum Control Logic.

This word will have the following format.

```
0 5 6 11 12
--- --- --- --- --- --- --- --- --- --- --- ---
status channel drum information
```
The status code which is returned from the UNIVAC controller will have only those values described below.

(00) - Channel Fault

An error was detected by the Disc-Drum Controller such that no request was passed on to the UNIVAC system.

The error detected is indicated within the Channel Status portion of the status word.

The contents of the 24 low-order bits of the status word are indeterminate and should be ignored.

(14) - Fault

The Fault status code is used to inform the processor that a hardware malfunction has occurred in the subsystem. Conditions which can cause a Fault indication are:

- More than one read-write head has been selected.
- Power to the drum units has been interrupted during the operation.
- Angular address circuits in an FH-432 drum unit are out of synchronization.
- The WRITE VOLTAGE switch in the control unit is OFF when any function was received.

The contents of the 24 low-order bits of the status word are indeterminate and should be ignored.

This error code can result from any of the valid function codes used on this system.

(20) - Angular Address

The Angular Address status code is sent to the processor in response to Send Angular Address function (22). For the FH-432 drum unit, the 11 low-order bits of the status word contain...
the angular address present about 10
microseconds before the time the drum flag
interrupt signal was turned on.  1164a2c1

(34) ENO-OF-FILE  1164a2d

The end-of-file status code is used to inform
the processor that the next sequential address
is outside the set of legitimate drum addresses
of the particular subsystem, is on an
inoperable drum, or is on logical drum unit 1
for a write function when a write LOCKOUT
switch is set and applied to drum unit 1.  1164a2c1

This status code is generated only through
increment of the drum address during a
function.  1164a2d2

A status word containing an end-of-file status
code is generated in response to any of the
valid function codes except send angular
address.  1164a2d3

The contents of the 24 low-order bits of the
status word are indeterminate and should be
ignored.  1164a2d4

(40) - Normal Completion  1164a2e

If a Normal Completion is generated at the end
of a data transfer, then the previous function
was completed without an error detected.  1164a2e1

The contents of the 24 low-order bits of the
status word are indeterminate and should be
ignored.  1164a2e2

(54) - Illegal Address  1164a2f

The Illegal Address status code is used to
inform the processor that the drum address in
the function word is invalid.  1164a2f1

An invalid address is defined as an address
specified in any read or write function word
which is not within the set of legitimate
addresses for the subsystem or which is on an
inoperable drum.  1164a2f2
An address specified in a write function word which is in the set of addresses locked out by a write LOOKOUT switch is also designated as an invalid address.

If a function word specifies an invalid address, the function is not initiated, and no data is transferred to or from the drum.

The contents of the 24 low-order bits of the status word are indeterminate and should be ignored.

(Ex) - Parity Error

The Parity error status code is used to inform the processor that the control unit detected a parity error during a read operation. The 24 low-order bits of the status word contain the drum address of the word in which the error was detected.

If a data parity error is detected, the status word is made available to the processor, and the interrupt signal is turned on only after the processor has accepted all parity-correct data words read for input to the processor before the error was detected. The error word is not made available to the processor.

The following procedure is recommended in attempting to recover from a parity error condition.

Initiate a continuous read (42) function and check whether the parity error persists.

If the parity error is reported, initiate a read early (41) function.

If the parity error persists, initiate a read late (43) function to check again for correct parity.

If the parity error is the response received for each step of the recovery procedure, then the error must be considered a non-recoverable drum error.
C. APPENDIX C, BRYANT DISC SYSTEM

1. General

The subsystem described here consists of a Bryant disc file series 4000, mod A2A, and a control unit. The present 7-disc system is capable of storing approximately 23 million 36-bit words.

The disc unit reference cell (URC) is a fixed three-word block of computer core memory.

<table>
<thead>
<tr>
<th>URC</th>
<th>70</th>
<th>pointer to command table</th>
</tr>
</thead>
<tbody>
<tr>
<td>URC+1</td>
<td>71</td>
<td>advance sector information</td>
</tr>
<tr>
<td>URC+2</td>
<td>72</td>
<td>error message</td>
</tr>
</tbody>
</table>

All words in the URC and the command table as used by the disc controller are 24-bit fields corresponding to bits 12 through 35 of the PDP-10 word format. Bits 0 through 11 will be ignored by the controller and returned as zeros when writing into core.

Data transferred to or from the disc will be 36-bit words plus odd parity.

2. CUNO and CONI Instructions

Five CUNO instructions are defined for the disc subsystem.

The CUNO codes are (device code 420)

<table>
<thead>
<tr>
<th>CUNO Code</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>72200 000010</td>
<td>Reset disc/drum system</td>
</tr>
<tr>
<td>72200 000012</td>
<td>Reset disc</td>
</tr>
<tr>
<td>72200 000014</td>
<td>Go chain</td>
</tr>
<tr>
<td>72200 000015</td>
<td>Go no-chain</td>
</tr>
<tr>
<td>72200 000016</td>
<td>Disconnect</td>
</tr>
</tbody>
</table>

The CUNO actions are:

Reset disc/drum system -- This CUNO immediately terminates any disc or drum operation which may be in process when the CUNO is received, and returns the disc/drum system to the disconnect state.
The digit designated "x" can be any number from 1 through 7 to signify one portion or portions of the word containing the parity error.

<table>
<thead>
<tr>
<th>Status Code</th>
<th>Incorrect Parity</th>
</tr>
</thead>
<tbody>
<tr>
<td>61</td>
<td>21 through 35</td>
</tr>
<tr>
<td>62</td>
<td>12 through 20</td>
</tr>
<tr>
<td>63</td>
<td>12 through 23 and 24 through 35</td>
</tr>
<tr>
<td>64</td>
<td>0 through 11</td>
</tr>
<tr>
<td>65</td>
<td>0 through 11 and 24 through 35</td>
</tr>
<tr>
<td>66</td>
<td>0 through 11 and 12 through 23</td>
</tr>
<tr>
<td>67</td>
<td>All three 12-bit segments</td>
</tr>
</tbody>
</table>

**Bits 6-11** This field is used by the Channel Logic to indicate any fault conditions that it may detect. The bits used and the corresponding errors are listed below.

- **Bit 6 -- Bad End**
- **Bit 7 -- Parity Error**
- **Bit 8 -- Illegal Function**
- **Bit 9 -- Drum Non-exempt**
- **Bits 10-11 -- Not Used**

The UNIVAC drum controller indicates a not ready state, does not complete a command, or is not plugged into the Channel Logic.

The Channel Logic detected a parity error when reading PUP-1U memory.

The first word in the buffer contained an illegal function code.

The PUP-1U memory address accessed by the drum portion of the disc-drum Channel Logic did not respond within 100 microseconds. This failure indicates either an illegal memory address or a malfunctioning memory unit.

These bits are currently not used and will always be returned as zeroes.
Go-chain -- This CONO causes the controller to start command processing.

processing always starts with the command addressed by the URC when the CONO is executed.

If a disconnect request has previously been stored by a disconnect CONO and the system is still busy (processing commands), a go-chain CONO cancels the disconnect request.

A go-chain CONO issued while the system is busy and no disconnect request is stored results in a command error.

Go-No chain -- This CONO causes the controller to process the single command table entry pointed to by the URC.

A go-no chain CONO received while the controller is processing commands results in a command error.

Reset -- This CONO immediately terminates any disc operation in process when the CONO is received, and returns the system to the disconnect state.

Disconnect -- This CONO causes the controller to disconnect at the next normal interrupt condition.

Two CONI conditions are sensed.

The CONI device code is 420

742240 YYYYYYYY sense input conditions

The conditions sensed are;

Bit 3a -- This bit is set to a one if the disc system is busy

Bit 3j -- This bit is set to a one if any outstanding error conditions exists on the disc subsystem. Execution of this instruction does not reset any error conditions.
Appendix C, Bryant Disc System

The execution of a wo-chain command before the next normal interrupt condition is reached cancels the disconnect request.

3. Command-Table Processing

After either GO or NO, the system begins processing commands with the command addressed by the UKC.

The UKC always points to the current command being processed.

In a GO or NO chain operation, after the successful completion of the command, the UKC is updated (incremented by 3) to point to the first word of the next command.

There are three types of commands in the command table.

Data Transfer Command -- This command consists of three command words in contiguous memory locations.

The first word contains the disc address. It consists of concatenated binary address fields. Not all combinations in certain address fields are used; the unused combinations form invalid addresses. The address word has the following format:

\[
\begin{array}{cccc}
T & L & H & S \\
14 & 15 & 22 & 31,35 \\
\end{array}
\]

Interrupt bit -- If bit 14 is a 1, a normal interrupt is given after successful completion of the command.

Track Address field (A bits) -- This field is used to select one of 256 head array positions. All bit combinations in this field are valid.
Zone Address field (4 bits) -- This field is used to select one of the three disc frequency zones as follows:

<table>
<thead>
<tr>
<th></th>
<th>Zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>Zone 0</td>
</tr>
<tr>
<td>01</td>
<td>Zone 1</td>
</tr>
<tr>
<td>10</td>
<td>Zone 2</td>
</tr>
<tr>
<td>11</td>
<td>Invalid</td>
</tr>
</tbody>
</table>

Head Address field (7 bits) -- This field is used to select one of the 20 data heads in the specified zone.

Heads are numbered 0 to 23, and are arranged two per physical surface per zone.

The valid addresses for the 6-disc system are 0000000 through 0011001.

Sector Address field (1 bit) -- This field is used to select the proper sector on a track.

The valid combinations for this field depend on the zone selected. Sectors are numbered zero to K, where K is one less than the number of sectors in the zone. The following combinations for each zone are valid.

<table>
<thead>
<tr>
<th>Zone</th>
<th>Address Field</th>
<th>Sectors</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0000-0001</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>0000-0100</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>0000-0110</td>
<td>7</td>
</tr>
</tbody>
</table>

The second word contains the class and word count. Its format is as follows:

```
<table>
<thead>
<tr>
<th>Class</th>
<th>Count</th>
</tr>
</thead>
</table>
```

Class field contains the Direction-of-Transfer bit (Read/Write) and information on headers. It is subdivided as follows:
SHI-AHC 1 JULY '71 0277
Appendix C, Bryant DISC System

12 13 14 15
-------------
: : : :
-------------
Head  I/O  Class  lic3blbaf

Head -- If this bit is a 1, header fields are written with the record.

I/O -- These bits determine the direction of transfer and the use of the class field as follows:

00  Head = No compare with class
01  Head = Compare with class
10  Write record and class field
11  Write if class compares equal

Class -- This 4-bit field appears in each record defining a class to which the record belongs. If class comparison is called for and fails, an error interrupt is given.

Count Field -- This field defines the number of 36-bit words to be transferred.

The maximum word count is 2048. Exceeding this count in the command word results in an illegal word count error.

If the field is zero the command serves to position the head array only. (Headers may be written with a word count of zero).

The third word contains the core memory address at which the transfer is to begin. The word format is:

12 13
-------------
: : :
-------------
Core Address  lic3blcl

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Core Address -- This field contains the absolute core address at which the information transfer is to begin.

Branch Command -- This command causes the next command word to be taken from the core location given in the branch command word rather than in sequence in the command table. The core address is absolute and no remapping takes place. The word format is:

```
12 14 19 35
------------------------
10 11 12
------------------------
I Core Address
```

If the interrupt bit is set a normal interrupt will be generated after the command is executed.

Note: After a branch command the URC is written with the entire contents of the branch command word.

Disconnect Command Word -- This word causes the disc controller to disconnect. The word format is:

```
12 14 35
------------------------
10 11 12
------------------------
I
```

If the interrupt bit is set a normal interrupt will be generated after the command is executed.

Disc File Formats

Disc Format: Each of the twelve data surfaces is divided into three zones, with a pair of heads for each zone. Each of the three zones has a separate clock frequency and bit density optimized for the zone.

Zone Format: A zone is divided into 512 tracks, corresponding to each of two heads at 256 positions of the head array.
Track Format: A track is divided into sectors by prerecorded sector pulses. The number of sectors per track is a function of the zone.

<table>
<thead>
<tr>
<th>Zone</th>
<th>Sectors/track</th>
<th>Zone Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2</td>
<td>Inner Zone</td>
</tr>
<tr>
<td>1</td>
<td>5</td>
<td>Middle Zone</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>Outer Zone</td>
</tr>
</tbody>
</table>

Sector Format: There is one fixed-length record per sector with a data field of 256 30-bit words. Associated with each record is a header field used to identify the record and ensure that head and zone selection are correct before writing or reading a record, and a class field grants access to records by class.

In all subfields of the sector a preamble and postamble ensure reliable reading of the first and last bits of the subfield.

These bits are all "ones," generated by the controller and never transferred to the computer.

The overall format of the sector is

<table>
<thead>
<tr>
<th>Header Field</th>
<th>Class Field</th>
<th>Data Field</th>
</tr>
</thead>
<tbody>
<tr>
<td>74 bits</td>
<td>37 bits</td>
<td>56 bits</td>
</tr>
</tbody>
</table>

The header field consists of two header words generated by the control unit and is not transferred to the central processor.

These words are only written when special key switches (one for each header word) are on and a 1 appears in the 0 bit of the class and count word.

Header Word 1

<table>
<thead>
<tr>
<th>Preamble</th>
<th>Track Address</th>
<th>Zeroes</th>
<th>Preamble</th>
<th>Postamble</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 bits</td>
<td>5 bits</td>
<td>1</td>
<td>3 bits</td>
<td>1</td>
</tr>
</tbody>
</table>
This word is written by the disc controller and is used for track verification.

Header word

<table>
<thead>
<tr>
<th>8 bits</th>
<th>2</th>
<th>7 bits</th>
<th>4 bits</th>
<th>1</th>
<th>3 bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>: Preamble : Z : Surface : Sector : P : Postamble:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Zone Subfield (2 bits) -- These two bits correspond to the zone address and are used to insure proper selection of the zone.

Head Subfield (7 bits) -- These seven bits are used to ensure correct selection of the head. Heads are arranged two per physical surface per zone.

Sector Subfield (4 bits) -- This subfield is used to identify the sector or record and is unique on each track.

Parity Subfield (1 bit) -- Odd parity is generated for each header word and is checked whenever the header is read.

Class Field Format -- The format of the class field is:

<table>
<thead>
<tr>
<th>8 bits</th>
<th>4 bits</th>
<th>9 bits</th>
<th>1</th>
<th>3 bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>: Preamble : Class : Zeros : P : Postamble:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Class Subfield -- This is a 4-bit field defining the class to which a record belongs. Normally the class field is read and compared with that appearing in the command word; if they are equal the operation proceeds.

Parity Subfield (1 bit) -- Odd parity

Data Field Format
Appendix C, Bryant disc system

6 bits  9472 bits  9 bits  3 bits
-----------------------------------
Preamble  :  Data  :  Check bits  :  Postamble
-----------------------------------

Data subfield (9472 bits) -- This subfield consists of 236 36-bit machine words. An odd parity bit is inserted every 30 bits by the control unit. It is transferred in its entirety on a read operation with odd parity generated for each word. If less than 236 words are transferred on a write, the control unit generates the necessary zeros to fill out the data subfield.

Check Subfield (9 bits) -- This subfield is used for error checking over the data record. It is generated by the control unit on a read or write operation and is never transferred to the central processor.

Gap Format -- A gap of 111 bit times is allowed between each alterable segment of the sector format and the next. This allows sufficient time for the recovery of the read amplifiers after writing a segment of the sector field.

5. Clocking

Clock tracks are prerecorded on a separate disc with its own set of heads which do not move. Each zone has a separate heads for write clock and sector/index pulse.

When the system is busy, the advance sector word is updated by the controller to indicate the next available sector in each zone. This word has the following format.

<table>
<thead>
<tr>
<th>12</th>
<th>15</th>
<th>16</th>
<th>23</th>
<th>27</th>
<th>31</th>
<th>35</th>
</tr>
</thead>
<tbody>
<tr>
<td>:</td>
<td>:</td>
<td>:</td>
<td>:</td>
<td>:</td>
<td>:</td>
<td>:</td>
</tr>
</tbody>
</table>

TV  Track  Zone 3  Zone 2  Zone 1

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"TV" is the track verification bit. When this bit is 1 the heads are settled on the addressed track.

The "track" code indicates the head array position if TV is 1 and head array destination if TV is 0.

One advance sector information as described here has been turned off in the hardware due to difficulties in this portion of the controller.

6. Error Conditions

Whenever an abnormal condition is detected by the controller the following actions occur:

- Any data transfer operation in process is terminated.

- A disc read operation is terminated immediately on detection of the error.

- On a disc write operation the remainder of the current sector is filled with zeros and the operation is terminated.

- Bits indicating the error conditions are written in the disc error word.

- An abnormal interrupt is generated.

- The controller goes to the disconnect state.

The disc error word contains a 1 for every abnormal condition that has occurred. At least one bit will always be set and more than one can be set.
Appendix C, Bryant Wisc System

The format of this word is

<table>
<thead>
<tr>
<th>Bit</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>Illegal</td>
</tr>
<tr>
<td>25</td>
<td>Control Unit Error</td>
</tr>
<tr>
<td>27</td>
<td>Class Not Equal</td>
</tr>
<tr>
<td>26</td>
<td>Not Ready</td>
</tr>
<tr>
<td>29</td>
<td>Angular Position Error</td>
</tr>
<tr>
<td>30</td>
<td>Head Position Error</td>
</tr>
<tr>
<td>31</td>
<td>Invalid Address</td>
</tr>
<tr>
<td>32</td>
<td>Command Error</td>
</tr>
<tr>
<td>33</td>
<td>Data Transfer Error</td>
</tr>
<tr>
<td>34</td>
<td>Check File Error</td>
</tr>
<tr>
<td>35</td>
<td>Word Parity Error</td>
</tr>
</tbody>
</table>

Data and Command Errors

Word Parity Error (Bit 35) -- This condition is set whenever the parity is incorrect on a 24-bit sequence in the data field of a record during a read operation.

Check Field Error (Bit 34) -- This bit is set whenever the check bits at the end of the record indicate that an error has been made in reading the record.

Data Transfer Error (Bit 33) -- This bit is set when data being transferred from the Central Processing Unit to the Control Unit has incorrect parity.

Command Error (Bit 32) -- This bit is set for the following conditions:

- Incorrect parity for a command word transferred from the computer.
- Invalid command code.
- A Go-No Go NVR received while busy.

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and Computer Augmented Team Interaction

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Appendix C, Bryant disc system

Addressing and Positioning Errors

invalid Address (bit 31) -- This bit is set when the disc address specified in a transfer command is invalid, or a data transfer exceeds the cylinder.

A cylinder consists of all tracks on all surfaces that can be accessed from a single head position.

Hea Position error (bit 30) -- This bit is set if the head array is not correctly positioned as determined by failure to get track verification after 7 revolutions or incorrect track address in header word 1.

Angular position Error (bit 29) -- This bit is set when the angular position specified in the address does not match that read from header word 2, or if a parity error is detected in header word 2.

Illegal word Count (bit 24) -- This bit is set when the word count in a data transfer command exceeds 2016.

Miscellaneous Errors

Not Ready (bit 20) -- This bit is set if the control unit receives an information transfer command and the disc is not ready.

Class Compare Not Equal (bit 27) -- This bit is set if a class compare is requested and the record has a different class from the Information Transfer Command.

Control unit Error (bit 26) -- This bit is set when timing or sequencing errors in the control unit prevent completion of the operation.