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SAIL INTELLIGENT TERMINAL EVALUATION

FINAL REPORT

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PREFACE

This document describes the work performed for and recommendations for future enhancements to the Systems Analysis and Integration Laboratory (SAIL) PDP-11 intelligent terminal complex. The work described herein was performed under NASA Contract Number NAS8-31714.

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LIST OF ACRONYMS

DEC	Digital Equipment Corporation
DOS	Disk Operating System
IAS	Interactive Application System
IGDS	Interactive Graphics Design System
MIPS	Marshall Interactive Planning System
MRL	Memory Required List
RSX-11D	Real Time System Executive
SAIL	Systems Analysis and Integration Laboratory

LIST OF FIGURES

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1. INTRODUCTION

Significant operational problems have been experienced at the Systems Analysis and Integration Laboratory (SAIL) intelligent terminal facility. This facility consists of a PDP-11/45 system dedicated to interactive graphics and a PDP-11/70 system for engineering program development.

The work described in this document consists of engineering assessments, recommendations, and equipment necessary to solve the operational problems and extend the operational flexibility of the intelligent terminal facility. The following capabilities were considered:

1. The capability to operate at least two D/D stations and one remote graphics terminal simultaneously.
2. The capability to run plotter, AIDS and FORTRAN programs simultaneously.
3. The capability for simultaneous use of system utility routines of D/D stations and remote graphics terminal.
4. The capability to provide large volume hardcopy of data and graphics.
5. The capability to eliminate or at least ease the current operation/programming problems with related labor costs.

Section 2 describes the overall intelligent terminal development, and plans guiding the analysis and equipment acquisitions for this contract. Section 3 summarizes the assessments and analyses performed. Section 4 describes the equipment and software acquisitions resulting from the assessment and analyses, providing the necessary operational extensions.

2. INTELLIGENT TERMINAL DEVELOPMENT

The Marshall Interactive Planning System (MIPS) is an integrated planning and analysis tool that is responsive to a wide variety of applications requiring systematic and rapid computer analysis. The MIPS, currently operating on the UNIVAC 1108, provides a flexible, interactive capability to utilize standard analysis programs (modules) for the varied applications. Analysis and utility modules are linked together with a simple interactive command language. The command language is user-oriented, masking procedures and computer-related controls which are not of interest to the user. The system is designed to operate at a remote terminal or in batch mode at a central site.

The growing use of the MIPS in the future will place increasing demands on the UNIVAC 1108 computer. The use of intelligent terminals can help off-load the use of the central UNIVAC 1108 computer and support a wider range of capabilities. This section describes the evolution of the PDP intelligent terminal capability and the planned directions for future development.

2.1 Evolution of the PDP System as an Intelligent Terminal

The PDP-11 system was originally installed at MSFC as an Interactive Graphics Design System (IGDS). The original configuration consisted of a PDP-11/45, 32K words of 16-bit core memory, a Tektronix 4014 graphic terminal, electronic digitizer, two 1.2 mission word disks, and a control console teletype. The system was a special purpose interactive graphic facility. However, the central processor was a general purpose minicomputer capable of serving a number of users in a multiprogramming environment. The decision was made to evaluate the PDP-11/45 as an intelligent terminal in support of the mission planning program. A major objective of this intelligent terminal effort was to determine the requirements for the final Marshall Interactive Planning System intelligent terminal. This section documents the efforts conducted to date in evaluating the use of the PDP-11/45 as an intelligent terminal. Section 2.2 presents the conclusions drawn during this evaluation study in the form of requirements for the final intelligent terminal.

2.1.1 Software Evolution

The original PDP configuration was a special purpose system with a very basic operating system. This original operating system could service only one terminal user and could address only 28K words of memory. The first step in converting the PDP system to an intelligent terminal, therefore, was to install an operating system capable of supporting a number of terminals. Since the resulting PDP system still had to service the original graphic application, the interactive graphic software was converted to operate under the new operating system.

To evaluate the PDP system in its new role of intelligent terminal, a selected group of application programs were converted from the 1108 to PDP. Since a major objective of the MIPS intelligent terminal was to maximize the utility of the 1108, an effort was begun on the PDP to link the two computers via communications lines. This effort intended to allow the PDP to access the 1108's massive computational power and input/output devices such as high-speed printers, plotters, microfilm recorders, magnetic tape, etc. The following paragraphs document each of these efforts.

PDP Operating System

The PDP Disk Operating System (DOS) was used in the original PDP system. DOS required only 2K words of memory but provided minimum programming support services. DOS would support only one user at a time and could not support over 28K words of core memory. The PDP Real Time System Executive (RSX-11D) was selected to overcome these problems. RSX-11D was specifically designed for the real time multiprogramming environment and is able to support 128K words of memory. The following RSX characteristics make it an attractive operating system for an intelligent terminal system:

- <u>Multiprogrammed</u> - The system supports many programs in memory at the same time. RSX allows 250 user priority levels. The highest priority program executes until it decides to wait, performs an input/output operation, or exits. Then, RSX immediately passes control to a lower priority task. This scheme minimizes the central processor's idle time, thereby maximizing its efficiency.

- <u>Disk Resident</u> - RSX is based on the concept that most tasks are disk resident. Thus, it keeps inactive tasks on the disk and puts only active tasks in memory.

- <u>Large Number of Tasks</u> - RSX can support over a billion words of disk storage and over a million words of core memory. With all this available capability, RSX can support as many tasks as one wishes.

- <u>Dynamically Allocatable Memory</u> - Tasks are kept in a relocatable format on the disk. Memory does not have to be permanently allocated; when a task completes, it is removed from memory and its space is reused for other tasks. By making use of the PDP memory management hardware, RSX will load a task into any available memory area. This provides a degree of flexibility without sacrificing time for software task build relocation, since the relocation is performed in hardware.

- **Checkpointing** - RSX supports checkpointing to maximize the use of memory. Checkpointing allows the system to free up memory before a task finishes its execution. A task is checkpointed, swapped out of memory, to allow a higher priority task to use its memory area. Any task in the system can be declared checkpointable by the user. Finally, a checkpointed task need not run in the same memory area from whence it was swapped.

- **Common Libraries** - In an intelligent terminal environment where many tasks are executing in support of a common function (i.e., mission planning), reentrant shared common routines can significantly reduce the total memory requirements.

- **FORTRAN IV** - RSX supports the higher level language, FORTRAN IV.

- **Task Scheduling** - RSX supports the following types of task scheduling:

  - Schedule a task to run at a fixed time.

  - Schedule a task to run at a lapsed time from now.

  - Schedule a task to run periodically.

- **Spooling** - Spooling allows a task to write to the disk instead of writing to a slower device like a printer. A symbiont task automatically takes the data off the disk and directs it to the desired peripheral. This allows a task to execute quickly and free up memory.

- **File Management** - RSX includes a file management system. This file management allows on-line allocation, deallocation, and reutilization of disk storage space as it is required. RSX provides volume and file protection. Files may be declared as no access, read-only access, read-write access, read/write/extend access, and read/write/extend/delete access.

- **Priority I/O** - I/O requests are queued to allow a task to overlap its input/output with its computation. These queues are priority ordered to ensure that the most important task in the system gets the peripheral first.

- <u>Protection</u> - Each task executes in a totally secluded environment only able to access its own area. A task cannot interface with protected files, cannot directly access peripherals, cannot interfere with the Executive, and cannot interfere with other tasks. System integrity is an essential part of a multiuser intelligent terminal system.

RSX-11D Version 4 was the first RSX system installed on the PDP-11/45. This was the initial release of RSX and over 100 problems were uncovered and documented before it was replaced with RSX-11D Version 6A. Version 6A has corrected most of the known problems and is currently performing the functions for which it was designed. RSX-11D Version 6B is scheduled to be installed within the next few weeks and promises to provide significant performance improvements by offering simple timesharing for multiterminal users. The time-based scheduling algorithm swaps checkpointable tasks within one or more designated partitions. The system manager specifies those partitions that are to be time-scheduled during system generation. The time scheduler operates only on checkpointable tasks in a time-scheduled partition. Noncheckpointable tasks in a time-scheduled partition are processed by the RSX priority scheduler.

The time scheduler uses the system clock to become active at specified time intervals. When active, it performs the following for each time-scheduled partition:

1. Determines whether a task is active in the time-scheduled partition and, if so, determines whether the task is checkpointable.

2. Checks a queue called the Memory Required List (MRL) for the highest priority task capable of running and swaps the two tasks regardless of their relative priorities.

3. Places the swapped-out task in an intermediate position (priority) in the queue as defined at system generation.

4. Loads the task to be swapped in.

5. Before exiting, increases the priority of all tasks currently in the queue.

In addition, the scheduler remembers which task was most recently swapped out so that the same task is not always the one swapped.

The time scheduler's approach produces the following effects:

1. Checkpointable tasks all receive an opportunity to execute without affecting real time tasks in the partition.

2. Because the scheduler increases the priority of all tasks in the queue each time the scheduler exits, no task remains at the low end of the queue.

Although all checkpointable tasks that run in the partition run at the partition priority, their priorities on the MRL vary depending on their state and how long they have been queued on the MRL.

IGDS Modifications

The RSX-based intelligent terminal system had to service the original Interactive Graphics Design System application for which the PDP-11/45 was intended. The original IGDS software was not designed to coexist with other applications and, therefore, had to be modified to share the system's measures with these tasks. The IGDS software was separated into three separate tasks, each executing under RSX and communicating with each other through RSX. Software performance enhancements were made which reduced the amount of time required to present a drawing by 50%, reduced the graphic software's processing requirements by 70%, and expanded the number of graphic terminals supported from 4 to 8 terminals. A hardware disk scanner has also been developed that will locate a graphic element or group of elements in a disk file without moving the data from disk to memory. The disk scanner will search an entire disk file at the hardware read rate of the disk. Only graphic elements that pass the scanner search criteria will be passed to core memory for software processing. The scanner will process over 4 million bits of data a second and perform this processing in parallel with the central processor operations. This hardware device should further reduce the graphic software's processing requirements by up to 80%.

MIPS Application Programs

A representative set of mission analysis function modules were selected to be converted to the PDP system to assess the capabilities of the new RSX multiprogramming environment. The six programs originally selected for conversion to the PDP were:

- WAMPUM - A man-interactive scheduling module that can be used by the planner to generate his crew/experiment timeline for the flight. It is a key module in the MIPS as it will coordinate data from several other modules and schedule the crew/experiment operations.

- SCREEM - This module, designated the Astronomy Experiment Scheduler, generates star target sequences based on several algorithm options, calculates slewing and subsystem profiles, and developes a target timeline.

- SLAVE - This module in conjunction with the module INFACE forms the astronomy orbit optimization cycle. This module analyzes star target data, preliminary orbital data, elapsed time from launch to initial vehicle position, viewing period start time and duration, and sensor data, and generates an acquisition/loss time history for the desired star targets.

- MOSS - This module provides bookkeeping with a chronological listing of the Orbital mission events (i.e., maneuvers) along with the start, stop, and duration time of each. The planner inputs each event and its corresponding data via cards and MOSS chronologically orders them and supplies the planner with a tabular presentation of the events versus time.

- ASEP - This module receives Shuttle maneuver data and data from the Optimizer Orbital Data identifying the launch time and insertion longitude and latitude and provides ephemeris data for the spacecraft orbital motion. Another output from ASEP provides the planner with ground track visibility plots and Earth traces.

- DASPRO - This module receives the crew/experiment timeline data, the experiment data requirements, and the acquisition/loss data and produces a data storage profile for the mission.

Of these six programs originally scheduled for conversion, the problems encountered were so numerous that only the WAMPUM and ASEP modules were converted during the scheduled effort. Since that time each problem has been adequately addressed and a number of additional programs have been successfully converted to the PDP system. The following paragraphs document each problem encountered during the application program conversion efforts and discuss the efforts made or being made to solve the problem.

- FORTRAN Compiler - The PDP FORTRAN IV compiler produced inefficient object code. Tho object code produced required 30% more memory and 300% more execution time than the same object code produced by the

Datacraft FORTRAN IV compiler. The Datacraft computer was used as a comparison because it was convenient and the application program being converted to the PDP was operational on the Datacraft. These memory and timing comparisons were bad enough to question the use of the PDP as the intelligent terminal system. However, a new FORTRAN compiler was announced by Digital Equipment Corporation (DEC) called FORTRAN IV PLUS. The new compiler was installed on the PDP-11/45 and the same comparisons were again made between the PDP and Datacraft computers. Using the new compiler, the application program required less memory and executed twice as fast on the PDP as it did on the Datacraft. The results of this test indicated that the PDP using the FORTRAN IV PLUS compiler was suitable for continued use as a prototype intelligent terminal system.

- <u>Application Program Size</u> - Many of the mission analysis function modules were designed and programmed to fit in 32K words of UNIVAC 1108 memory. The memory word size of the PDP is less than 1/2 the size of an 1108 word and the PDP system does not allow a single program to occupy more than 32K words of PDP memory. The inefficiencies of the initial PDP FORTRAN IV compiler eliminated the hope of a straightforward conversion of many of the larger MIPS 1108-based programs. The new FORTRAN IV PLUS compiler solved most of this problem by providing a one-for-one translation with regard to memory requirements. A program currently operational on the 1108 within 32K words of memory can normally be converted directly to the PDP without violating the 32K size restriction of the PDP. A software Extended Memory Access Method (EMAM) was developed to allow programs larger than 32K words to be used on the PDP without the burden of program overlaying. The EMAM is based on the features of RSX-11D which support the simultaneous execution of multiple programs with each program addressing up to 32K words of memory. This method allows any number of large data arrays to be broken out of the main program and identified to RSX as separate independent programs. Operating system services are provided to pass data between the executing program and its data arrays. The EMAM has been successfully demonstrated on a sample MIPS function module.

- <u>Tektronix Plot Services</u> - Some of the MIPS function modules produce graphic output. These programs use the Tektronix Corporation TEKPLOT subroutine package to communicate with CRT terminals. The TEKPLOT subroutine package was not available on the PDP; however, the IGDS provided the same type of features. Therefore, a set of TEKPLOT compatible routines were developed to interface to IGDS and provide the application programs with the plot services. IGDS operates as a separate task from the application programs; therefore, its core requirements are not added to the application program invoking its plot services. The IGDS plot services provide the following capabilities:

  - Erasing the screen.

  - Making hard copies.

  - Placing alphanumeric characters at predefined coordinates.

  - Plotting in any of the available modes, either absolutely or relative to the current graphic position.

  - Performing graphics input of either points or relative coordinates.

  These plot service routines allow the current MIPS graphic application modules to run on the PDP in an unmodified state.

- <u>MIPS Executive</u> - The mission analysis function modules executing in the 1108 make extensive use of the MIPS Executive for module control, module interaction, terminal interaction, and data base control. Programs using these MIPS Executive services make numerous references to Executive routines. To convert these programs to the PDP requires converting these MIPS Executive service routines to the PDP. The 1108-based MIPS Executive represents many man years of development effort and its conversion to the PDP is a much larger task than the conversion of any set of application modules. An extensive study and evaluation effort has been conducted to determine the feasibility and desirability of implementing the MIPS Executive on the PDP system. No actual implementation has been done to date. Section 2.2 presents some recommendations on a PDP-based Executive.

- **Interactive User Response** - A primary goal of RSX-11D is to minimize the central processor's idle time and, therefore, maximize its efficiency. In a multiuser interactive mode of operation, strict adherence to this goal can produce long response times to interactive requests. RSX-11D executes programs strictly on a priority basis. The highest priority program executes until it decides to wait, performs an input/output operations, or exits. The amount of time a program keeps control of the system is determined by the program. RSX-11D Version 6B offers a simple timesharing mode for multiterminal interactive users. This time-based scheduling algorithm swaps checkpointable tasks within a designated time-scheduled partition. The time scheduler uses the system clock to become active at specified time intervals and forces the execution of one task to end and another task to begin. This new RSX feature will allow all tasks to receive an opportunity to execute and, therefore, improve the user terminal response time.

- **Memory Contentions** - When users at several terminals request the execution of application programs, the compiler, and system utilities, the system memory resources are quickly exhausted. Since all user tasks and system tasks are currently running at the same priority level, no task can checkpoint another task. The first task or group of tasks initiated remain in memory until they complete while other requested tasks must wait in the Memory Request List. The timesharing mode of operation supported in RSX-11D Version 6B will alleviate this situation by allowing each task a period of time within memory and automatically checkpointing tasks as needed to share the system resources evenly among the active tasks.

  RSX-11D Version 6B will also provide a memory compaction feature that will compress fragmented memory. A task cannot be loaded into a system controlled partition unless there is sufficient contiguous space for it between other tasks loaded in the partition. When a task terminates, it can leave a space which is insufficient alone to load another task, but considered together with other unused areas can be used to contain a task. The automatic memory compaction feature will move tasks in a partition to obtain a large enough area in the partition to load another task.

PDP/1108 Communications

A major objective of the intelligent terminal system is to maximize the utility of the UNIVAC 1108 system, its current MIPS Executive capabilities, and its available data base. To fulfill this goal, the PDP and 1108 were linked together via communication lines. To eliminate system software problems at the 1108 system, the PDP was interfaced to the 1108 as if it were standard teletype compatible terminal. It was recognized that this arrangement would be inefficient and would limit the utility of the computer-to-computer link, but it provided an expedient method of communicating between the computers and an adequate testbed for evaluation of a future more capable computer-to-computer link. The programming required to support this communication has been completed and is waiting for the installation of full-duplex communication equipment.

2.1.2 Hardware Evaluation

As the system capabilities have been continually increased and the number of system users has increased, the hardware configuration has been expanded to service the new requirements. The original Interactive Graphics Design System consisted of a PDP-11/45, 32K words of memory, a Tektronix 4014 terminal, an electronic digitizer, and two 1.2 million word disks. This configuration has been upgraded with additional memory, disks, and terminals to the current configuration presented in Figure 2-1. Additional hardware has been ordered and will be available in September, 1976, to replace the PDP-11/45 with 128K words of memory with a PDP-11/70 with 256K words of memory This configuration is presented in Figure 2-2. The following paragraphs describe each of the major hardware additions to the system.

Core Memory

The current PDP-11/45 system has 128K words of memory. This memory is currently dedicated as follows:

o	Operating System	30K words.
o	IGDS	40K words.
o	Plotting and Terminal Users	58K words.

Since a single terminal user can occupy most of the final partition, most terminal users find that they are constantly waiting for available memory to execute. This has led to an intolerable terminal response time and constant

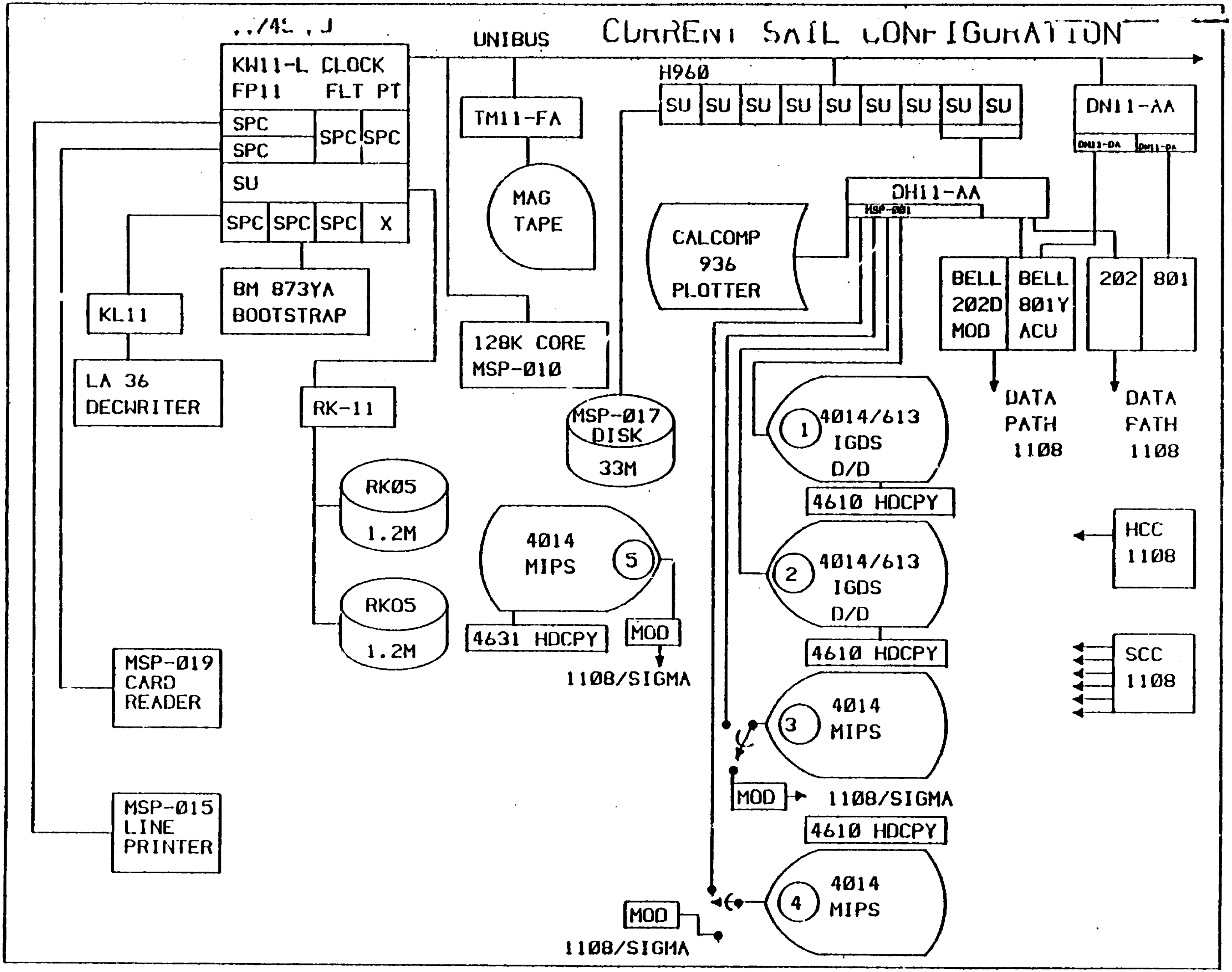

CURRENT SAIL CONFIGURATION
UNIBUS
KW11-L CLOCK
FP11 FLT PT
SPC
SPC
SPC SPC
SU
SPC SPC SPC X
BM 873YA BOOTSTRAP
KL11
LA 36 DECWRITER
RK-11
RK05 1.2M
RK05 1.2M
TM11-FA
MAG TAPE
128K CORE MSP-010
MSP-017 DISK 33M
H960
SU SU SU SU SU SU SU SU SU
DH11-AA
MSP-001
CALCOMP 936 PLOTTER
DN11-AA
DN11-DA
DN11-DA
BELL 202D MOD
BELL 801Y ACU
202
801
DATA PATH 1108
DATA FATH 1108
1 4014/613 IGDS D/D
4610 HDCPY
2 4014/613 IGDS D/D
4610 HDCPY
3 4014 MIPS
MOD
1108/SIGMA
4610 HDCPY
4 4014 MIPS
MOD
1108/SIGMA
4014 MIPS 5
4631 HDCPY
MOD
1108/SIGMA
HCC 1108
SCC 1108
MSP-019 CARD READER
MSP-015 LINE PRINTER

Figure 2-1

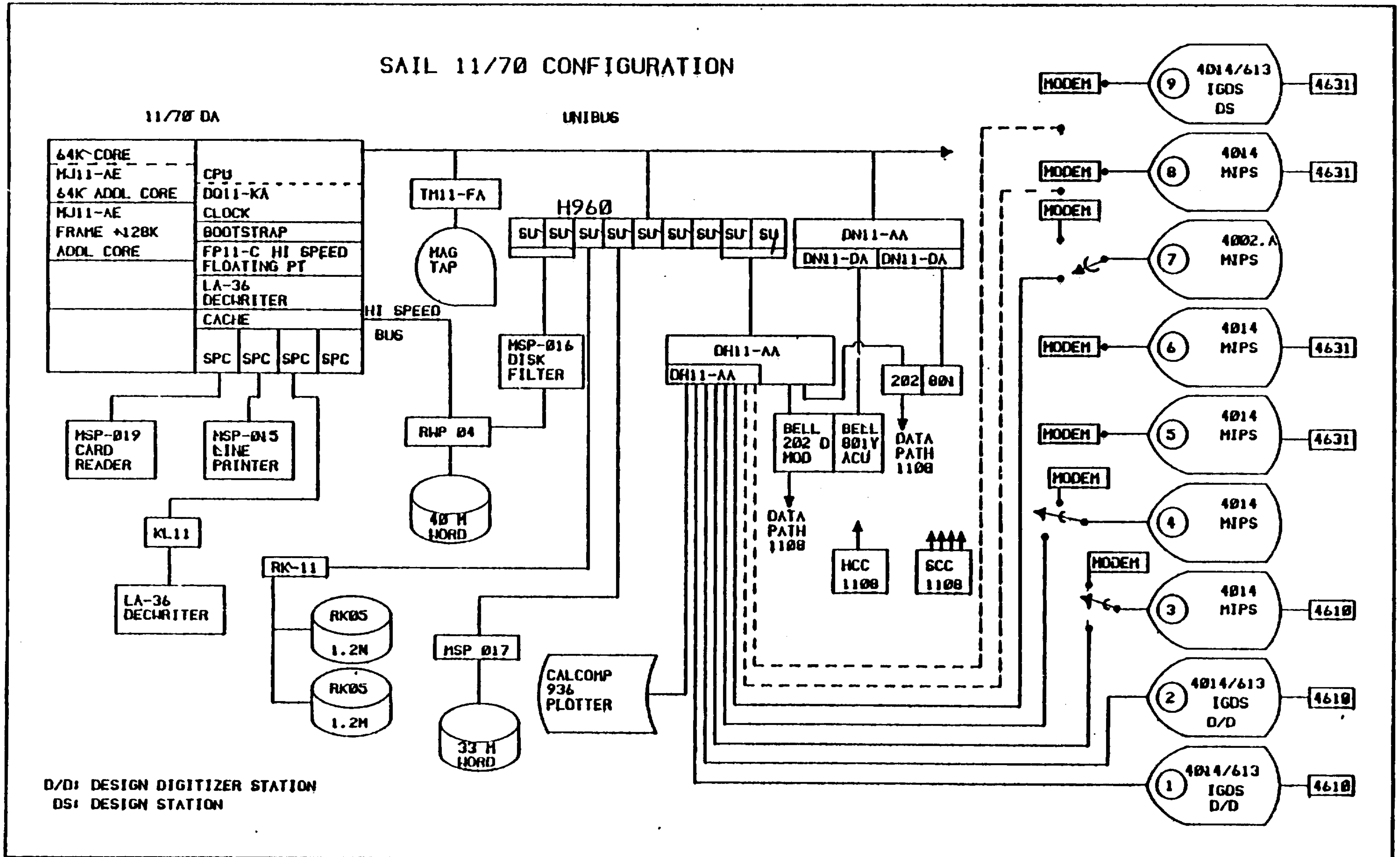

SAIL 11/70 CONFIGURATION
11/70 DA
UNIBUS
64K CORE
MJ11-AE
64K ADDL CORE
MJ11-AE
FRAME ~128K
ADDL CORE
CPU
DQ11-KA
CLOCK
BOOTSTRAP
FP11-C HI SPEED
FLOATING PT
LA-36
DECWRITER
CACHE
SPC
SPC
SPC
SPC
HI SPEED
BUS
TM11-FA
MAG
TAP
H960
SU
SU
SU
SU
SU
SU
SU
SU
SU
DN11-AA
DN11-DA
DN11-DA
MSP-016
DISK
FILTER
RWP 04
40 M
WORD
DH11-AA
DH11-AA
BELL
202 D
MOD
BELL
801Y
ACU
202
801
DATA
PATH
1108
DATA
PATH
1108
HCC
1108
SCC
1108
MSP-019
CARD
READER
MSP-015
LINE
PRINTER
KL11
LA-36
DECWRITER
RK-11
RK05
1.2M
RK05
1.2M
MSP 017
33 M
WORD
CALCOMP
936
PLOTTER
MODEM
9
4014/613
IGDS
DS
4631
MODEM
8
4014
MIPS
4631
MODEM
7
4002.A
MIPS
MODEM
6
4014
MIPS
4631
MODEM
5
4014
MIPS
4631
MODEM
4
4014
MIPS
MODEM
3
4014
MIPS
4610
2
4014/613
IGDS
D/D
4610
1
4014/613
IGDS
D/D
4610
D/D: DESIGN DIGITIZER STATION
DS: DESIGN STATION

Figure 2-2

user dissatisfaction with the system. The time-sharing feature of RSX-11D Version 6B will improve the terminal user's response time; however, for time-sharing to be reasonably efficient, sufficient memory must be available to support at least two programs concurrently resident in memory. The PDP-11/70 system scheduled for September 1976, will contain 256K words of memory. This will provide a large time-sharing partition for the interactive terminal users.

Disk Storage

The initial PDP system had 2.4 million words of disk storage. With the conversion to RSX approximately one-third of this storage was required to support the operating system and its supporting software. The remaining disk storage was insufficient to contain the program source code and program operational data required to support on-line users. The drawing files created by the IGDS users began to require more and more on-line space as additional drawings were digitized into the system. The situation quickly reached the point that one user had to release space on the disk before he or another user could add data to the disk. This situation complicated the operation of the system, especially for users located a considerable distance from the computer.

To solve the disk space problem, two large capacity disk storage devices have been added to the system: a DEC RP04, 44 million word disk and a CDC, 33 million word disk. The DEC RP04 disk is a high-performance disk that will be used to contain the on-line data necessary to support the interactive terminal users including the IGDS users. The CDC disk offers an extremely attractive cost for a large amount of storage. Up to eight 33 million word disks can be added to the system for $8,000 each. It is planned that this storage potential will be used for archival storage of programs, data, and drawing files.

Terminals

As the system hardware and software capabilities have increased, the number of users of the system has increased. Figure 2-3 illustrates the number of terminals currently planned for the interactive terminal system through 1976. The number of active terminals has consistently overloaded the PDP system and has, to date, dictated the major configuration upgrades. Based on our experience with the current PDP-11/45 system, IGDS, the PDP-11/70 performance, and the mission planning system requirements, M&S Computing has projected the number of terminals that can be serviced with good user response. Figure 2-4 presents the results of this projection for a series of PDP configurations. In each configuration involving more than one

PLANNED USE OF PDP INTERACTIVE TERMINAL SYSTEM

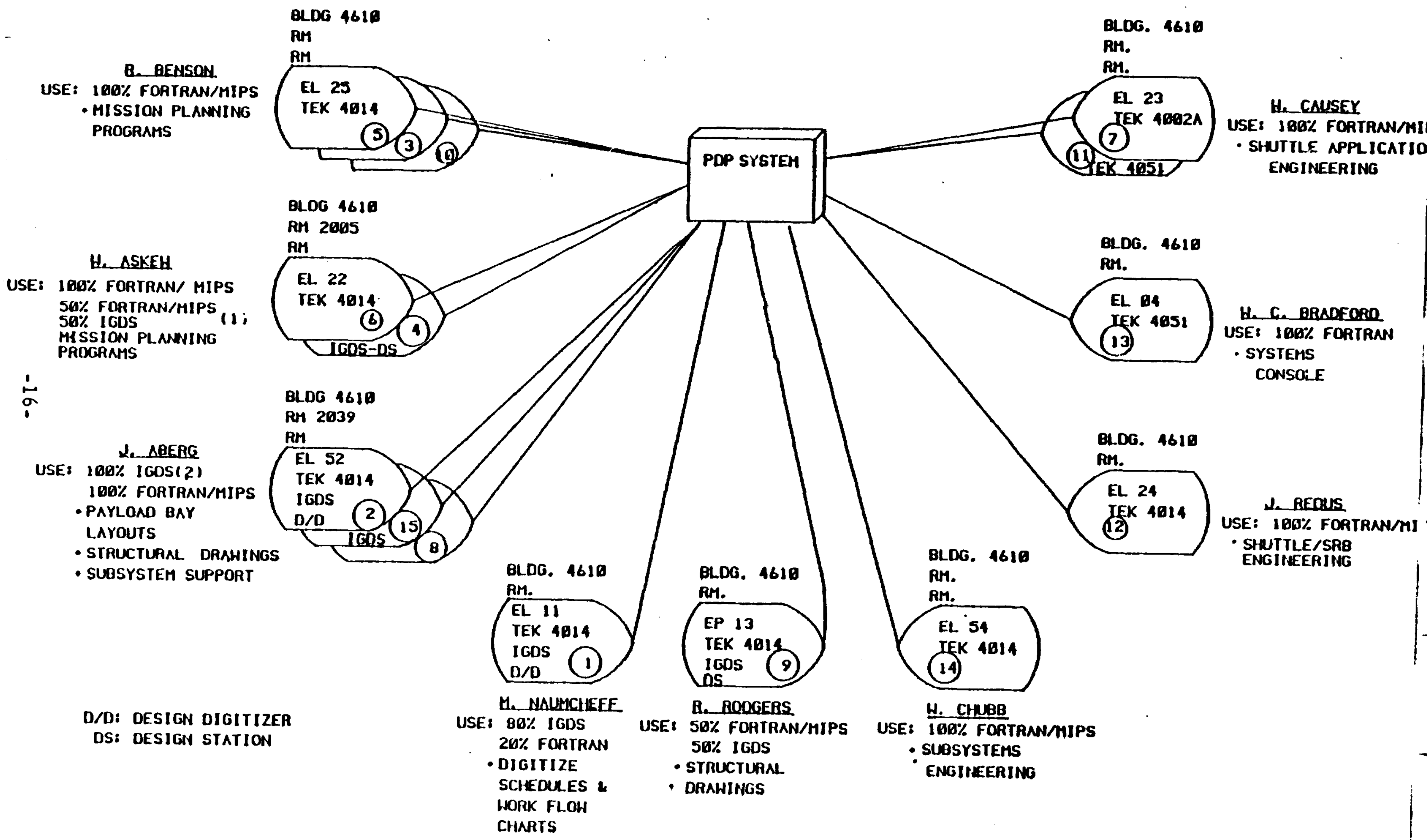


Figure 2-3

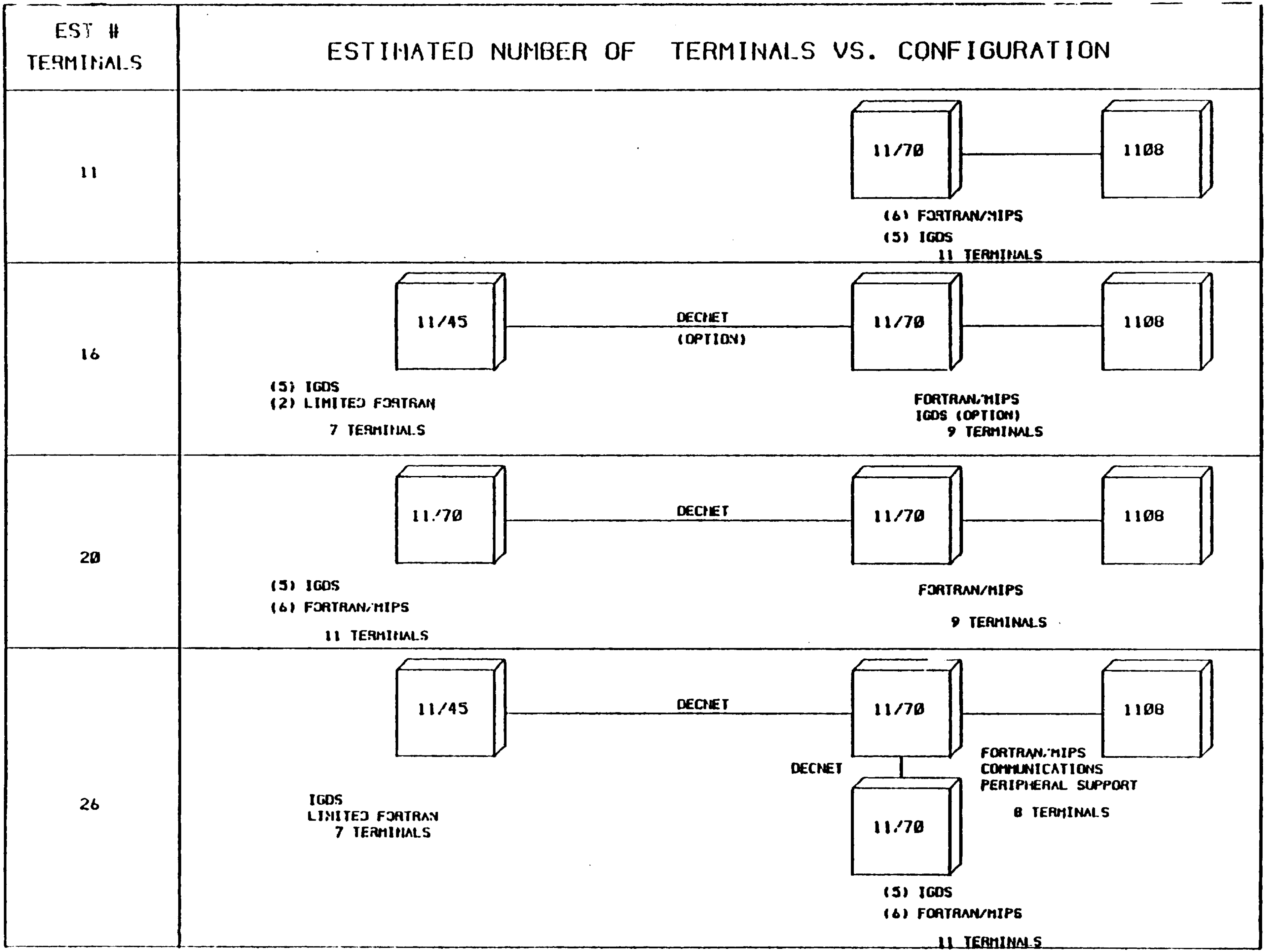

EST # TERMINALS
ESTIMATED NUMBER OF TERMINALS VS. CONFIGURATION
11
11/70
1108
(6) FORTRAN/MIPS
(5) IGDS
11 TERMINALS
16
11/45
DECNET
(OPTION)
11/70
1108
(5) IGDS
(2) LIMITED FORTRAN
7 TERMINALS
FORTRAN/MIPS
IGDS (OPTION)
9 TERMINALS
20
11/70
DECNET
11/70
1108
(5) IGDS
(6) FORTRAN/MIPS
11 TERMINALS
FORTRAN/MIPS
9 TERMINALS
26
11/45
DECNET
11/70
1108
DECNET
11/70
FORTRAN/MIPS
COMMUNICATIONS
PERIPHERAL SUPPORT
8 TERMINALS
IGDS
LIMITED FORTRAN
7 TERMINALS
(5) IGDS
(6) FORTRAN/MIPS
11 TERMINALS

Figure 2-4

CPU, the computers are linked via a standard DEC communication software package, DECNET. This communication network will allow the computers to share peripherals and will provide an access to the 1108 via the central PDP-11/70. Figure 2-5 presents a more detailed configuration of the terminal distribution for a PDP-11/45 and PDP-11/70 network. Figure 2-6 illustrates the terminal distribution for a dual PDP-11/70 network.

Peripherals

A card reader and line printer have been added to the PDP to support the development of software programs. A CalComp 936 plotter has also been added to produce hard copy outputs of IGDS-produced drawings.

Communications Equipment

Interface equipment has been added to the PDP system to allow the computer to communicate with the UNIVAC 1108 computer in Huntsville and/or Slidell, Mississippi. In addition to the modem interface hardware, an automatic dialing unit was attached to the computer to allow a terminal user to request access to a particular computer and have the PDP system automati:ally establish the communication link.

Disk Scanner

A hardware disk scanner has been developed by M&S Computing which will locate a graphic element or group of elements in a disk file without moving the data from disk to memory. The disk scanner will search an entire disk file at the hardware read rate of the disk. Only graphic elements that pass the scanner search criteria will be passed to core memory for software processing. The scanner will process over four million bits of data a second and perform this searching function in parallel with the central processor's operations. This hardware device should reduce the graphic software's processing requirements by up to 80%.

2.2 Requirements for a Final Intelligent Terminal System

The prototype intelligent terminal system has evolved into a large, general purpose minicomputer facility capable of simultaneously supporting five IGDS users and six MIPS FORTRAN programming terminals. The additional system capabilities required to support the final MIPS Intelligent Terminal System depend on the functions required for the final intelligent terminal. This section defines a set of functions that should be supported by an intelligent terminal system and proposes the software and hardware capabilities required to support these functions.

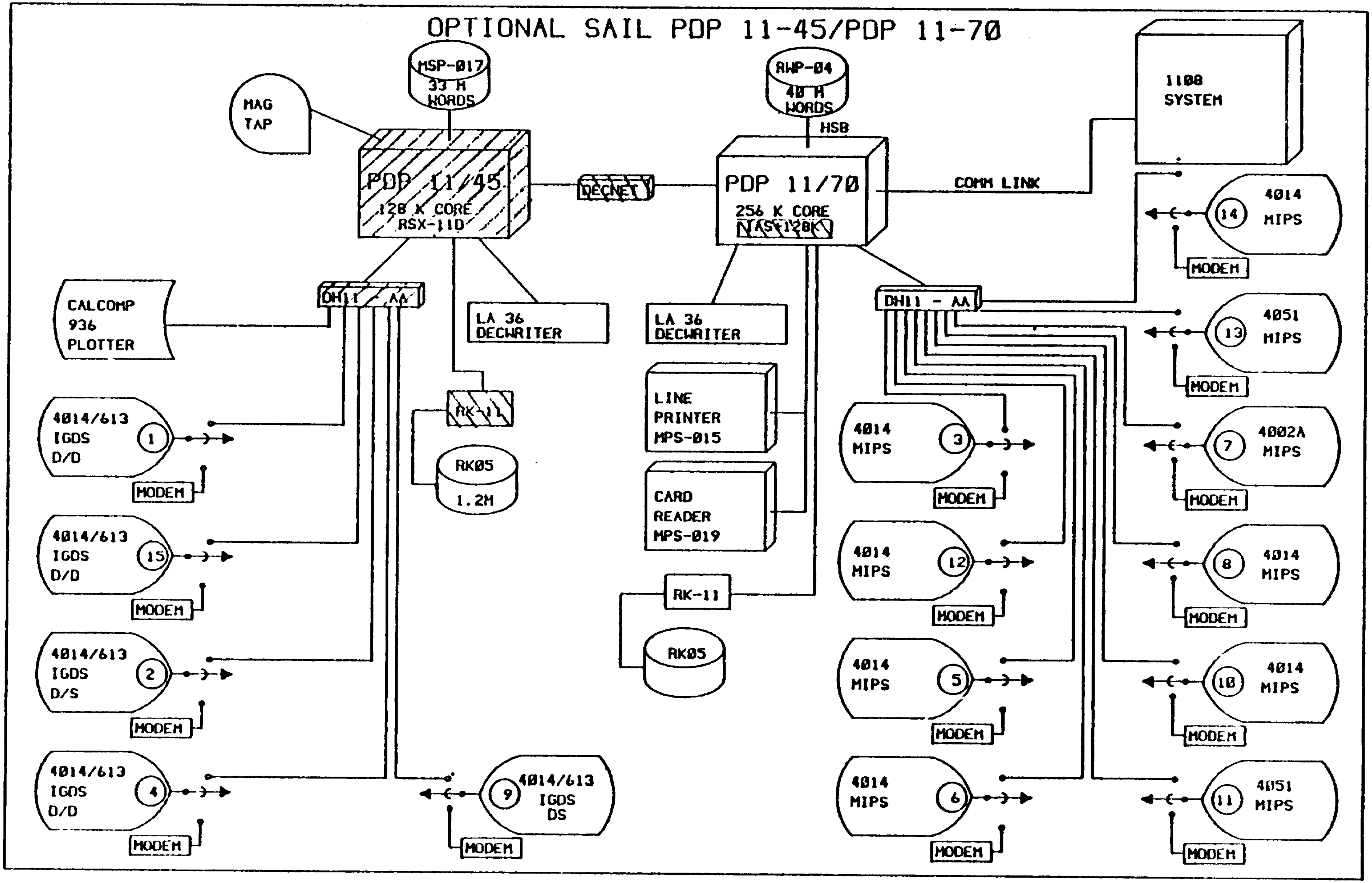
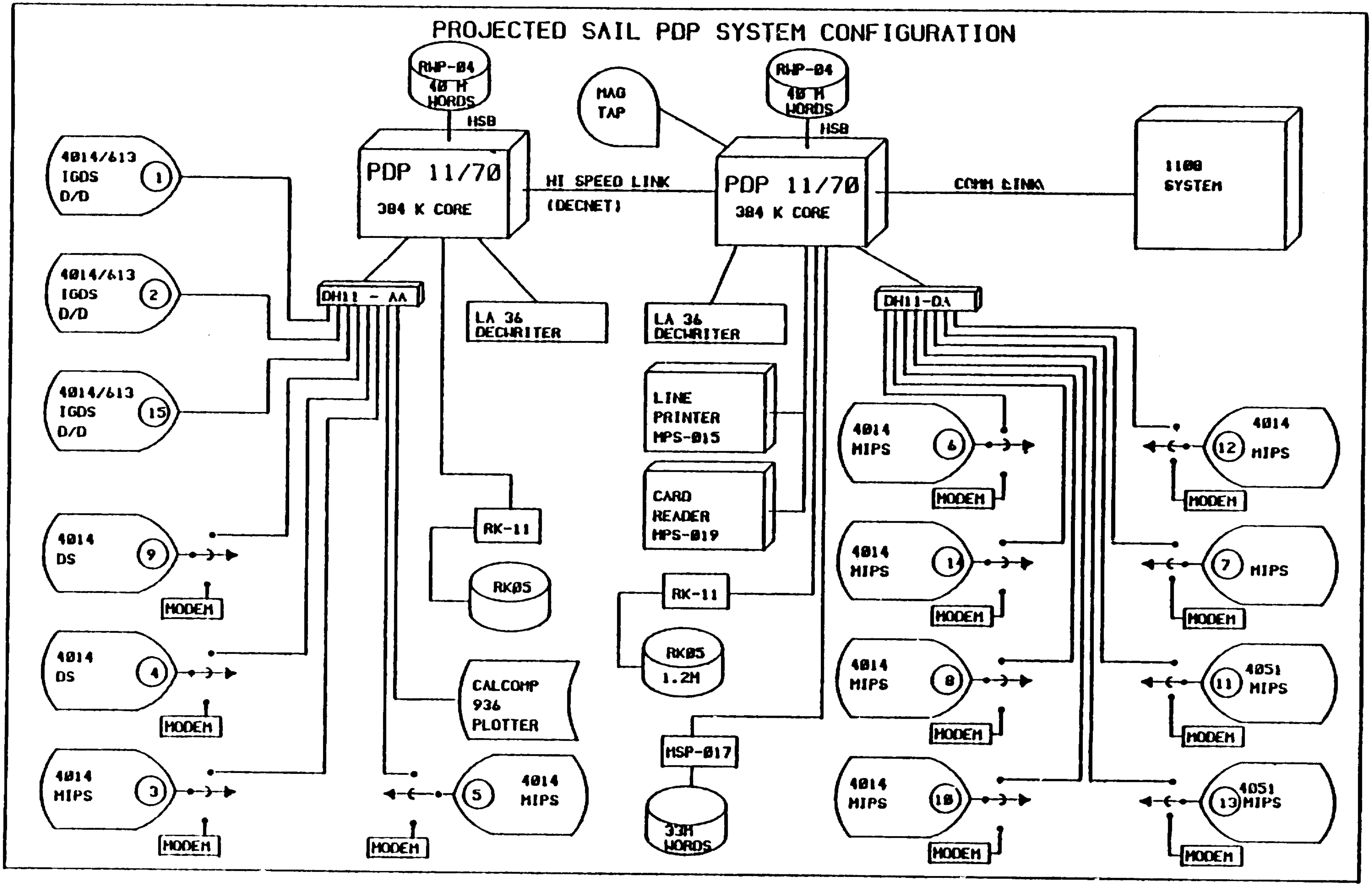

OPTIONAL SAIL PDP 11-45/PDP 11-70
MSP-017 33 M WORDS
MAG TAP
PDP 11/45 128 K CORE RSX-11D
DECNET
RWP-04 40 M WORDS
HSB
PDP 11/70 256 K CORE IAS(128K)
COMM LINK
1108 SYSTEM
CALCOMP 936 PLOTTER
DH11 - AA
LA 36 DECWRITER
RK-11
RK05 1.2M
LA 36 DECWRITER
LINE PRINTER MPS-015
CARD READER MPS-019
RK-11
RK05
DH11 - AA
4014/613 IGDS D/D 1
4014/613 IGDS D/D 15
4014/613 IGDS D/S 2
4014/613 IGDS D/D 4
9 4014/613 IGDS DS
4014 MIPS 3
4014 MIPS 12
4014 MIPS 5
4014 MIPS 6
14 4014 MIPS
13 4051 MIPS
7 4002A MIPS
8 4014 MIPS
10 4014 MIPS
11 4051 MIPS
MODEM

Figure 2-5



D/D: DESIGN DIGITIZER STATION
DS: DESIGN STATION

Figure 2-6

The argument for having a minicomputer-based intelligent terminal is to do nontrivial local processing like user/computer interaction, attention handling, prompting, providing feedback, data base editing, program development, etc. A minicomputer-based system should be capable of performing a majority of user-requested tasks without recourse to the mainframe. Such a system should be sufficiently powerful to run standalone applications. The remainder of this section discusses each of the necessary functions of the MIPS intelligent terminal and gives the hardware and software requirements associated with each function.

2.2.1 Communication to the 1108

The UNIVAC 1108 is the major computer facility for supporting mission analysis function modules. Therefore, a major goal of an intelligent terminal must be to maximize the utility of the 1108. For the intelligent terminal and 1108 to work together, communication between the two computers must be established. In the currently implemented mode of operation, the PDP system emulates a Tektronix 4014 terminal and communicates with the 1108 in a conversational mode at a transmission rate of 1200 bits per second. At this rate, an average size program consisting of 3,000 lines of code or comments would require 36 minutes to transfer from one computer to the other. The same file would require 4.6 minutes at 9,600 bits per second and would require only 53 seconds at 50,000 bits per second. If the PDP system is to multiplex a number of user terminals to the 1108, a high-speed link between the computers will be needed. The current transmission rate is almost unusable and the 9,600 baud rate will produce a system bottleneck as additional terminals are added to the PDP and request communication services to the 1108. Figure 2-7 illustrates a phasing plan for PDP/1108 communication capabilities that eventually results in a high-speed 50K baud communication link.

File-to-file transfers between the 1108 and the PDP should be supported. Program and data files are maintained at each computer in a different format and, therefore, utility programs must be developed to perform the simple translation between the various file formats. For example, FORTRAN source files are maintained on the 1108 in a UNIVAC-supported field data code format and/or maintained on the PDP in an ASCII format. All utilities used to maintain compatibility between computers should be transparent to the user initiating the data transmission request.

2.2.2 Shared Computer Peripherals

The PDP system must be able to use the 1108 for an archival data base, for massive computational power, and for input/output devices such as high-

PHASING PLAN FOR PDP/1108 COMMUNICATIONS

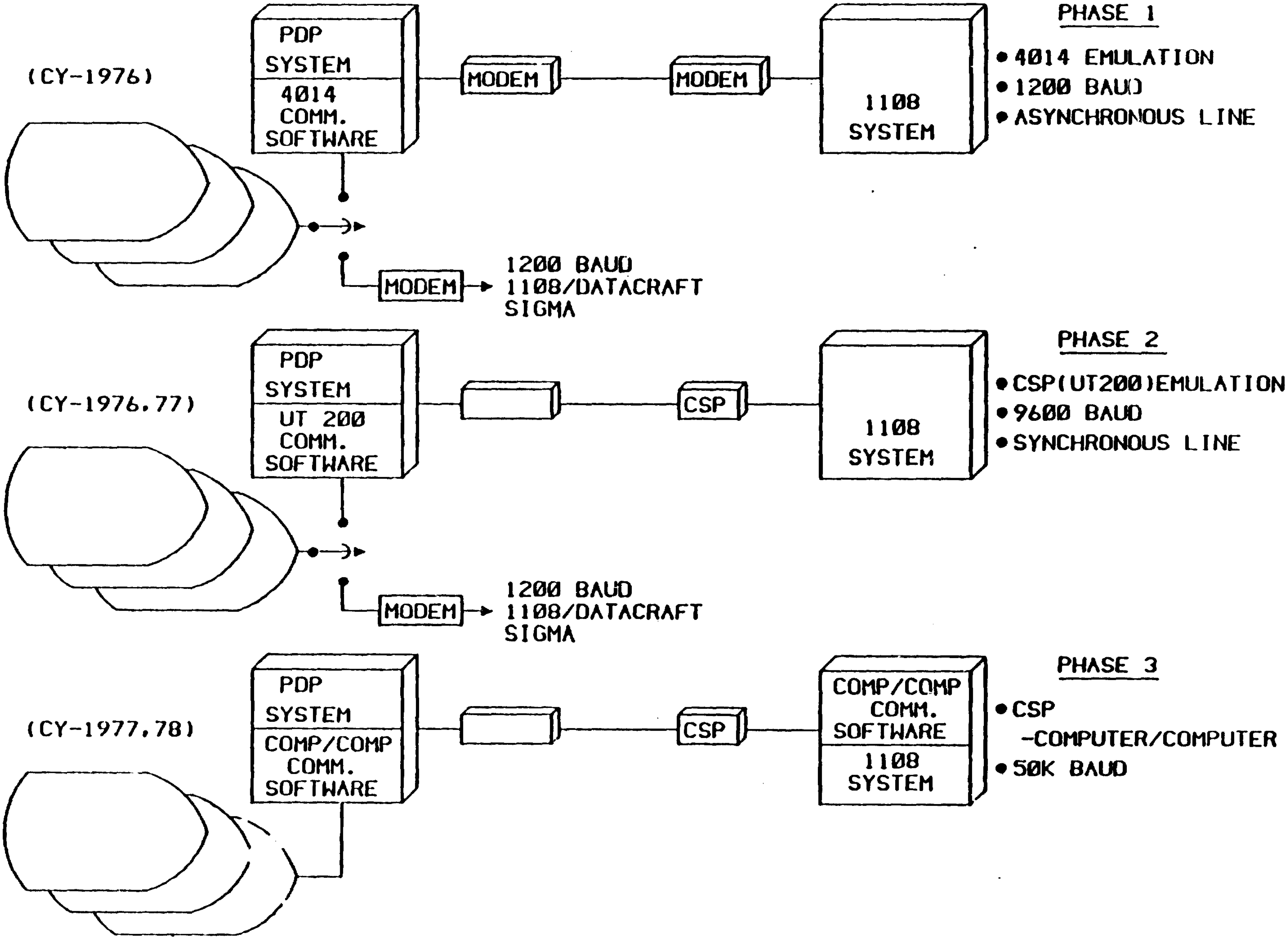


Figure 2-7

speed printers, plotters, microfilm recorders, magnetic tape, etc. The 1108 should, in turn, be able to route line printer outputs and plot requests to the PDP system.

2.2.3 Time-Sharing

The prime objective of a time-sharing scheduler is to reduce, as far as possible, the average response time to all user demands. This can cause an extremely inefficient system due to swapping tasks between memory and disk. RSX-11D Version 6B provides a limited time-sharing algorithm which ensures that each user receives a quantum of time. Using Version 6B, a fixed partition of memory is defined as the time-scheduled partition. All user tasks in this partition are assigned the same execution priority and each are given a quantum of time for execution on a round robin basis. When insufficient memory is available to hold all active tasks, a queue called the Memory Required List is maintained for all tasks active but needing memory for execution. When a task in the MRL is scheduled for execution, a task in memory is swapped out to free-up the required memory.

DEC has announced a new operating system, Interactive Application System (IAS), which is an extended version of RSX-11D Version 6B. IAS has a more extensive time-sharing algorithm that attempts to dynamically assign priorities to tasks being time-shared. The scheduler distinguishes between various levels of user importance and urgency of service. The scheduler maintains a number of round robin queues, or levels of tasks to be scheduled. The scheduler scans each level, high to low, in a round robin fashion until it finds a memory-resident, runnable task. A non-resident ready-to-run task will cause the swapping system to be activated. A task which uses a full-time quantum is transferred to the next lower level unless it is already at the lowest level. Tasks at lower levels are not scheduled as often as tasks at a higher level, so a time factor is associated with each level. Tasks allocated to a lower priority level are given a longer time quantum when next activated. Thus, large jobs are run and swapped less frequently, but, in compensation, receive more processor time once activated.

To prevent tasks from being starved of processor time because the scheduler is continuously scheduling higher priority tasks, a means of promoting tasks from one level to the level above is provided. If, over a given period of time, no scheduling has been performed at a given level, then a task at that level is moved to the bottom of the level above.

If the scheduler finds a runnable task which is not resident, then the task must be loaded into memory to receive its quantum of CPU time. Space will be created in memory by moving resident tasks to create the required contiguous space, and, if necessary, by writing inactive tasks to the swap area on disk(s). The IAS time-sharing Executive requires 10K words of memory and significant CPU resources. M&S Computing does not feel that this level of time-sharing sophistication is necessary in the intelligent terminal system and questions the capability of a minicomputer to live up to the capabilities implied by such an algorithm. Time-sharing in a multiuser conversational mode is essential; however, the capabilities of the minicomputer are being strained by swapping between disk and memory. The memory on the intelligent terminal should be expanded as the number of users of the system increases.

2.2.4 Batch Processing

The RSX-11D batch capability allows the user to submit jobs to a system operator for subsequent processing. Each job contains a series of commands to the system and, optionally, associated data. Once the job has been submitted, its tasks can execute without operator intervention unless the job explicitly requests operator action. Jobs submitted to batch are executed as low priority jobs. Batch is, however, an excellent means of executing larger data processing jobs for which real time requirements are not critical. Many of the non-time critical processing requirements of the intelligent terminal should be performed in the batch mode. Plotting should always be done in the batch mode, primarily because it requires constant operator intervention to set up the paper properly and load and unload the plotting pins as requested. Batch processing is also an economical method of using the PDP system on a multiwork shift basis.

2.2.5 System Utility Library

The intelligent terminal system should contain a complete set of utility support services to aid the user in handling his data or developing software. The PDP system has a comprehensive set of utility software which may be used interactively by the user at a system terminal or they may be invoked and controlled through the batch job stream. These utility programs are:

- Peripheral Interchange Program (PIP) - PIP provides the user with facilities for copying, renaming, listing, deleting, and unlocking his files. Also supplied is a facility for setting the User Identification Code (UIC).

- File Dump Utility (DMP) - DMP provides the user with a facility for obtaining a printed copy of any of his files.

- Line Text Editor (EDI) - EDI provides the user with a facility for adding, deleting, and maintaining text on his files.

- File Verification Program (VERIFY) - VERIFY provides the user with a facility for verifying the consistency and validity of a file structure on a specified device.

- Source Language Input Program (SLIPR) - SLIPR is an editing program used to create and maintain source language files on disk under RSX-11D.

2.2.6 On-Line Function Module Development

A primary objective of the intelligent terminal system is to make the power and utility of the computer more accessible to the user so he can accomplish his work faster and more efficiently. The user should be able to compose his program on-line and review the results of his compilation immediately. The user should be able to run his program interactively and be assisted by the computer system in debugging his program on-line. Results of interactively run programs should be made available immediately to the user in tabular and/or graphic format.

2.2.7 Executive/User Dialogue

Highly interactive man/computer dialogues are more efficiently conducted by a minicomputer than by a high-performance computer such as the 1108. Maximum efficiency can be achieved on the 1108 by maximizing the time the CPU spends processing. The MIPS Executive/user dialogue currently performed on the 1108 should be performed on the intelligent terminal system. The intelligent terminal system should supply the interactive user with a post processing library which allows an engineer to review, plot, display, reduce, and analyze results from executed function modules. Section 3 presents the functional requirements for the PDP-11 MIPS Executive and a development plan.

2.2.8 Local Execution of Function Modules

The intelligent terminal should support the local execution of function modules in addition to the user/Executive dialogue. Such a capability can significantly reduce the load on the 1108 freeing it for heavy computational loads. Local execution of function modules also provides a backup capability if the 1108 is not available.

3. ASSESSMENTS AND ANALYSES PERFORMED

Over the contract period, a number of assessments and analyses have been performed. These have resulted in recommendations for additional equipment and new procedures to provide SAIL with an efficient and effective intelligent terminal capability. Some of the required equipment has been procured under the provisions of this contract. Many of the other recommendations have led to equipment acquisitions under new contracts. Section 4 summarizes the procurements under this contract.

3.1 Summary of Analyses

The major objective of the analyses performed is to offer the proper hardware additions to NASA to alleviate current memory problems and ensure that they will have sufficient computer CPU capacity to meet requirements. Insufficient computer capability forces unnecessary procedural restraints on NASA's highly skilled professional engineering staff, so that the total operation is not cost-effective. For example, engineers must wait at terminals that have a slow response, or they are sometimes unable to do their work for hours while waiting for core availability.

The job types and job mixes operating on the existing PDP-11/45 system are of two separate applications. The first is the IGDS work, including generating drawings and producing local hardcopy and plots. The second is the interactive mission planning (MIPS) work that allows mission planners to interact with mission planning programs to optimize flight equipment utilization, crew schedules, etc. FORTRAN programs are developed, debugged and executed to support both of these functions.

The principal problem that the users of this system must deal with is the utilization of storage. Current storage capacity falls far short of current needs. For example, with IGDS and the plotter software executing in core, the mission planning programs, e.g., WAMPUM, cannot execute because of insufficient available core. If WAMPUM is executing, then their sophisticated plotter (CalComp 936) is unable to operate because the plot software does not fit into core.

The PDP-11/45 core capacity is limited to 128K. The mission planning interactive FORTRAN programs average in excess of 20K in size. Therefore the mission planners need about 180K for nine simultaneous users plus about 50K for RSX and communications. In addition, the interactive FORTRAN programs are largely arithmetic operations with very little input-output interrupts until computations are completed. This causes these programs to consume large blocks of time, locking out IGDS functions and plot routines, which results in unnecessary delays in the interactive graphics response time

Many terminals are planned for both mission planning and IGDS uses through 1976. The current configuration supports only five terminals. However, it should be noted that with additional core and disk space, about seven terminals could be supported.

A projected PDP-11/70 configuration would be limited to a total of eleven terminals, far short of the requirements through 1976.

The most cost effective solution would be for NASA to retain the PDP-11/45, procure a PDP-11/70, and separate the IGDS and mission planning functions. The separation of the two functions, intercomputer communication via DECNET, is the most cost-effective way to accomplish the functions, when one considers the efficient utilization of time by the NASA engineers.

3.2 Recommendations

- o NASA should separate their two special purpose applications (i.e., IGDS drawings, plots, etc., and interactive mission planning) into two separate PDP-11 computer systems. In other words, they should retain their existing PDP-11/45 and procure an additional PDP-11/70 with 256K of core and an MPS-017 disk.

- o NASA needs sufficient core memory and mass storage disks in each computer to support these functions without contention for core when interactive tasks are in progress.

- o Each computer should operate under the same operating system (DEC's RSX-11D, version 6).

- o A back up solution, if NASA lacks funds for two PDP systems, would be a single PDP-11/70 with 512K of core to accommodate the two distinct applications if they must be co-resident. This is not an optimal solution since their principal usage requires two distinctly different special purpose applications and their projected usage indicates that the PDP-11/70 will not have sufficient CPU capacity.

- o The operational efficiency and user response can be significantly improved by the addition of small, user-oriented disk capability. It is recommended that a Diablo disk drive be added to the system. This drive will provide the necessary capability for convenient user access to his data and the system.

- Additional capability for high speed communications to remote terminals is needed. It is recommended that interface equipment to provide 307,000 baud communications be purchased to extend the capability of remote 4014 terminals.

- Additional capability for the current Univac 1108 communication software on the PDP computer is needed. This software should provide the capability to transfer PDP disk files to the Univac 1108 and track the 4014 terminals thumb wheel cursor.

4. EQUIPMENT AND SOFTWARE ACQUISITIONS

The following equipment and software has been provided under the provisions of this contract, consistent with the recommendations in Section 3:

1. Tektronix 4014-1 Display Terminal with Options 30, 31, 2, and 34, Option 1 for Tektronix 4014, Multiplexer for 4610.

2. RWP04 Disk Drive.

3. 32K Parity Memory.

4. Card Reader s/Interface.

5. Line Printer s/Interface.

6. Upgrade M&S Computing Proprietary Software from IGDS-4 to IGDS-5.

7. Changeout 96K non-parity memory for 96K parity memory.

8. Option 1 for Tektronix 4014, One 300 Baud Coupler.

9. Disk Filter.

10. Interface Transceiver.

11. DH11 Line Driver/Receiver.

12. Tektronix Line Driver/Receiver (2 each).

13. 550' Cable.

14. High Speed Interface Controller.

15. RK11 Cartridge Disk Drive and Controller.

16. Upgrade 4014 emulation software.