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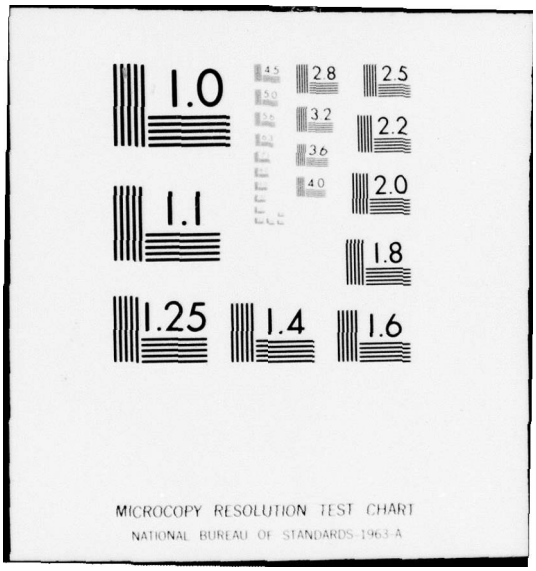
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NRL Memorandum Report 3451

NRL/ARPANET Remote Data Collection, Processing, and Display Terminal

JAMES R. FISHER

Advanced Projects Group
Acoustics Division

February 1977

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NRL Memorandum Report 3451	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) NRL/ARPANET REMOTE DATA COLLECTION, PROCESSING, AND DISPLAY TERMINAL		5. TYPE OF REPORT & PERIOD COVERED Interim report on a continuing NRL problem. 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) James R. Fisher		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Research Laboratory Washington, D.C. 20375		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS NRL Problem S01-61
11. CONTROLLING OFFICE NAME AND ADDRESS NRL-MR-3451		12. REPORT DATE February 1977 13. NUMBER OF PAGES 39
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) 12 39p.		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Data processing
Graphic displays
Computer systems

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A computer system for reducing data on the ARPA network is described. The relationships of the Illiac IV complex the ARPANET, NRL's computer system, and hardware/software considerations are discussed.

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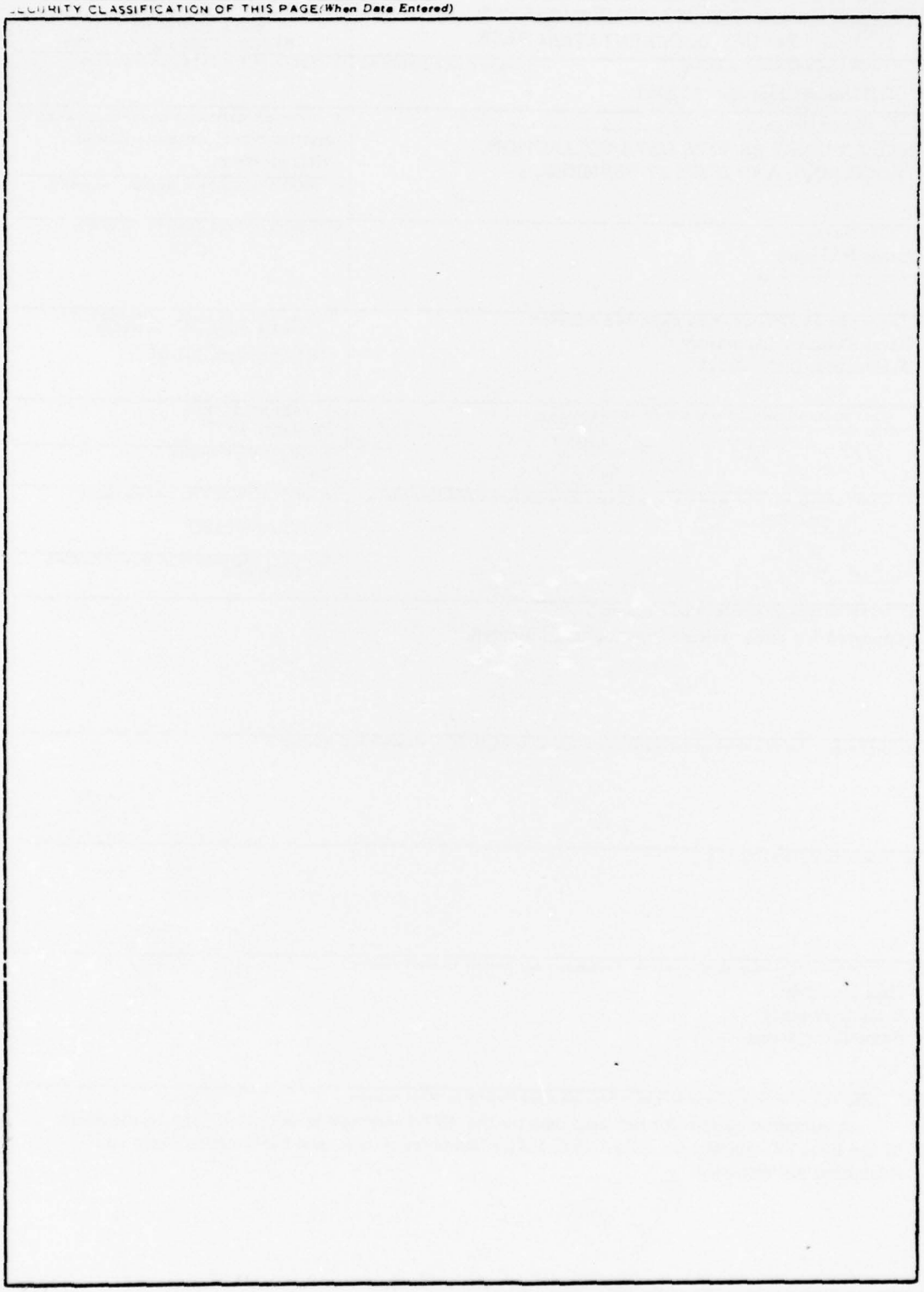

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NRL/ARPANET REMOTE DATA COLLECTION, PROCESSING, AND DISPLAY TERMINAL

I. INTRODUCTION

NRL is involved in a research study to determine the ability to cross correlate acoustic signals emanating from sources in the ocean after propagating over long and widely separated distances.

During the fall of 1973 over 800 hours of digitized recordings were recorded at several acoustic stations. The ability to reduce and analyze this data presents an enormous task when the number of computations and the number of parameters that can be applied to each computation are considered. In pursuit of solutions to these problems, extensive use has been made of the Illiac IV computer complex for high speed computation. A computer terminal system is located at NRL for visual and statistical interpretation of the Illiac IV data output.

It is the purpose of this report to define the relationship of the Illiac IV complex, the ARPANET, NRL's dedicated computer installation and the hardware/software considerations used to unify all of these into a productive system. Included in a separate report are flowcharts of the system and technical details of the subprograms.

The aspects of the total system can be categorized into four broad general areas.

A. ARPA system modules
B. NRL system modules
C. NRL-ARPANET interrelational modules
D. Unifying software

Each of these areas will be discussed, outlining the individual components and responsibilities as they relate to the overall system for accessing raw field data and displaying computed results.

System Overview

Successful reduction of recorded data to a form desirable by NRL for examination of computed results requires many steps and subfunctions before meaningful parameters can be extracted from the data base. During the summer and fall of 1973, acoustic signals were recorded at the ARPA Acoustic Research Center for later analysis by the Illiac IV complex.

Since all signals from each remote site were multiplexed onto a single magnetic tape, they must be separated and reformatted into a form more suitable to the Illiac IV. In addition, the source signal that was recorded on board the ship must be included into the data base

Note: Manuscript submitted January 31, 1977.

recorded by the Acoustic Research Center personnel. The approximate starting time of the acoustic signal must be located for each site to avoid lengthy computations on the Illiac that do not include the signal of interest. Furthermore, the tapes must be adjusted relative to each other since the acoustic signal arrives at each remote site at different times due to the long propagation path involved. Finally these signals must be digitally filtered and converted to a floating point notation suitable to the Illiac instruction code and scaled according to relative signal level of the recorded data.

Once the tapes are prepared in the above manner, NRL personnel can request that selected data be transferred to the Illiac IV complex for inclusion into the I4-Tenex for analysis by the correlation algorithm in the Illiac IV processor. This correlation program was written by the staff of SCI and is documented in references 1, 2, and 3.

Fig. 1 is a system overview of the various modules that are included in reduction of new data. The heavy outlined areas and blocks indicate hardware facilities of the ARPANET, NRL and the Illiac IV computer complex. Dotted lines and blocks indicate logical steps and interactions performed to completely reduce magnetic tape input to displays at NRL for analysis and parameter extraction.

As shown in step 1B of Fig. 1, a request for new experimental data is initiated at NRL. This information is sent via the ARPANET to personnel at the Institute for Advanced Computation (IAC). The experimental data is read into the disk memory and held there temporarily until the correlation program can be executed on the Illiac IV processor. Upon proper completion of the Illiac program, the input data is generally deleted in order to allow space for new input data. If it is desired to vary parameters on the same section of data, the Tenex disk areas may be preserved until completion of all computations.

If it is desired to change parameters on the correlation program, the procedure outlined in 1A of Fig. 1 is followed. All parameters that can be adjusted on the correlation program are contained in a special Tenex disk file. Fig. 2 contains a complete listing of this file and displays all the parameters that may be adjusted on the correlation program. This parameter program will be explained in more detail in the following sections.

As shown in 1A of Fig.1, the parameter file is modified at NRL. Before these parameters can be utilized by the Illiac IV, however, they must be compiled by the Borroughs B6700 computer; this is accomplished during the normal batch processing of a job submission to the I4-Tenex.

The I4-Tenex is the master control computer for all job submissions

and for control of all other computers and subassemblies. Requests for new data tapes, modification of parameters, execution of the Illiac array program, storage of resulting data, and transmission of results via the ARPANET are all initiated or controlled by the I4-Tenex.

All of these functions of the I4-Tenex are not automatic. Each step must be controlled by constructing a special file of commands (called ACL) that direct each process or subassembly in the Illiac IV complex. These ACL statements are contained in a Tenex disk file known as the Primary Input File (PIF); they can be modified via the NRL operator to define new input data, obtain new parameters from the B6700, assign disk areas for computational results, etc. Logically the PIF is shown in step 2 of Fig. 1. The PIF is described more fully in another section and is shown in Fig. 3.

One of the responsibilities of the PIF is to assign areas on the Illiac IV disk memory (I4DM). This disk, logical unit 3 of Fig. 1, is associated with a particular NRL job only during actual execution of the correlation program. It should not be confused with the Tenex disk, logical unit 4 in Fig. 1, which is used for long term storage of all programs and input/output data. The I4DM is specially designed to support the fast computation speed of the parallel processor. All input data (from magnetic tape) must be placed on the I4DM before the parallel processor begins. All output computations are placed on the I4DM as the correlation program executes on the processor.

Computational output, logical step 3B of Fig. 1, on the I4DM must be transferred to the Tenex disk (or other bulk storage), under direction of the PIF, if it is to be saved and transmitted to NRL for analysis. When the PIF has completed the data transfer to Tenex disk, the I4DM is deallocated from the present job and the next user in the batch queue takes command of the I4DM.

Once the output computations are available on the Tenex disk memory, the data may be reformatted for graphical display, statistical printout, etc., and transmitted to NRL. The programs for transmission reside in the I4-Tenex and the Tenex disk data base is accessed according to directions supplied by the NRL operator. These interactive commands allow the operator to select, via the PDP-11 terminal system, the mode of transmission and the output device at NRL to receive the data. Examples of presently available outputs are shown in Figs. 5B, 6, 7, 8, 9 and explained in following sections. The PDP-11 terminal system is shown in Fig. 10.

Major emphasis is being placed on preparing a more complete operating system for the PDP-11 system. This system will permit automated interaction, under operator control, with the data base and allow the operator

to flexibly examine the computed results and parameters by various methods.

Introduction of New Correlation Parameters

The actual submission of an executable job requires several preliminary steps before actual execution on the parallel processor can begin. The first operation is the evaluation of preliminary data at NRL to determine which parameters are to be varied for a given test run. If the data had been run before, adjustments to the parameters may be required to provide further studies and analyses of the signals.

The number of options available in the program is quite large. However, under normal conditions only a small number will be changed at any one execution on the Illiac processor. Under a typical run, those parameters needing adjustment would be modified by a program called PARMVO.SOURCE.

A typical listing of this program is shown in Fig. 2. In line 1, a frequency of 33 Hz is defined by the parameter F. (Note that <:=> is the symbol for definition and <;> is a delimiter that separates one parameter from another.)

LOWESTLEVFMT is a program control parameter that limits the formatted (suitable for typing) output. Depending on the application only higher level integration times may be needed for the present analysis. (The meaning of these integration times is defined more fully in another section). This parameter is defined as an integer whose value is associated with the integration time. Typically this value is set to 5 so that only the integration levels of 5 and above are output from the program and sent to permanent storage. Seven is the highest level integration time permitted by the present program. If this parameter is defined as 8 only summary statistics are output. A value greater than 8 suppresses all output. It should be emphasized that these outputs are suitable only for outputting to a teletype or line printer.

Data suitable for graphics display is controlled by the parameter LOWESTLEVDSK. The values (1 thru 7) of this parameter have the same meaning as defined above. A value greater than 7 produces only the mean matrices and summary statistics (unformatted) on all the matrices starting from integration time of 10 seconds up through the maximum of 640 seconds.

In line 2 of Fig. 2, LC defines the type of multiplication used by the correlation algorithm. If only polarity of the signal is used to define the input signal then LC is set to 2. For linear processing, LC:=1 indicates linear processing utilizing all eight data bits in the

samples. If LC:=3 then both processes are performed.

In line 3, the value of K is used to reduce the redundancy in the sampled input data. Only every Kth sample of the input data stream is used for computation of the covariance matrices and statistics.

In line 4 and 5, MTAU (time register) and QDLT (doppler) define the resolution of the covariance computations and matrices. The values are expressed as absolute values. In terms of a matrix this refers to the rows and columns on either side of the center lines. $\pm$ 16 MTAU and $\pm$ 16 QDLT thus defines a 33 x 33 matrix. These are typical values.

In line 6, the parameter NT1 is the number of samples used by the program for the lowest level calculation. It is equal to 1/K times the number of samples in a level 1 (10 seconds) integration time. (i.e., 1/K x (33 x 8) samples/sec x 10 secs). For the program in Fig. 2 this gives a value of 83 for NT1.

In line 7, NTDNT1 defines the limits of integration time for a computation. It is the ratio of the number of samples used for the longest integration time to the smallest. (Typically 640 seconds/10 secs = 64).

In line 8, NTAU is the incremental shift (in units of data samples) in the time domain for each computation of the covariance coefficient.

In line 9, DELDEL is the fundamental doppler increment used in the covariance coefficient calculation. It is a decimal number expressed as a fraction and an exponent of base 10.

In line 10, N1 is a bias value associated with the input data. If it is not desired to start the calculations until a specific time, this value identifies a starting point referenced in samples from the beginning of the data.

Lines 11 through 40 consist of 15 pairs of parameters for each combination of processing for the 5 data streams. If it is desired to process only certain pairs of data then only those parameters associated with that pair are included. The integers in brackets indicate which pair of data streams are being processed. For example, in lines 13 and 14, it is desired to crosscorrelate received data set 2 with the set 1. A value of 1 indicates the data was the original signal used as a transmitting source in the experiment. The values 2 through 5 are receiving sites. The value of NYXA for a given X,Y pair is the anticipated time arrival difference (measured in samples) between the two recording sites. The value of DYXA is the anticipated doppler shift between the arriving signals.

Control of Experimental Parameters

Execution of a program on the Illiac IV is presently done by batch processing. Control statements are stored upon the disk storage mechanism of the Tenex system and placed in a queue for later execution by the Illiac IV complex. A list of these control statements is shown in Fig. 3. When these statements are entered into the batch queue, they become known as the Primary Input File (PIF). The PIF establishes the proper control of the Illiac IV subsystems and directs the flow of data at the required times.

When the PIF reaches the top of the queue, the file containing the PIF commands is opened, and the control statements (known as ACL statements) are processed in the sequence shown in Fig. 3.

The PIF consists of six separate functions that (1) acquire new parameters for the correlation algorithm, (2) combine various sub-modules of the SCI correlation program, (3) format the Illiac disk for acceptance of the input data, (4) move data from magnetic tape storage to the Illiac disk (not the same as the Tenex disk where the PIF is stored), (5) execute the Illiac processor program and, (6) place the program results on the Tenex disk memory where it can be transmitted to NRL.

(1) Input New Parameters

On each request for a new data run, various parameters can be manipulated in the correlation algorithm to produce the desired statistics and covariance coefficients. As the program is presently configured, these parameters are placed in a special program that is compiled by the B6700 computer and then placed in a Tenex file for inclusion into the Illiac when the NRL request for a program run reaches the top of the queue. At the present time, the queue is executed on a first in, first out basis during the evening hours at the Illiac complex. If a request by NRL is placed in the queue during the day, the run will be executed the same evening and be available for inspection and display by the following morning.

The parameters that may be manipulated were described in another section and shown in Fig. 2. Once these parameters are corrected as desired, they are placed in the Tenex file PARMVIWLA.SOURCE. In the overall sequence of processing, this corresponds to step 1A in Fig. 1.

Most of the modules used by the correlation function are written in GLYPNIR. This is a high level language similar to FORTRAN and ALGOL. Special features are included that are unique to the Illiac processor. The parallelism required to perform an algorithm efficiently on the Illiac is not solved by GLYPNIR. This procedure must be specified in detail by

the programmer. (In Norse mythology, the gods despaired because a monster roamed uncontrolled throughout the land. Dwarfs were commissioned to smith a magic chain, called GLEIPNER, to bind the monster to his lair.)

The PIF of Fig. 3 takes the parameter file PARMV1WLA.SOURCE and compiles it. The control command in the PIF that performs this task is shown in Fig. 3, line 1. The command GLYP in the PIF invokes the GLYPNIR compiler which resides in the Borroghs B6700 computer. PARMV1WLA.SOURCE tells the compiler the name of the Tenex file (Fig. 2) where the newly created parameters may be found. With this information, the compiler proceeds to produce another file, based on the source file, that is written in machine language acceptable to the Illiac processor. This new file is placed on the Tenex disk, and given the name associated with the second parameter in line 1 of Fig. 3. , PARMV1JF.REL .(Parameters are delimited by commas.)

The third parameter in line 1, PARMV1JF.LIST, is the name of yet another Tenex disk file. In this file a listing of compiled statements in Fig. 3 are placed. Any mistakes detected in the source file by the compiler are denoted in this list file.

In addition to GLYPNIR, there is another language available for programming the Illiac. This is known as the ASK assembler. ASK is a more basic language specially suited for programming the individual Processing Elements (PE's) of the Illiac. ASK includes the instructions such as addition, multiplication, testing, etc., that are part of the PE's repertoire. In line 10 of Fig. 3, the module ASKV1JF is written in ASK assembly language.

(2) Link Modules for Execution

The compiler output files (such as PARMV1JF.REL described above) are formatted in a special binary machine language that allows the program to be "relocated" to any location in the computer memory. Thus these files are denoted by the extension REL on the file name. It is the purpose of LINKED (a program residing in the Tenex) to take all the submodules, "link" them together as one complete program, and produce a binary file which is no longer relocatable but assigned to absolute locations in Illiac memory. This is accomplished in lines 2 thru 11 of Fig. 3.

The acronym ISV, line 3, instructs LINKED to "save", for later execution, all the files in the absolute program that will later be executed on the Illiac array. The files to be "included" are shown in lines 4 thru 10. These included files are documented in Ref. 1. Each module included performs a separate function on the Illiac system. Note that in line 8, the parameter file produced in step 1 is included

in the complete program to be linked into the absolute file and saved on CASEV1.ISV.

Line 11 of the PIF, terminates the LINKED program.

(3) Mapping the Illiac Disk

Before any data transfers can actually begin on I4DM, a special program called MAP must be invoked to properly format the areas on the disk memory. The MAP subsystem is called from the PIF in line 12. In line 12, MAPOUT is the name of a Tenex file that will contain allocation tables used to establish physical areas on the multidisk, multihead I4DM memory system.

The I4DM can be physically visualized as containing 52 identical bands (13 synchronized disks with 4 bands on each). Each band is divided into 300 contiguous pages, with each page containing 1024 words of 64 bits per word. The page is the smallest area that can be accessed (read or write) at a given transfer. It is equivalent in length to one PE (Processing Element) of the Illiac IV processor.

The allocation tables generated by MAP are created from FORMAT statements, lines 13-22 of Fig. 3, that define data areas from a programming standpoint. This greatly simplifies programming efforts since the physical considerations mentioned above need not be considered. The allocation tables produce a collection of pages in a specified relationship to each other.

The FORMAT control statement is used to specify an area on the I4DM and associate a name to it that may be referenced by the program within the Illiac processor. In lines 13-22 of Fig. 3, these areas have been given the names FZ, FA, FB, FC, FD, FE, and FF. The quantity shown in parenthesis after each area is called a FORMATSPEC that identifies the logical location and length of each named area.

There are two main commands used in the FORMATSPEC. These are the skip command (denoted by S) and the page command (denoted by P). By use of these operators, the entire I4DM may be formatted according to the needs of the program and the length of the input and output data.

The MAP subsystem contains a logical pointer that may be positioned by pages anywhere on the I4DM. By use of the S operator, the pointer can be moved forward or backward n pages from its present position by the command $\pm$ n S. At the location of the pointer, n pages can be reserved by the command $\pm$ n P. (A negative sign would reserve pages from the pointer backward against the rotation of the disk). The P command resets the pointer according to the number of pages reserved.

In lines 13-19 of Fig. 3, various page lengths and areas have been reserved for the five data files that will contain the magnetic tape data from the four receiving sites and the source signal recorded during the experiment.

The source data will be placed in the area FF. From line 15, we see that this area starts at page location 7201 on the I4DM and consists of 94 pages. In line 16, the pointer is positioned 7295 pages into the disk area with 90 pages reserved for area FB. Note that area FB starts on the next available page after area FF (7201 + 94 = 7295). It is not necessary that areas be contiguous in this fashion, but it is good practice to minimize the total space used on the I4DM.

In line 14, one page at the beginning of the source data is reserved for a label identifying the particular data tape and run number that is presently being processed. At first it might appear that area FA is 95 pages long. However area FF, the source signal data, overlaps area FA except for the page location 7200. Line 13 establishes a relative starting point at page location 7200. The area FZ is zero pages in length and is used to establish the beginning pointer location for the Illiac program.

In lines 20-22 space on the I4DM is reserved for the computed results of the Illiac program. The correlation program has three general areas of output and three I4DM disk areas are reserved for each.

In line 22, 150 pages have been reserved for the packed binary information. This includes the correlation matrices and the statistics (standard deviation, mean, measure of significance, peak value) that are associated with each matrix. It is this file that is used by NRL for producing the graphical interpretation and printing of statistics shown in Figs. 5B, 6, 7, 8, 9. The actual packing of these values is described more fully in another section and shown in Fig. 4. A complete description may be found in Ref. 3.

The area FOUT contains debugging information produced during the execution of the program. In the event of failure of execution, this area may be examined to locate any problems encountered by the executing program.

The file PRINTF contains information similar to AREAO. It is formatted in ASCII notation so that it may be typed directly on a terminal and the computed values may be examined directly.

Line 23 ends the MAP subsystem. The configuration tables necessary to completely format the I4DM are now complete and reside on the file MAPOUT. It should be noted that the MAP subsystem has not actually

required the I4DM during this process. Other commands in the MAP subsystem could be used at this time to display how the I4DM would look before actual program execution is initiated. In this way errors could be detected and corrected before actual execution on the Illiac array itself. More information on these commands as well as the entire Illiac IV control language can be found in Reference 4.

In line 24, the physical disk areas of I4DM are actually reserved and allocated according to the procedure described above. The ALLOC command requests use of the I4DM and uses the first parameter MAPOUT (this allocation table was established in line 12 and filed with information by lines 13-22) as an identifier to find the allocation tables on the Tenex disk.

The second parameter, ALCID, is a name that will be assigned to all the areas that are allocated to this particular job. During the period that this identifier is in effect, no other users of the Illiac processor can occupy the spaces reserved on the I4DM under this name. When the job is completed, this name will be used to deallocate the reserved areas and allow their use by other jobs.

(4) Loading the IV Disk

We are now in a position to begin data movement onto the I4DM disk. This is accomplished with the MOVE instructions in lines 25-30. The procedure is to acquire data from the Tenex disk and move it to the I4DM disk.

Since there were five sites recorded during the field experiment, five files of data are transferred to the I4DM disk. This data was obtained from magnetic tape and placed on the Tenex disk before the PIF was entered into the Illiac queue. The five sites are identified in the first parameter of the MOVE commands. In lines 26-30, these data files are identified as run 41C2, sites S0 thru S4.

These data files are assigned to the I4DM in the second parameter of the MOVE command. Note that these names (FE thru FF in lines 26-30) are identical to the areas that were allocated by the MAP subsystem in lines 15-19.

Line 25 is a label file used for identification of the magentic tape data. As explained before, it consists of 1 page of information. The programs executed at NRL access this information to identify the particular data run.

(5) Executing the Illiac Program

Line 31 is the line we have all been waiting for. Until now we have

only been making preparations to execute a program. The new parameters have been compiled in line 1 of the PIF. The programs have been linked together in lines 2 thru 11; and the Illiac IV disk has been allocated and data entered into the proper areas in lines 12 thru 30.

The RUN command enters the programs (linked and identified as CASEV1.ISV in line 3 of the PIF) into the Control Unit (CU) and the Processing Elements (PE's) of the Illiac IV processor. As the program is executing, it will request input data from the I4DM by using the area names FA, FE, FD, FC, FB, FF. As the correlation coefficients are computed, they are written to the I4DM using the areas PRINTF, FOUT, AREAO.

The second parameter of line 31 allocates the maximum time, in seconds, that the Illiac IV processor can use for this particular run. In the unlikely event that the program loops continuously, this parameter will terminate the run at the allocated time.

(6) Saving the Computed Results

When the program has finished executing, the batch queue processor goes to the next line, 32, to identify the areas on the Tenex disk that will be used for storage of the computed results. As explained before, these areas are PRINTF, FOUT, AREAO. In the particular PIF shown in Fig. 3, only the binary data file, AREAO is permanently saved on the disk. This is the file used by NRL for formation of the graphic data and compilation of statistics described in another section and shown in Figs. 5B, 6, 7, 8, 9. As shown in line 32 of the PIF this saved area is given the Tenex file name OUTV2.DISK. If the areas FOUT, PRINTF are to be saved, additional MOVE statements would be included in the PIF with Tenex file names to identify them.

Line 33 terminates the PIF by deallocating the I4DM reserved areas. These areas are now free for the next user in the batch queue. The next sections describe how the information from the Illiac IV data is extracted for transmission and processing at NRL.

NRL Data Acquisition and Display

The binary file displayed in Fig. 4 contains tabulated statistics and the covariance coefficients computed for each matrix. NRL has developed algorithms for unpacking the data from the Tenex disk file and transmitting it to NRL. Additional algorithms transform the correlation coefficients to display vectors suitable for graphic display as a simulated 3-D plot with isometric projection and hidden line removal. For examination of actual parameters, the statistics may be collated according to a particular site pair and tabulated for each matrix in the computation.

Graphics Display

Graphics display of the data requires: (1) accessing the binary data file containing the computed covariance coefficients, (2) unpacking a matrix from the binary file via parameters issued from the NRL terminal, (3) transmission of the matrix coefficients to NRL, (4) formation of a simulated 3-D display, (5) identification, extraction and display of peak information. As shown in Fig. 4, all matrices, along with identifying statistics, are packed within one Tenex disk file. In order for the unpacking algorithm to access a desired matrix, certain minimum information is required by the program. The program is written to query the operator interactively as it requires information to select a particular matrix. In Fig. 5A, the program has been loaded and immediately requests the NRL operator to identify the particular Tenex file that is to be displayed. In Fig. 5A, the underlined alphanumerics are the questions the program asks of the operator. The operator responds (not underlined) until sufficient information is supplied to identify a unique matrix.

For the example shown, the operator has requested the file OUTV2.DISK. The name of this file was created during the batch run on the Illiac IV. This name was allocated by line 32 of the Primary Input File, Fig. 3.

In the next line, the program requests the operator to confirm that output data is to be sent to the terminal that loaded the program. This is accomplished by typing TTY: and confirming with a carriage return. In the future it is expected that more than one terminal or data path may be active at a time. Typing in a different acronym here would divert the output as desired.

The program then requests the operator to identify the run number that is presently being processed. This information is used to identify the graphics display. These run numbers correspond to the notation used during the experiment to identify the type of signal and its origin.

On the next two lines, the program requests the operator to identify the signals that were correlated. In this particular example, site 0 (the source signal) is crosscorrelated with site 1.

In the next line, the operator selects which type of processing he desires. In the matrix shown, Fig. 5B, linear was selected. Both Linear (8 bits of magnitude) and Clipped (sign only) versions of the data can be made available in the same binary file. This parameter was established in line 2 of Fig. 2 during the batch execution of the Illiac programs. As shown, and discussed elsewhere, the value 3 instructs the program to produce clipped and linear versions of the covariance matrices.

Finally, the operator must establish the level of integration time and the interval within that integration time. As shown in Fig. 5A, an integration time of 6 is selected. Integration times can assume the values 10 sec, 20 sec, 40 sec, 80 sec, 160 sec, 320 sec, and 640 sec. The LEVEL 1 requested in Fig. 5A, selects an integration time of 10 secs. A level 7 request would yield the matrix that corresponds to an integration time of 640 seconds.

The value of RK identifies which interval in a given integration time is requested. Since level 7 is the highest integration time, there is only one interval at level 7. Therefore a value of 0 is selected. (The numbering system runs from 0 to 63 and not 1 to 64). For LEVEL 1, there are 64 ten second intervals available. Should an invalid value be typed, the program will type an error message and request a new value. The values of RK and LEVEL are more easily visualized in tabulations such as Fig. 6, where each matrix for a given RK (the leftmost column) is tabulated against the seven integration times, T1 thru T7.

At this point, all information needed to identify a unique matrix has been introduced and the graphics program exists from the interactive mode and begins unpacking the binary data file. As the matrix is unpacked, the header (described in another section and Fig. 4) is examined and displayed on the CRT, along with the graphic vectors, as a confirmation of the identity of the matrix. As shown in Fig. 5B, the header indicates this matrix to be the results of site pair 0, 1 for run 41C2. It is a linear matrix with LEVEL=6 (320 sec) as the operator requested in Fig. 5A. The other statistics shown in Fig. 5B further identify the matrix and the parameters that produced it. These parameters were described in the section dealing with Fig. 2.

At the top of Fig. 5B are two cross-plots that precisely display the peak value of the plot. The display program searches the matrix for the largest value and then extracts the row (TAU or time dimension) and the column (DELTA or doppler dimension) associated with the displayed matrix.

As shown, the TAU crossplot displays the peak in the hidden line display as if no other lines were present. The TAU crossplot shows the precise location of the peak in relation to the 33 points of the correlation function. From the parameters (Fig. 2) introduced into the Batch stream when the Illiac program was run, the exact TAU value could be ascertained. (Automatic labeling of the tic marks with the actual values of TAU and DELTA will be done in the next version of the graphics program).

Similarly a crossplot along a specific column is produced to give better insight into the DELTA parameter. This plot looks "into" the display at the column number containing the peak.

Statistical Parameter Tabulations

For the correlation of a pair of recorded signals, the statistics of each integration interval may be examined. This is done by collating the statistics of each matrix and tabulating them individually. This is shown in Figs. 6, 7, 8, and 9 where the means, standard deviation, measures of significance and peak values of each matrix are displayed.

Once the program is executing, information is requested of the operator to identify the statistics desired. The procedure involving the operator is similar in nature to the one described under graphics display. At present, the statistics program described here and the graphics program described previously are separate entities. In the near future these programs will be linked; then computer algorithms, under operator control, will select and display only those matrices that are of interest to the operator. Additional interactive commands will be included to allow the operator to establish constraints upon the algorithm and select the values of interest. This will permit the operator to selectively extract information from the data base.

As before, the requests of the program are underlined, with the operator response following. In Fig. 6, for example, the Illiac IV data file OUTV2.DISK is identified as the data base for the tabulations to follow; this file of data represents Run 41C2 of the experiment as shown in the third line of Fig. 6. In the next two lines, site 0 and site 1 are the site pair we wish to examine. This is followed by a declaration to select only linear correlation values. Finally the particular statistic desired is declared.

Given this information, the program searches for the desired statistics and prints out a header that confirms, from information contained in the binary file, the input parameters. The values of each matrix are printed according to the integration time and the interval within the 640 second data base. As shown, the value of RK along the left-hand side determines the interval number. The integration times are T1 thru T7 representing 10 second thru 640 second integration times. As can be seen, there are sixty-four 10 second intervals, thirty-two 20 second intervals, etc. At level T7 (640 seconds) there is only one value since this correlation integral has the limits of the entire data base.

After the last RK values are listed, the mean value of the individual integration times is listed.

Figs. 7 and 8, the means and standard deviations of the matrices are tabulated in a similar manner to the measures of significance.

Fig. 9 shows the tabulations for the peaks and the indices of the peaks for each matrix. These values may be used to establish

calibration values on the graphic display of Fig. 5B. From Fig. 5B, we find that this matrix was produced from Run 41C2, sites 0 and 1, with an RK=0 interval value in level 6. From Fig. 9, we find that this particular matrix (level T6 and RK=0) has a peak value of 5156. A doppler, or delta, index value (DI) of 18 is associated with this peak. The time, or tau, index (TI) has the value 16. This can be crosschecked on Fig. 5B from the crossplots at the top. The tick marks are numbered 1 to 33 with a value of 17 in the center. As can be seen, the peak occurs at DELTA and TAU values 18 and 16 respectively. In the near future, the values of Fig. 9 will be used to automatically label the diagrams of Fig. 5B, by linking the two programs together.

Illiac IV output data

The Illiac IV program assumes that Tenex disk memory is partitioned into 64 bit words with 8 bytes per word. The covariance coefficients amplitudes have been restricted to one byte in length. Thus eight coefficients can be neatly packed in one word. A Tenex page is defined as 2048 bytes.

A covariance coefficient matrix is defined as $S_1=(2\ tau + 1)(2\ delta + 1)$ elements, where tau and delta define the limits of the matrix. It is anticipated that M and Q will remain fixed at 16 for the near future. This gives a matrix of 33 by 33 or 1089 distinct elements. As the matrices are computed, they are stored sequentially on the Tenex disk memory. In order to identify each matrix, a 96 byte header precedes each matrix. Thus $ST=(S_1+96)=1185$ bytes are required for each matrix.

By convention, each matrix and header start on a page boundary. If the total byte count, ST, does not fill the complete page of 2048 bytes the remainder of the page is left unused. Fig. 4 shows the format of the header and the matrix.

Five separate signals can be used in the correlation program. As explained in another section, the XY pairs that are used as input data to the Illiac correlation program can be selected by the parameter NYXA in Fig. 2.

The XY pairs are computed and stored in the following sequence:

(0,0),(1,1),(2,2),(3,3),(4,4),(0,1),(0,2),(0,3),(0,4),(1,2),(2,3), (3,4),(1,3),(2,4),(1,4).

If a particular XY pair is not requested, no space is allocated to it in the file. The integers 0 thru 4 are used to identify the sites associated with the raw field data. The ship source signal is denoted by 0.

NRL Terminal System

The NRL Terminal System is shown in Fig. 10. The system is configured for flexibility in acquisition and display of information available on the ARPANET. The total system consists of a PDP-11/40 central computer, an Imlac PDS-4 refresh CRT, a Versatec 1100A Printer/ Plotter, and a Computek 415 storage screen CRT.

For acquisition of ARPANET data, the 11/40 interfaces to a Bell System 202R modem with a direct line to a Terminal Interface Processor (TIP) located at the Mitre Corporation, McLean, Virginia. The 202R modem allows simultaneous (full-duplex) transmission at a 1200 bit/sec rate between the NRL system and the ARPANET. The 202R uses asynchronous transmission (start and stop bits on each 8 bit data character).

As shown in Fig. 10, ARPANET information is received and sent by a full duplex module in the PDP-11. Also shown, in dotted lines, is a similar connection to a full duplex module in the Imlac PDS-4. With this direct connection the Imlac CRT could receive graphics information directly from the network and bypass the PDP-11 computer. This mode would be useful for direct viewing of graphics information available at the host computer. This direct mode of operation, however, does not allow much flexibility in operation since the CPU associated with the Imlac is designed primarily to support graphics. This would place a much larger burden on the host computer (the I4-Tenex) to provide the operator interaction and data manipulation that will be required of the NRL system to effectively analyze the large data base produced by the Illiac IV. Responsive operator interaction would be inhibited in this mode.

The output of the Illiac IV consists of a data structure shown in Fig. 4. This file can be transmitted in its entirety to the PDP-11 where local programs can direct the data streams along several paths under operator control. In most cases, the entire data file will be transferred to magnetic tape for permanent storage of the Illiac IV computed results. For on-line operation this file can be stored on the disk memory where rapid, random access to the individual matrices and statistics are available. The disk is used in all operations that support graphics.

The matrix shown in Fig. 5B consists of 1089=33x33 discrete points. The amplitudes are quantized in 8 bit samples. If each sample contains a start and stop bit, as required for asynchronous transmission, then 1089x10=10890 bits must be transmitted for each matrix. At a 1200 bit/ second rate, this would require about 9 seconds to completely transmit the matrix information from the host, I4-Tenex, to the NRL system. In reality, the transmission takes longer and is variable dependent on the number of users logged onto the I4-Tenex system, the amount of traffic

on the network itself, computer overhead, etc. If operation near this maximum rate is desired, the data transfer can be done during the less busy hours such as early morning.

The present disk storage capability of the PDP-11 is 2.4 million bytes (8 bits) of storage. If we assume half of the disk is available for data storage (the other half is reserved for the monitor and programs) then about 1100 matrices (1.2×10^6 bytes/1.089×10^3 bytes/matrix) are available for rapid display and analysis at any one time.

If the display device is the Imlac PDS-4, the disk data can be transmitted at a very high rate of transfer. The Imlac CPU connects directly to the PDP-11 Unibus. This allows data transfers at memory speeds. High speed transfers are essential if displays require rapid modification (such as on-line rotation) and continuity of the CRT image is to be maintained without flicker. Estimation of the maximum number of images (matrices) that can be transferred between the two devices is difficult since applications software must be included in the timing estimates. Actual data transfers would be in the multikilobit range; overhead to support data acquisition from the disk and programs to format raw data to graphic images and interact with operator commands will add to the overhead and dilute the high transfer speeds. For realistic applications, however, this will pose no problem; images must be viewed by operators, and parameters extracted, for each image displayed. The actual requests for new data by the operator will be quite slow compared to hardware speeds.

The Imlac PDS-4 contains a unique hardcopy device that allows any arbitrary display on the CRT to be photographically copied to sensitive paper. Hardcopy devices, such as the one associated with the Computek in Fig. 10, are quite commonly used for storage screen CRT devices. Since the image is statically stored on a phosphor screen it can be easily scanned electrically for line-by-line serial transfer to sensitive paper. Unlike the storage screen devices, a refresh CRT always displays a dynamic picture from vector information contained in memory. This vector information cannot be scanned serially by line-by-line techniques. In the Imlac hardcopy device, a separate small CRT image is projected with lenses onto sensitive paper. The hardcopy CRT is connected in parallel with the main CRT; thus any image is easily copied.

Under its present configuration the Imlac can display 8 thousand vectors of arbitrary length within the screen area. If the vectors are less than full screen size, fewer bits are needed to define them with the result that even more vectors can be included in a display.

The display area of the Imlac is divided into 2048 x 2048 individually addressable units. There are three vector modes for addressing a particular point on the screen: (1) Long vector mode uses two words

(16 bit words) of memory to define a vector. This allows maximum "jumps" across the screen, (2) Medium vector mode requires one word of memory. A maximum of 64 display units can be spanned in this mode, (3) In the short vector mode the longest movement is three units. These vectors are packed two in a word.

The Imlac PDS-4 also contains a scaling instruction that multiplies the above vector lengths by factors up thru 8. This allows even more flexibility when defining vectors and permits very compact storage when proper programming techniques are applied.

Additional features include a hardware "blink" feature. Any figure displayed can be made to blink on and off. The Imlac also contains programmable intensity they can add 16 level gray tones to figures on the screen. There is also a hardware rotation figure that permits rotation by multiples of 90°.

Other graphics capability in Fig. 10 include a Versatec 1100A printer/plotter. The Versatec uses an electrostatic writing principle that uses line-by-line writing techniques. Each line consists of writing nibs packed on .01 inch centers. Characters or graphics are produced by breaking the images into separate full length (about 10 inches on the 1100A) scans with each nib containing an electrostatic charge proportional to the "slice" of the image that is being displayed. The nibs electrify the moving paper which passes over a liquid toner containing suspended carbon particles which adhere to the charges on the paper. In plotting mode, there are 120 scans per second with the paper supply moving at 1.2 inches per second. Thus a 10 inch x 10 inch plot can be completed in 12 seconds with a 100 point/inch resolution in both the X & Y directions.

Additional features allow the plotting mode and character printing mode to operate simultaneously, permitting alphanumeric annotation of any graphics display. In the alphanumerics mode there are 132 columns of characters per line and 6.6 printed lines per inch. Maximum printing speed is 500 lines per minute.

The NRL system includes both seven and nine track magnetic tape facilities. Nine track tape units are used primarily for the experimental data since the computed correlation coefficients are quantized to eight bits of magnitude. The seven track unit is available for compatibility with the source signal recordings of the experiment. Additionally, this seven track unit provides access to previously recorded data bases collected by NRL during field operations of other experiments.

REFERENCES

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3. Output Format for Case Level 2, Systems Control Incorporated - Technical Memo #5109-700-03.

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5. C. McCoy, Jr. and A.W. Gonda, Jr., "The U.S.S. Queenfish (SSN651) as a Projector Platform for Low-Frequency Sound Propagation Experiments (Installation and Operational Problems)", NRL Memorandum Report 3012; March 1975 (Confidential).

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8. A.A. Gerlach, "Localization and Dynamics Determinations Over Spherical Surfaces", NRL Memorandum Report 3077; June 1975 (Unclassified).

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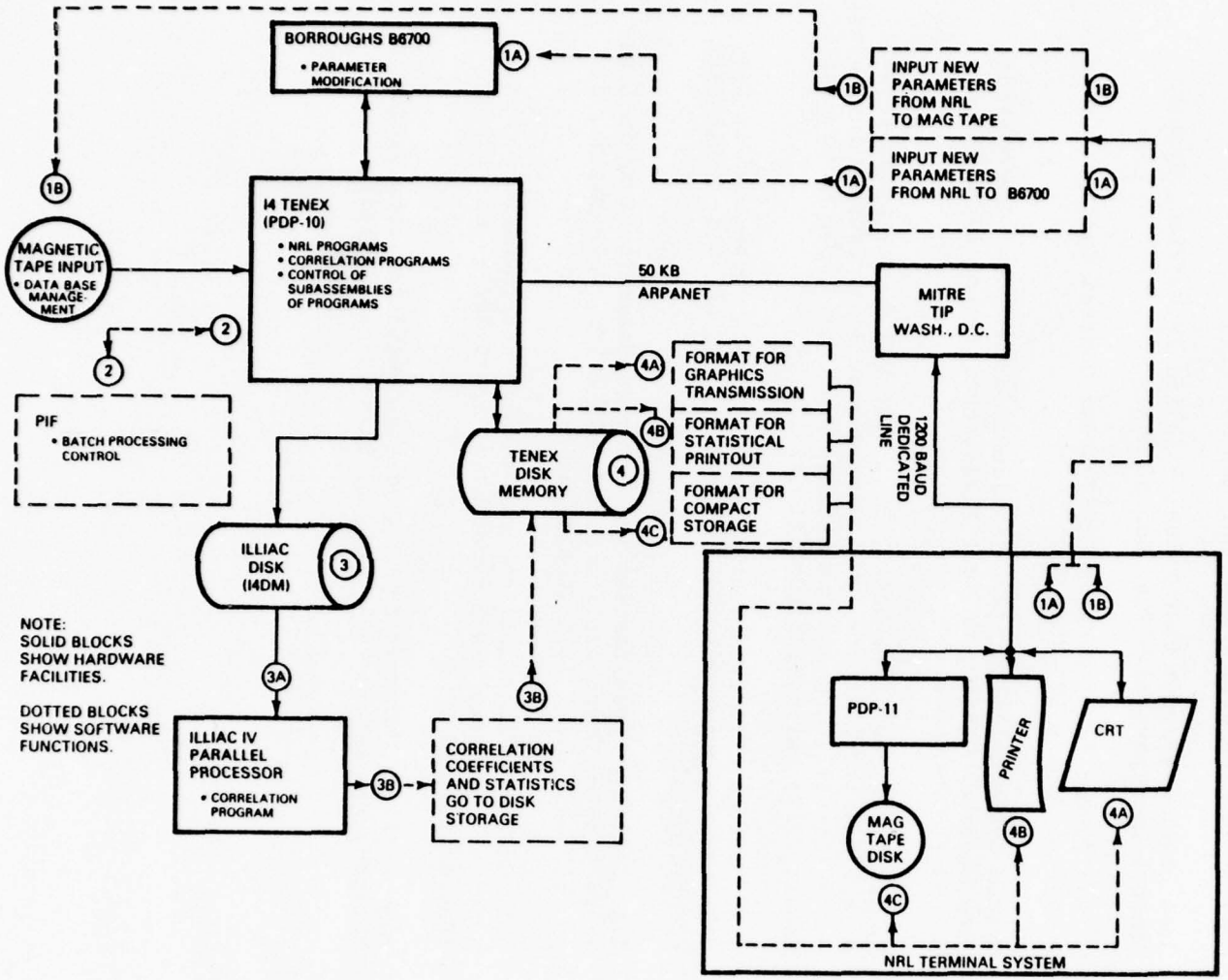


Fig. 1 — System overview

```
1  F:=33;LOWESTLEVBSX:=5;LOWESTLEVFXT:=5;ISYNUM:=2;
2  LC:=3;
3  A:=32;
4  NTAJ:=16;
5  NDLT:=16;
6  NT1:=33;
7    NTDNT1:=64;
8  NTAJ:=528;
9  DELDEL:=.23530-4;
10 N1:=25400;
11 DYXA[1,1]:=0.00018816;
12 NYXA[1,1]:=4224;
13 DYXA[2,1]:=0.00018816;
14 NYXA[2,1]:=4224;
15 DYXA[3,1]:=0.00018816;
16 NYXA[3,1]:=4224;
17 DYXA[4,1]:=0.00018816;
18 NYXA[4,1]:=4224;
19 DYXA[5,1]:=0.00018816;
20 NYXA[5,1]:=4224;
21 DYXA[2,2]:=0.00018816;
22 NYXA[2,2]:=4224;
23 DYXA[3,2]:=0.00018816;
24 NYXA[3,2]:=4224;
25 DYXA[4,2]:=0.00018816;
26 NYXA[4,2]:=4224;
27 DYXA[5,2]:=0.00018816;
28 NYXA[5,2]:=4224;
29 DYXA[3,3]:=0.00018816;
30 NYXA[3,3]:=4224;
31 DYXA[4,3]:=0.00018816;
32 NYXA[4,3]:=4224;
33 DYXA[5,3]:=0.00018816;
34 NYXA[5,3]:=4224;
35 DYXA[4,4]:=0.00018816;
36 NYXA[4,4]:=4224;
37 DYXA[5,4]:=0.00018816;
38 NYXA[5,4]:=4224;
39 DYXA[5,5]:=0.00018816;
40 NYXA[5,5]:=4224;
41 SWD     SIMWRITE(LINE,"SETPARM EXIT.",DYX,DDYXA[*]);
42        END.
```

Fig. 2 — Illiac IV parameter list

```
1 GLYP PARMV1WLA.SOURCE,PARMV1JF.REL,PARMV1JF.LIST
2 LINKED
3 ISV CASEV1.ISV
4 INCLUDE MAINV1JF.REL
5 INCLUDE DISKV1JF.REL
6 INCLUDE GINITV1JF.REL
7 INCLUDE INPUTVD.REL
8 INCLUDE PARMV1JF.REL
9 INCLUDE DELTAV1JF.REL
10 INCLUDE ASKV1JF.REL
11 END
12  MAP ,MAPOUT
13 FORMAT FZ,(7200S,0P)
14 FORMAT FA,(7200S,95P)
15 FORMAT FF,(7201S,94P)
16 FORMAT FB,(7295S,90P)
17 FORMAT FC,(7385S,90P)
18 FORMAT FD,(7475S,90P)
19 FORMAT FE,(7565S,90P)
20 FORMAT PRINTF,(7700S,100P)
21 FORMAT FOUT,(7800S,10P)
22 FORMAT AREA0,(7900S,150P)
23 END
24 ALLOC MAPOUT,ALCID
25 MOVE  LABLE-33.41C2,I4DM:FA
26 MOVE  RUN-33.41C2-S0,I4DM:FE
27 MOVE  RUN-33.41C2-S1,I4DM:FD
28 MOVE  RUN-33.41C2-S2,I4DM:FC
29 MOVE  RUN-33.41C2-S3,I4DM:FB
30 MOVE  SCI-17.41C2-S4,I4DM:FF
31 RUN CASEV1.ISV,MAXTIM=3600
32 MOVE I4DM:AREA0,OUTV2.DISK
33  DALLOC ALCID
```

Fig. 3 — Primary input file (PIF)

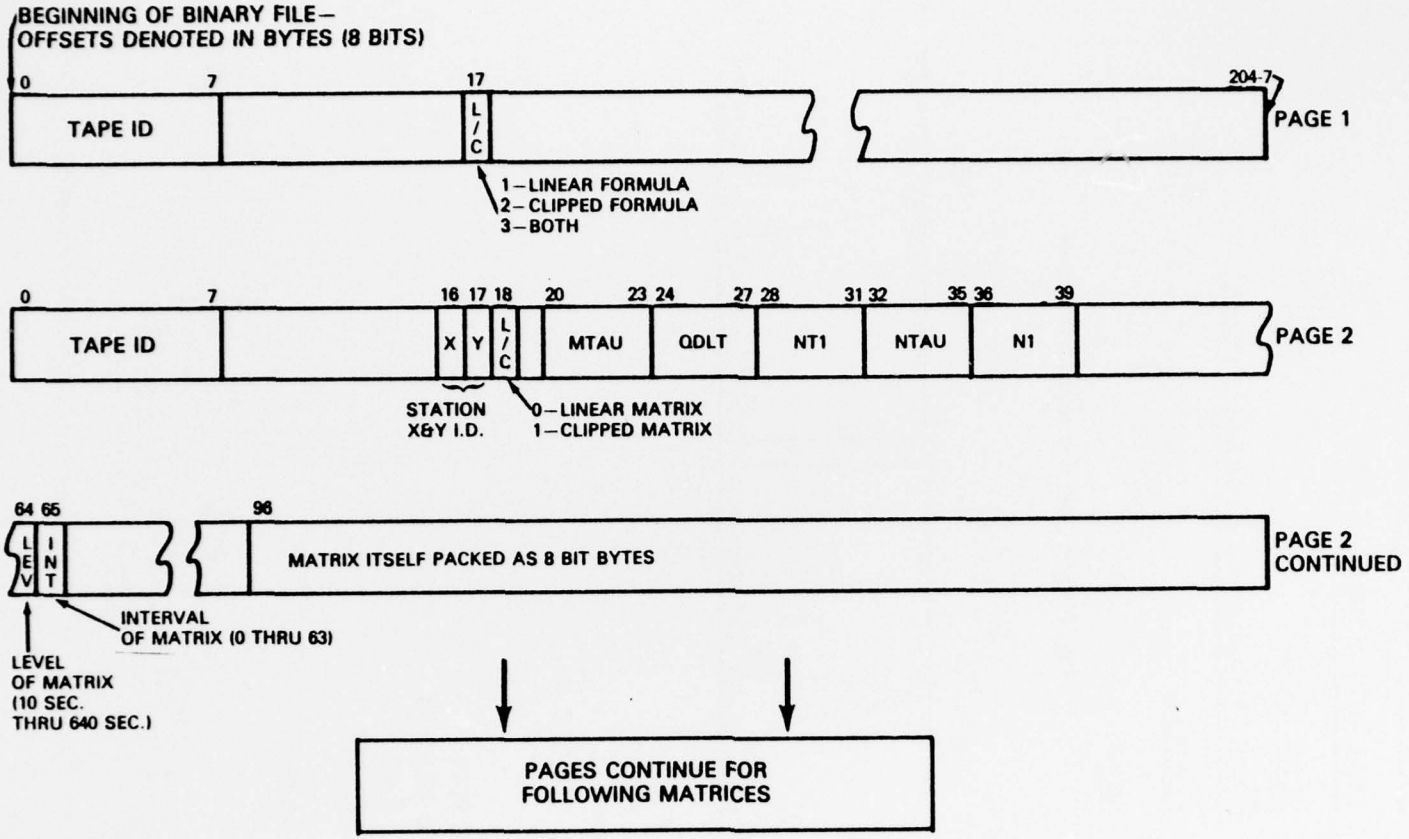
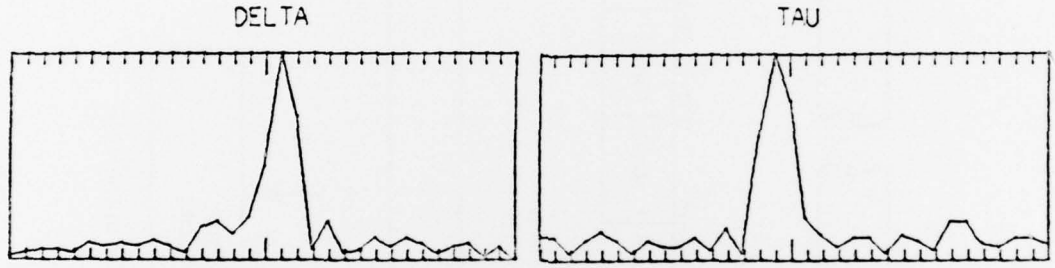


Fig. 4 — Illiac IV output file

```
RUNNING KA-10 CODE ON A KI-10
TYPE FILE NAME OF ILLIAC DATA: OUTV2.DISK
TYPE TTY:TTY: [CONFIRM] CR

TYPE RUN NUMBER: 4102

SITE X= 0
SITE Y= 1
TYPE CLIPPED OR LINEAR: LINEAR

LEVEL=6

RK=0
```

Fig. 5(a) — Operator matrix selection




```
RUN NO.= 41C2
CTR-FREQ= 33 HZ.
L/C= LINEAR
INT-TIME= 32Ø SEC.
STA. X= Ø
STA. Y= 1
DELTAU= 2 SEC.
DELDEL= Ø.521E-Ø4
DEL YX= Ø.ØØ
T-START= 272 SEC.
RK= Ø
SIGNIF= 1Ø.72
```

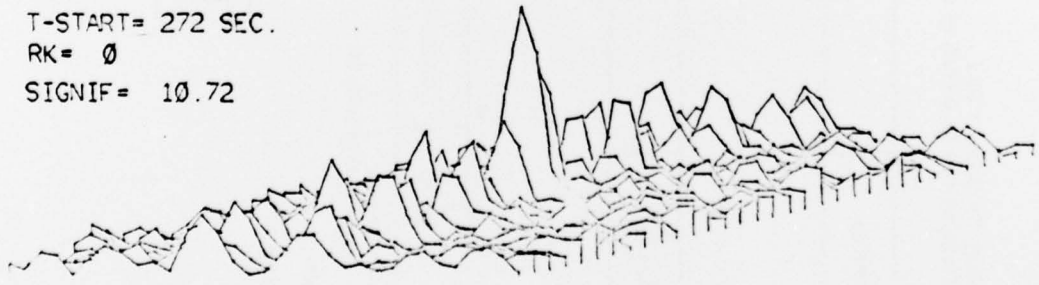


Fig. 5(b) — Graphic display of third level processing

```
TYPE FILE NAME OF ILLIAC DATA: <GERLACH>OUTV2.DISLNLR
TYPE TTY:TTY: [CONFIRM]

TYPE RUN NUMBER: 4102


SITE X= 0
SITE Y= 1
TYPE CLIPPED OR LINEAR: LINEAR

TYPE EXACTLY ONE OF THE FOLLOWING
MEANS  STDDV  PEAKS  MSIGN  IJJIT
MSIGN
```

STATISTICAL PARAMETER TABULATIONS
4102

SITE X= 0 SITE Y= 1 LINEAR 33 HZ.

MEASURES OF SIGNIFICANCE

RK	T1	T2	T3	T4	T5	T6	T7
0	4.4	4.5	4.7	5.4	6.9	10.7	12.4
1	4.4	4.4	5.0	5.5	7.8	10.5	
2	4.5	4.4	4.5	6.0	7.1		
3	4.4	4.7	4.7	7.0	7.8		
4	4.4	4.6	5.0	5.7			
5	4.4	4.7	4.8	6.0			
6	4.5	4.5	4.9	6.2			
7	4.4	4.5	5.1	6.2			
8	4.5	4.5	5.1				
9	4.7	4.6	4.7				
10	4.6	4.8	4.9				
11	4.7	4.6	4.7				
12	4.6	4.5	5.1				
13	4.4	4.4	5.1				
14	4.4	4.8	4.9				
15	4.4	4.8	4.8				
16	4.4	4.6					
17	4.3	4.4					
18	4.6	4.3					
19	4.6	4.6					
20	4.7	4.6					
21	4.8	4.8					

Fig. 6 — Measures of significance tabulations (Continues)

22	4.6	4.4					
23	4.6	4.4					
24	4.5	4.3					
25	4.4	4.9					
26	4.2	4.7					
27	4.5	4.7					
28	4.3	4.4					
29	4.9	4.5					
30	4.5	4.7					
31	4.8	4.7					
32	4.7						
33	4.5						
34	4.4						
35	4.4						
36	4.4						
37	4.3						
38	4.3						
39	4.8						
40	4.7						
41	4.5						
42	4.8						
43	4.6						
44	4.5						
45	4.3						
46	4.3						
47	4.5						
48	4.0						
49	4.4						
50	4.6						
51	5.2						
52	4.6						
53	4.8						
54	4.9						
55	4.2						
56	4.3						
57	4.3						
58	4.2						
59	4.5						
60	5.1						
61	4.5						
62	4.8						
63	4.8						
MEAN	5.7	5.3	7.0	8.0	9.0	11.4	12.4

Fig. 6 (Continued) — Measures of significance tabulations

```
SITE X= MMO
SITE Y= 1
TYPE SLIPPED OR LINEAR: LINEAR

TYPE EXACTLY ONE OF THE FOLLOWING
MEANS  STDDV  PEAKS  MSIGN  IQUIT
MEANS
```

STATISTICAL PARAMETER TABULATIONS
4102

SITE X= 0 SITE Y= 1 LINEAR 33 HZ.

MEAN TABULATIONS

RK	T1	T2	T3	T4	T5	T6	T7
0	654	687	776	822	672	518	370
1	797	756	750	953	774	572	
2	811	688	743	960	820		
3	747	546	827	1003	776		
4	714	706	870	1006			
5	639	745	856	1133			
6	502	621	992	1035			
7	589	802	921	1061			
8	665	798	969				
9	762	635	916				
10	797	749	909				
11	682	746	960				
12	614	802	959				
13	636	878	968				
14	809	727	1097				
15	821	809	823				
16	854	715					
17	701	808					
18	589	848					
19	659	793					
20	716	808					
21	773	778					
22	762	819					
23	729	846					
24	685	847					

Fig. 7 — Mean tabulations
(Continues)

25	813	589					
26	876	782					
27	767	804					
28	700	981					
29	692	816					
30	790	738					
31	751	750					
32	726						
33	702						
34	729						
35	865						
36	838						
37	875						
38	792						
39	714						
40	760						
41	828						
42	776						
43	723						
44	749						
45	839						
46	895						
47	839						
48	875						
49	747						
50	696						
51	677						
52	782						
53	746						
54	740						
55	779						
56	958						
57	927						
58	834						
59	682						
60	690						
61	792						
62	761						
63	757						
MEAN	753	767	896	997	761	545	370

Fig. 7 (Continued) — Mean tabulations

```
SITE X= 0
SITE Y= 1
TYPE CLIPPED OR LINEAR: LINEAR

TYPE EXACTLY ONE OF THE FOLLOWING
MEANS  STDDV  PEAKS  MSIGN  IQUIT
STDDV
```

STATISTICAL PARAMETER TABULATIONS

41C2

SITE X= 0 SITE Y= 1 LINEAR 33 HZ.

STANDARD DEVIATIONS

RK	T1	T2	T3	T4	T5	T6	T7
0	832.8	925.6	960.2	737.6	556.5	432.5	387.3
1	1054.7	1117.2	725.4	720.7	550.3	489.5	
2	1135.3	958.3	1034.9	708.5	637.6		
3	1118.6	739.2	900.3	663.8	603.0		
4	1055.9	1061.7	860.5	836.5			
5	922.9	1042.6	1022.3	779.8			
6	708.0	797.5	978.5	697.7			
7	839.8	1183.1	936.3	791.5			
8	1038.0	1110.3	914.9				
9	1117.2	880.6	1098.7				
10	1156.2	1136.3	1053.7				
11	970.5	1094.8	1113.6				
12	896.3	1056.2	898.5				
13	781.2	1172.6	963.2				
14	1249.2	943.1	1045.1				
15	1152.9	1174.6	1110.1				
16	1249.6	1039.4					
17	1040.8	1173.6					
18	816.9	1291.6					
19	1012.3	1058.6					
20	1103.9	1184.7					
21	1194.2	1104.0					
22	1182.1	1116.2					
23	1052.8	1307.1					
24	953.0	1160.8					
25	1253.2	985.9					
26	1286.4	1204.9					
27	1150.2	1022.3					

Fig. 8 — Standard deviation tabulations (Continues)

28	1012.5	1368.5					
29	1023.2	1058.4					
30	1221.4	1114.3					
31	1193.4	1227.5					
32	1114.7						
33	1011.1						
34	971.6						
35	1363.0						
36	1290.9						
37	1311.7						
38	1190.7						
39	970.3						
40	1149.4						
41	1307.9						
42	1191.5						
43	1140.5						
44	978.5						
45	1312.4						
46	1339.0						
47	1292.6						
48	1325.6						
49	1089.7						
50	991.9						
51	1010.2						
52	1235.3						
53	1223.9						
54	1125.9						
55	1035.4						
56	1459.0						
57	1355.7						
58	1220.0						
59	990.7						
60	1042.1						
61	1247.9						
62	1203.4						
63	1242.3						
MEAN	876.2	790.1	675.4	558.4	479.2	428.3	387.3

Fig. 8 (Continued) — Standard deviation tabulations

```
SITE X= 0
SITE Y= 1
TYPE CLIPPED OR LINEAR: LINEAR

TYPE EXACTLY ONE OF THE FOLLOWING
MEANS  STDDV  PEAKS  MSIGN  IQUIT
PEAKS
```

STATISTICAL PARAMETER TABULATIONS
4102

SITE X= 0 SITE Y= 1 LINEAR 33 HZ.

PEAK AND PEAK INDICES

RK		T1	T2	T3	T4	T5	T6	T7
0		4338	4838	5273	4801	4494	5156	5158
	DI	17	17	17	17	18	18	19
	TI	16	16	16	16	16	16	16
1		5422	5710	4378	5012	5064	5733	
	DI	15	17	17	17	18	18	
	TI	2	16	16	16	16	16	
2		5911	4858	5439	5182	5335		
	DI	18	17	17	17	18		
	TI	24	16	16	16	16		
3		5697	3987	5095	5638	5464		
	DI	19	17	17	17	18		
	TI	30	16	16	16	16		
4		5316	5550	5210	5807			
	DI	16	20	17	17			
	TI	9	6	16	16			
5		4699	5643	5795	5850			
	DI	19	17	17	17			
	TI	32	16	16	16			
6		3788	4208	5768	5373			
	DI	17	13	17	17			
	TI	16	32	16	16			
7		4289	6091	5672	5960			
	DI	19	17	17	17			
	TI	2	16	16	16			
8		5312	5740	5640				
	DI	17	17	17				
	TI	17	16	16				

Fig. 9 — Peak and peak indices tabulations (Continues)

9		6010	4727	6042
	DI	19	21	17
	TI	2	4	16
10		6124	6159	6073
	DI	17	17	17
	TI	16	16	16
11		5291	5781	6216
	DI	15	17	17
	TI	29	16	16
12		4734	5541	5542
	DI	15	17	17
	TI	30	16	16
13		4067	6003	5913
	DI	15	17	17
	TI	33	16	16
14		6282	5238	6225
	DI	17	17	17
	TI	16	16	16
15		5937	6392	6156
	DI	17	17	17
	TI	15	16	16
16		6300	5542	
	DI	17	13	
	TI	16	28	
17		5188	5977	
	DI	17	18	
	TI	16	20	
18		4381	6457	
	DI	19	17	
	TI	3	16	
19		5325	5639	
	DI	19	17	
	TI	4	16	
20		5901	6240	
	DI	17	17	
	TI	16	16	
21		6499	6110	
	DI	17	17	
	TI	16	16	
22		6151	5777	
	DI	16	17	
	TI	21	16	
23		5593	5657	
	DI	16	17	
	TI	24	16	
24		4940	5842	

Fig. 9 -- Peak and peak indices tabulations (Continues)

	DI	17	17
	TI	24	16
25		6271	5552
	DI	18	21
	TI	24	3
26		6274	6504
	DI	15	17
	TI	7	16
27		5921	5633
	DI	19	17
	TI	23	16
28		5041	6938
	DI	17	17
	TI	16	16
29		5667	5537
	DI	18	17
	TI	10	16
30		6402	6030
	DI	17	17
	TI	16	16
31		6534	6552
	DI	17	17
	TI	17	16
32		5934	
	DI	15	
	TI	28	
33		5312	
	DI	15	
	TI	29	
34		5003	
	DI	17	
	TI	16	
35		6897	
	DI	17	
	TI	16	
36		6535	
	DI	17	
	TI	16	
37		6542	
	DI	16	
	TI	9	
38		5913	
	DI	17	
	TI	16	
39		5392	

Fig. 9 — Peak and peak indices tabulations (Continues)

```
    DI        17
    TI        16
40          6112
    DI        19
    TI         3
41          6681
    DI        17
    TI        16
42          6518
    DI        17
    TI        16
43          5939
    DI        15
    TI        31
44          5135
    DI        17
    TI        16
45          6543
    DI        18
    TI        24
46          6669
    DI        17
    TI        16
47          6648
    DI        17
    TI        16
48          6209
    DI        17
    TI        16
49          5487
    DI        17
    TI        16
50          5306
    DI        19
    TI         2
51          5965
    DI        19
    TI         4
52          6476
    DI        17
    TI        16
53          6632
    DI        17
    TI        16
54          6285
    DI        15
    TI        27
```

Fig. 9 — Peak and peak indices tabulations (Continues)

55	5147						
DI	17						
TI	16						
56	7219						
DI	17						
TI	16						
57	6703						
DI	15						
TI	4						
58	5942						
DI	17						
TI	16						
59	5172						
DI	17						
TI	17						
60	5998						
DI	19						
TI	1						
61	6496						
DI	17						
TI	16						
62	6497						
DI	17						
TI	16						
63	6687						
DI	17						
TI	16						
MEAN	5737	5720	5656	5454	5090	5445	5158
DI	17	17	17	17	18	18	19
TI	16	16	16	16	16	16	16

Fig. 9 (Continued) — Peak and peak indices tabulations

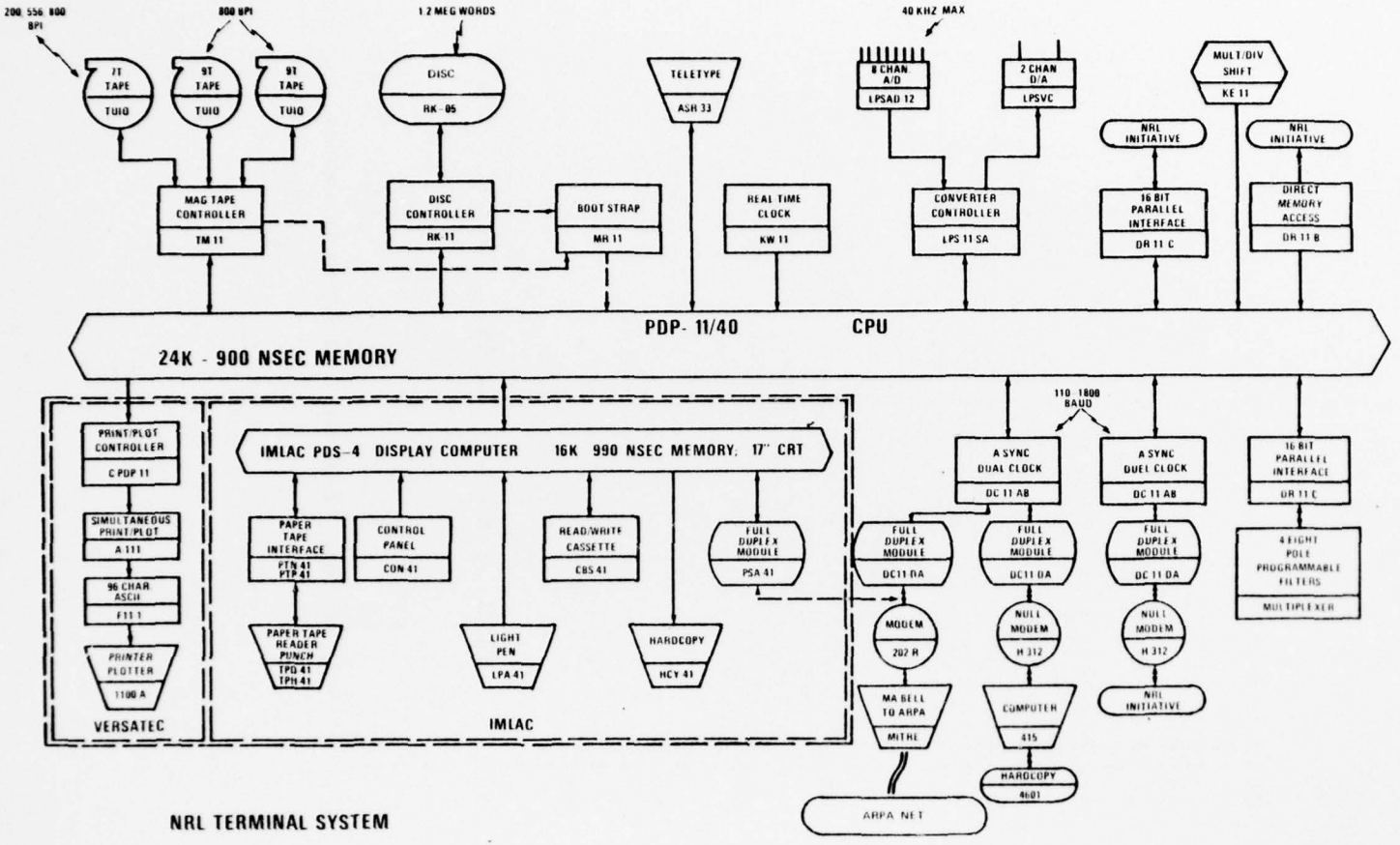


Fig. 10 — NRL computer system