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HOUSTON, TX

ABSTRACT

The Institutional Data Systems Division (IDSD) operates the Central Computational Facility (CCF) at the Johnson Space Center (JSC) in Houston, Texas. The CCF supports a variety of applications with the focus primarily on space shuttle development and data reduction services. Current plans are to replace four aging UNIVAC 1108 computers with more cost-efficient systems.

This document presents the results of a MITRE study to investigate the communication options available to support both the remaining CCF computer systems and the proposed U1108 replacements. Additionally, the facilities utilized to link the remote user terminals with the CCF were analyzed and guidelines to provide more efficient communications were established.

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Abbreviations and Acronyms

AC	Adapter Cluster
ACF	Advanced Communication Function
AMTB	Asynchronous Modem Terminal Board
APB	Asynchronous Port Board
BBC	Broadband Control
BIU	Bus Interface Unit
BPS	Bits/Second
BTN	Budget Tracking Number
CAA	Concurrently Average Active
CATV	Community Antenna Television
CB	Control Board
CCF	Central Computer Facility
CDC	Control Data Corporation
CFE	Computer Front-End
CSC	Computer Sciences Corporation
CSMA	Carrier Sense Multiple Access
CS/P	Communications Symbiont/Processor
CTMC	Communications Terminal Module Controller
DCDC	Data Communication to Disc Control
DCP	Data Communications Processor
DCP	Distributed Communications Processor
FCC	Federal Communications Commission
FDS	Flight Design System
FECP	Front-End Communications Processor(s)
FIFO	First-In First-Out
FLT	Float
FY	Fiscal Year

GCS	General Communications Subsystem
GDP	Generalized Document Processor
GRW	Growth
HS	High Speed
H2K	Hazeltine 2000
H4K	Hazeltine 4000
IBAS	Interactive Basic Accounting System
IBM	International Business Machines Corporation
IDSD	Institutional Data Systems Division
I/O	Input/Output
JSC	Johnson Space Center
KBPS	Kilo-Bits/Second
KCS	Keyboard Class Select
LDM	Limited Distance Modem
LEC	Lockheed Electronics Company, Inc.
LPM	Lines/Minute
LS	Low Speed
LSR	Low Speed Replacements
LWT	Listen-While-Talk
MTC	Memory-to-Memory Control
NASA	National Aeronautics and Space Administration
NCE	Network Control Element
NCP	Network Control Program
NPU	Network Processing Unit

OFT	Orbital Flight Test
PACX	Private Automatic Computer Exchange
PMATS	Program Management and Tracking System
RIOC	Remote Input Output Controller
RTIU	Remote Terminal Interface Unit
SMTB	Synchronous Modem Port Board
SNA	System Network Architecture
SPB	Synchronous Port Board
S.W. Bell	Southwestern Bell Telephone Company
TCU	Thumbwheel Connect Unit
TDM	Time Division Multiplexor
TMS	Trend Monitoring System
TS	Time Sharing
VS	Virtual Storage
WO	Wearout

SECTION I
INTRODUCTION

1.0 BACKGROUND

The Institutional Data Systems Division (IDSD) operates four UNIVAC 1108 unit processor systems, one UNIVAC 1110 multi-processor system, one IBM 360/65 computer system, and one Control Data Corporation CYBER 74 computer system at the Johnson Space Center (JSC), Houston, Texas. These systems provide a variety of support functions with the focus primarily on space shuttle development and data reduction services.

The U1108's are at least ten years old and the current costs of operations and maintenance are high. Consequently, IDSD is planning to replace these computer systems with more cost-efficient systems. This paper documents a study of the communication subsystem design required to support both the replacement computer systems and those existing systems to be retained.

1.1 Background

The four UNIVAC 1108s will be replaced by two or three large computer systems in a three phase implementation. Each U1108 has the capacity to service 15 concurrently active terminal users and still meet goal response. The four U1108s, thus, can service up to 60 concurrently active users.

The Phase A replacement, scheduled for FY81, will replace two of the U1108s having the capacity to service 30 user terminals. Phase B, scheduled for FY82, will replace the remaining two U1108s bring the replacement capacity to 60 concurrently active users. The final replacement phase, Phase C, scheduled for FY83, would bring the replacement system capacity up to 90 concurrently active terminal users.

All terminal communication lines to the UNIVAC computer systems are routed through the building 12 patch panel. From the patch panel, the lines are then directed to individual systems. Since this routing procedure requires manual intervention, a full-time operator is required.

Because of the increasing importance of communications on IDSD computer system operations, a study was undertaken by MITRE to investigate the current communications subsystem and to assess the impact of future requirements. The communication study was divided into two areas. Initially, the communications between the patch panel and the various computer systems were addressed with recommendations being made concerning the communication interfaces to both the replacement computer systems and the retained computer systems. Next, the communications from the user terminals to the patch panel were studied.

1.2 Scope of Paper

The following section in this document deals with user terminal requirements. The current terminal population is presented and yearly terminal requirements through FY85 are projected. These terminal projections are classified by computer system, location, and JSC organization. Next, the number of concurrently average active (CAA) terminals on each system are estimated using the terminal connect time estimates contained in the yearly Budget Tracking Numbers (BTNs). This data is required for communications subsystem sizing purposes.

Section 3 describes the communication options available to connect the data lines from the patch panel to the various host systems. Current operating procedures are described and a communications concept detailing future support requirements is developed. Several communications subsystem components are described and integrated designs are presented using these components. Considerations of the communications design costs and reliability are included.

In section 4, the cost of communications between the user terminals and the patch panel are investigated. The costs of leasing communication lines from S. W. Bell are presented along with comparative costs of communication equipment leasing vs purchase. Guidelines are then developed for terminal linkage as functions of terminal location and concentration.

SECTION II
CCF TERMINAL REQUIREMENTS

2.0 INTRODUCTION

In order to determine the communication subsystem best suited to the support of the post-Phase C computer system upgrade, a reasonable projection of the future computer terminal population is essential. With the aid of various terminal inventory lists the current terminal population was computed. With knowledge of the current terminal population and with estimates of new terminal requirements derived from budget requests, the expected terminal requirements for the future years through FY85 have been computed and are presented in the following paragraphs.

2.1 Current Terminal Population

At the start of the terminal population survey the most recent data available were for August 1978. Figure 2.1-1 illustrates the terminal and remote I/O device population supported by the IDSD computer systems (UNIVAC U1110, UNIVAC U1108's, IBM 360/65, and CDC CYBER 74). All lines to the UNIVAC systems are routed through the building 12 patch panel. Most of these lines are dedicated and are 'normaled through' to a particular port in one of the hardwired CTMCs (Communications Terminal Controller). Other lines are dedicated from the remote site to the patch panel but require operator intervention to patch the line into the appropriate port upon request. The third type of communications line is the dial-up type. Here, users requesting computer service dial-up the patch panel operator over regular Bell system switched circuits. Only six such CENTREX ports are available to support remote users. The relative dedicated/dial-up line populations are also shown in Figure 2.1-1. Low speed terminals are defined here to have a data rate $\leq$ 300 bps. High speed terminals are those with speeds in excess of 300 bps.

Communications to the IBM 360/65 system are mainly via its own local network with two tie lines to the building 12 patch panel. This computer system is used for word processing functions and all of the connected terminals are low speed.

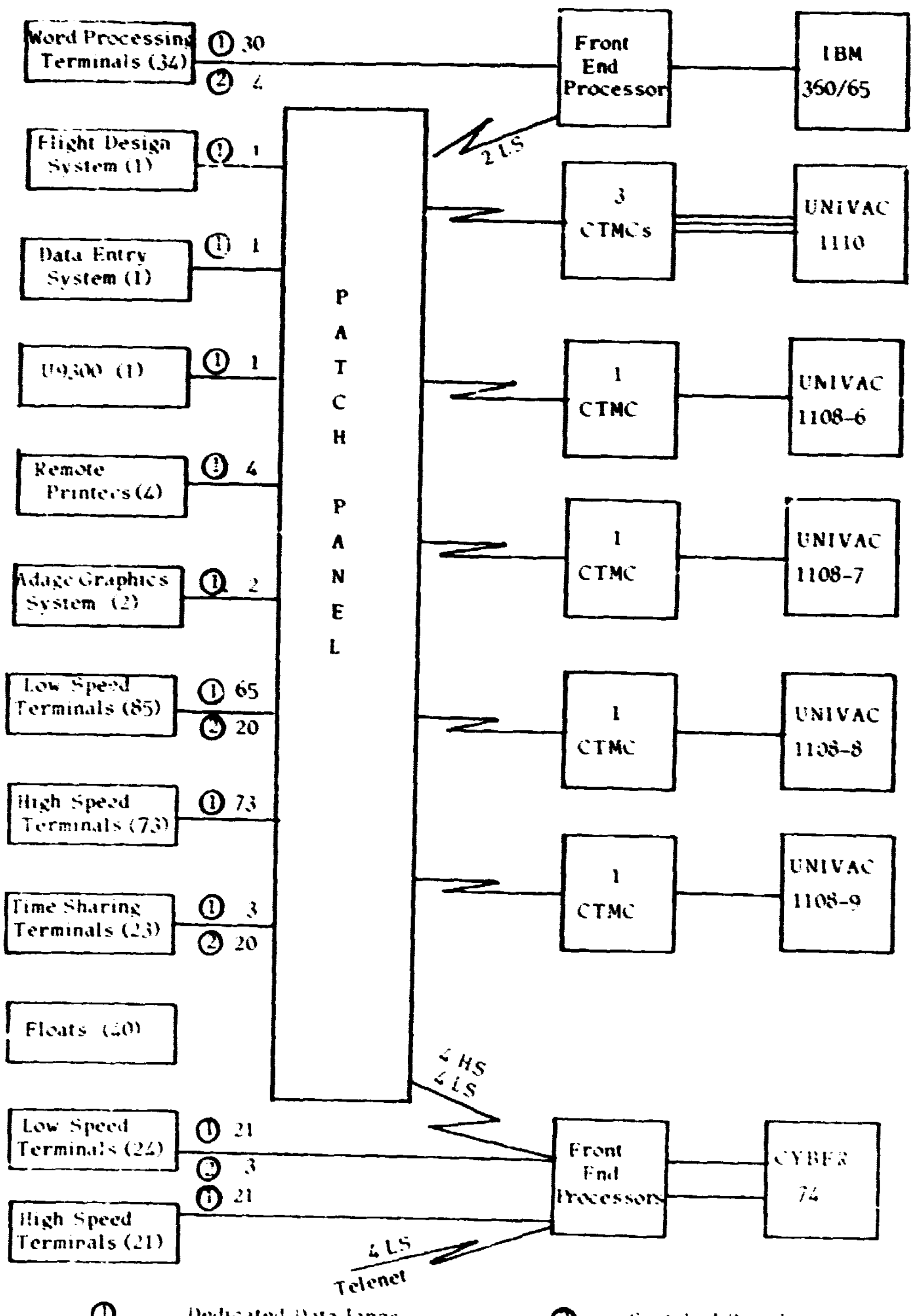


Figure 2.1-1 CCF Systems Configurations

The CDC CYBER 74 computer also maintains its own local network controlled by two front-end interfaces. Low speed lines are all connected to the 6676 Data Set Controller and the high speed lines are connected to the 2550 Network Processing Unit. Four of the low speed and four of the high speed ports are connected to the building 12 patch panel. Service to the CYBER 74 is available to other NASA installations via the Telenet packet switched network. Four ports on the 6676 Data Set Controller are currently assigned for Telenet access.

2.1.1 Terminal Population Characteristics

The IDSD terminal population is heterogenous in its makeup. Many terminals of different manufacture operate with the same functional abilities while others operate in different modes with different protocols. Table 2.1.1-1 lists the various terminal types along with associated attributes. Descriptions in this table are valid for current operating procedures. Most of the terminals are switch selectable to operate at different speeds (with the proper line adapters and modems) and the Megadata terminals have the ability to operate in one of three emulation modes. Currently these Megadata terminals operate in the UNIVAC UNISCOPE 200 emulation mode (9600 bps, synchronous transmission) but can also emulate IBM 3275 high speed synchronous terminals and low speed asynchronous terminals.

The August 1978 terminal population inventory for the IDSD computer systems is presented in Table A-1 in Appendix A. In this table the terminal population is separated by computer system and further by category and organization. Forty of the low speed terminals are listed as floats. These terminals are either operational and not assigned or are awaiting repair. The terminals listed as Time Sharing Terminals are those assigned to the users of commercial time sharing facilities but could be reassigned via the patch panel to one of the IDSD hosts.

2.1.2 Inter-computer Communications

For a three week period in October 1978 the building 12 patch panel operator's logs were inspected to determine the amount of inter-computer terminal communications. The results were divided into three exclusive sets; the number of terminals accessing the UNIVAC U1110 and one or more U1108s, those

Table 2.1.1-1 Device Characteristics

DEVICE	MODE	SPEED	COMMENTS
Low Speed Terminals	asynchronous	300 bps	several manufacturers
Hazeltine 4000	synchronous	to 9600 bps	
Megadata	synchronous	9600 bps	emulating terminal
Tektronix 4014	asynchronous	4800 bps	graphics terminal
Adage	synchronous	19200 bps	graphics system
Flight Design System	synchronous	19200 bps	link to INTERDATA 8-32 in bldg. 30
Remote Printers	asynchronous	4800 bps	Printronix 300 lpm printers
Mohawk 2410 - II	synchronous	9600 bps	remote data entry system
U9300	synchronous	19200 bps	UNIVAC data communications subsystem

accessing the CYBER 74 and one or more UNIVAC systems, and those accessing the IBM 360/65 and one of the UNIVAC systems. The summary is presented below:

- U1110 & U1108s 23 terminals
- UNIVAC & CYBER 74 7 terminals
- UNIVAC & IBM 360/65 3 terminals

From these data it is seen that for the measured three week period 33 terminals accessed multiple computer types. This represents approximately 11% of the total terminal population.

2.2 Requirements Projection

Using the August 1978 terminal inventory as a starting point, estimates of the FY79 through FY85 terminal requirements were made. Several sources were utilized in the attempt to make the terminal projection as realistic as possible. The FY79 BTN requirements call was used to provide estimates of terminal connect time and the number of concurrent users. Informal contacts with users provided further data in this effort. Finally in cases where lack of data (or conflicting data) impacted the projection of terminal requirements, judgement was used to settle the issue. The purpose of this task was to attain a reasonable representation of the future terminal requirements for planning the IDSD Phases A, B, and C computer system upgrade implementation scheme.

2.2.1 Assumptions Used

Due to the dynamic nature of the work performed on the CCF systems, it is very difficult to ascertain the long range terminal requirements. For this study the following assumptions were used to estimate these needs.

- Where terminal type was not specified by the user, increases were assumed to be for high speed terminals.
- The on-site/off-site terminal ratio would not change.
- Time sharing terminals can access the CCF via CENTREX and as many as five dedicated data lines.
- The terminal float population will change from 40 low speed terminals to 20 low speed and 20 high speed terminals by FY81.

2.2.2 User Projections FY79–FY85

Table A-2 (Appendix A) lists the projected user terminal population for the CCF computer systems for the years FY79 through FY85. Again this is broken down by system, division, and terminal mode ('LS' - low speed; 'HS' - high speed). The high speed terminal increases on the CYBER 74 are indicated to be Hazeltine 4000 terminals, however, the increases will either be Hazeltine 4000 terminals or Megadata terminals emulating the Hazeltine 4000.

The UNIVAC terminal 'float' population is projected to change from 40 low speed terminals in FY78 to 20 low speed and 20 high speed terminals in FY81. Remote I/O device changes indicate that both the U9300 and Mohawk devices will not be supported past FY80, and starting in FY81 600 line/minute remote printers will be integrated into the CCF.

Using BTN projections of terminal connect time requirements and available connect time statistics, estimates of the number of concurrently active users on each of the computer systems were computed. The average number of users connected was determined by dividing the weekly connect time estimates by 40 hours (8 hours/working day) and the peak number of concurrently active users was estimated at 125% of the average. Table 2.2.2-1 lists the average and peak numbers of concurrently active users by computer system through FY85.

2.2.3 Adjustments to Projections

Two adjustments to terminal projections described in the previous paragraphs are reflected in Table A-3 (Appendix A). These adjustments include:

- Low speed terminals on the UNIVAC computer systems that wear out will be replaced by high speed terminals. The wear out rate of low speed terminals is estimated to be 5% per year starting in FY82.
- The BTN requirements shows a flat projection in high speed Megadata type terminals from FY83 to FY85. With the projected increase in CCF computing capacity it was felt that there would probably be an increase in the number of new high speed terminals required over this period. For FY83 to FY85 a high speed terminal adjustment of 10% per year was added to the UNIVAC terminal projections.

Table 2.2.2-1 Concurrently Active Terminals

COMPUTER SYSTEM	CONCURRENTLY ACTIVE TERMINALS						
	FY79	FY80	FY81	FY82	FY83	FY84	FY85
UNIVAC							
• average	68	66	75	77	77	78	79
• peak	85	83	94	96	96	98	99
CYBER 74							
• average	14	24	26	28	32	34	36
• peak	18	30	33	35	40	43	45
IBM 360/65							
• average	23	23	23	23	23	23	23
• peak	29	29	29	29	29	29	29

2.2.4 New Systems Terminal Requirements

The four UNIVAC 1108 computers are scheduled to be replaced in three phases over the period FY81 through FY83. Phase A would have the capacity of two U1108's, Phase B would replace the other two U1108's and the final phase (Phase C) would result in a total replacement capacity of six U1108's. In order to plan for the terminal interface to the new computer systems, the number of terminals and remote I/O devices directed to these systems must be determined.

Tables A-2 and A-3 presented the terminal requirements for the UNIVAC computer systems. This grouping included the U1110 computer and the U1108 computers (or their replacements). Table 2.2.4-1 lists only those terminals and remote I/O devices projected for the U1108 computers (or their replacements). For many of the communications subsystem design options presented in this document the Phase C requirements (FY83) are used. The FY83 replacement systems communications requirements are illustrated in Figure 2.2.4-1.

Table 2.2.4-1 Replacement Systems Terminal Requirements (Summary by On/Off Site)

Category or Organization	Sept. 1978		POPULATION PROJECTIONS													
			FY79		FY80		FY81		FY82		FY83		FY84		FY85	
	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF
LOW S ED:	44	40	40	58	40	58	40	58	37	55	35	51	33	47	30	44
HIGH SPEED:																
MEGADATA	15	6	31	8	42	9	46	9	49	12	66	18	83	27	100	33
TEKRONIX	7	2	17	5	21	6	23	7	25	7	27	7	27	7	27	7
TOTAL HS	22	8	48	13	63	15	69	16	74	19	93	25	110	34	127	40
REMOTE I/O:																
Flight Design System	1		1		1		2		2		2		2		2	
Mohawk	1		1		1		0		0		0		0		0	
Printronix																
300 LPM	1	2	2	3	2	6	6	1	6	1	6	3	6	3	6	3
600 LPM							1	1	2	2	3	3	3	3	3	4
U9300		1		0		0		0		0		0		0		0
Total Remote	3	3	4	3	4	6	9	2	10	3	11	6	11	6	11	7

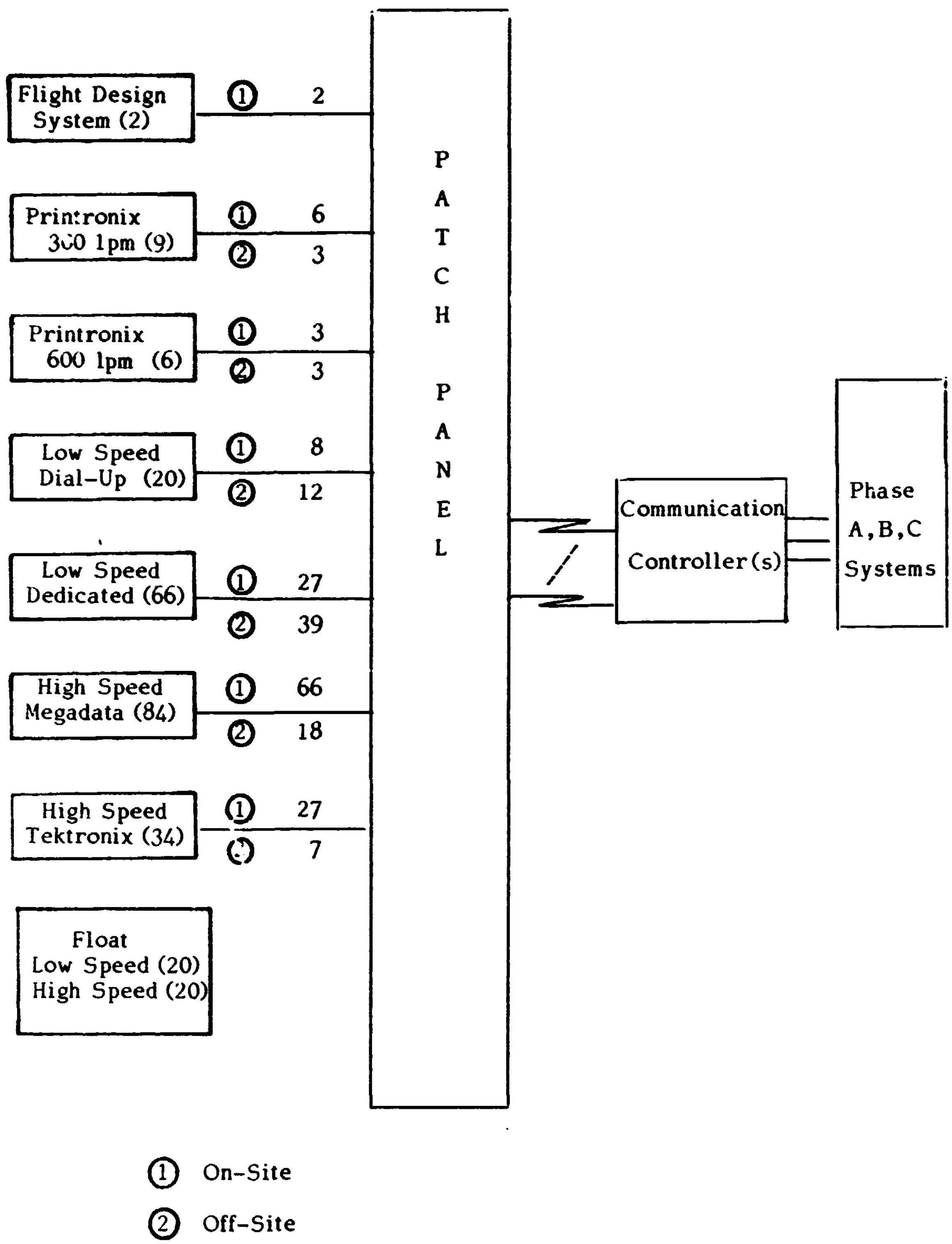


Figure 2.2.2-1 FY83 Replacement System Configuration

SECTION III
COMMUNICATION SUBSYSTEM DESIGN

3.0 INTRODUCTION

The Central Computer Facility (CCF) consists of a hetrogeneous mix of computer equipment from several manufacturers. The post - Phase C configuration will consist of computers from UNIVAC, CDC, IBM and possibly a fourth vendor. In this section the communication requirements of the replacement systems will be investigated along with the total requirements of the CCF facility.

3.1 Communications Concepts

Prior to any analysis of the future CCF communication requirements, a communications concept must be established. This concept describes the level of communications support expected of any candidate communication subsystem. Several items in the communications concept are described below.

Multiple Host Support: The communications subsystem should be able to operate in the environment of multiple hetrogenous computer systems.

Terminal Support: Terminals are defined either to be dedicated to a single host system or as general purpose with access to multiple hosts.

Patch Panel Operations: The patch panel will be kept for line monitoring and diagnostics. Manual patching will be allowed for abnormal circumstances only.

CENTREX Ports: Six dial-up ports will be available to the building 12 patch panel. All six dial-up ports could be assigned to one host at any time.

Communications Subsystem Failures: After any single component failure in the communications subsystem, acceptable degraded operations must be resumed.

Communications Subsystem Expandability: The communications subsystem should have the capability to expand support to one additional host computer and up to 50% more high speed terminals. This expansion should be accomplished through the purchase of additional hardware modules and should not require a complete subsystem redesign.

Sign-on/Sign-off: There should be a standard sign-on/sign-off procedure to an application or host. In addition, automatic hang-up detection and automatic disconnect features are required.

Load Leveling: Load leveling between dissimilar host systems will not be required.

Terminal-to-Terminal Communications: User-to-user terminal communications are not required.

Communications Software: No non-standard network management software is required.

Communications Subsystem Operator: A full-time communications subsystem operator should not be required.

Additional Communications Support Functions:

- error detection, correction, and logging
- network statistics
- access authorization

3.2 Current Communication Facilities

Communication lines to the UNIVAC systems, U1110 and U1108's, are connected to the building 12 patch panel and then are routed to one of the UNIVAC hosts via its Communications Terminal Module Controller (CTMC). This last connection to the CTMC may be permanently dedicated or may require operator intervention to perform manual patching for each session. Each CTMC is dedicated to one UNIVAC host and can control up to 32 lines. Currently, each U1108 has one CTMC and the U1110 has three CTMCs.

The IBM 360/65 word processing system utilizes a Memorex 1270 as the interface to its terminals. In addition, two low speed lines from the patch panel to the Memorex 1270 allow some UNIVAC terminals to be patched into the word processor.

The CDC CYBER 74 in building 30 has its own patch facility to interface its terminals. In addition, four high speed and four low speed lines from the building 12 patch panel to the CYBER 74 patch facility provide access to the CYBER 74 for those terminals normally terminating in building 12. Low speed lines to the CYBER 74 are routed through the 6676 Data Set Controller and the high speed lines are routed through the 2550 Network Processing Unit.

For the communications subsystem designs presented in the following paragraphs it is assumed that the communications facilities of the systems not scheduled for replacement (U1110, CYBER 74, IBM 360/65) will be available for future operations.

3.3 Communication Subsystem Considerations

The FY83 replacement system requirements will be used to configure the following comparisons. In addition to those terminal requirements listed in paragraph 2.2.4, two other groups of terminals are added. First, the float terminals (20 high speed and 20 low speed) are added to the general terminal population since they are available for assignment at any time. Second, the low speed timesharing terminals (5 dedicated and 33 dial-up) are also added to the general terminal population since they may be patched to the replacement systems. Figure 3.3-1 illustrates the modified FY83 terminal requirements for the replacement systems and Table 3.3-1 describes the terminal characteristics.

Several computer equipment manufacturers were contacted and presented with the requirements for the communication subsystem. Some vendors returned preliminary designs along with cost estimates while others supplied equipment specifications along with pricing information from which preliminary designs could be made. Exact cost comparisons of similar designs from different vendors are, in some cases, difficult. This is due to the fact that some designs will have slightly different options than others and some designs may not be compatible with different U1108 replacement system vendors (e.g. an IBM communication processor with a Burroughs host computer). For this reason, where possible, different communication design alternatives will include data from more than one vendor.

For most of the communication equipment presented in this section, maintenance is available from the vendor at a set cost. However, some vendors do not provide maintenance contracts but will fix any faulty component on order.

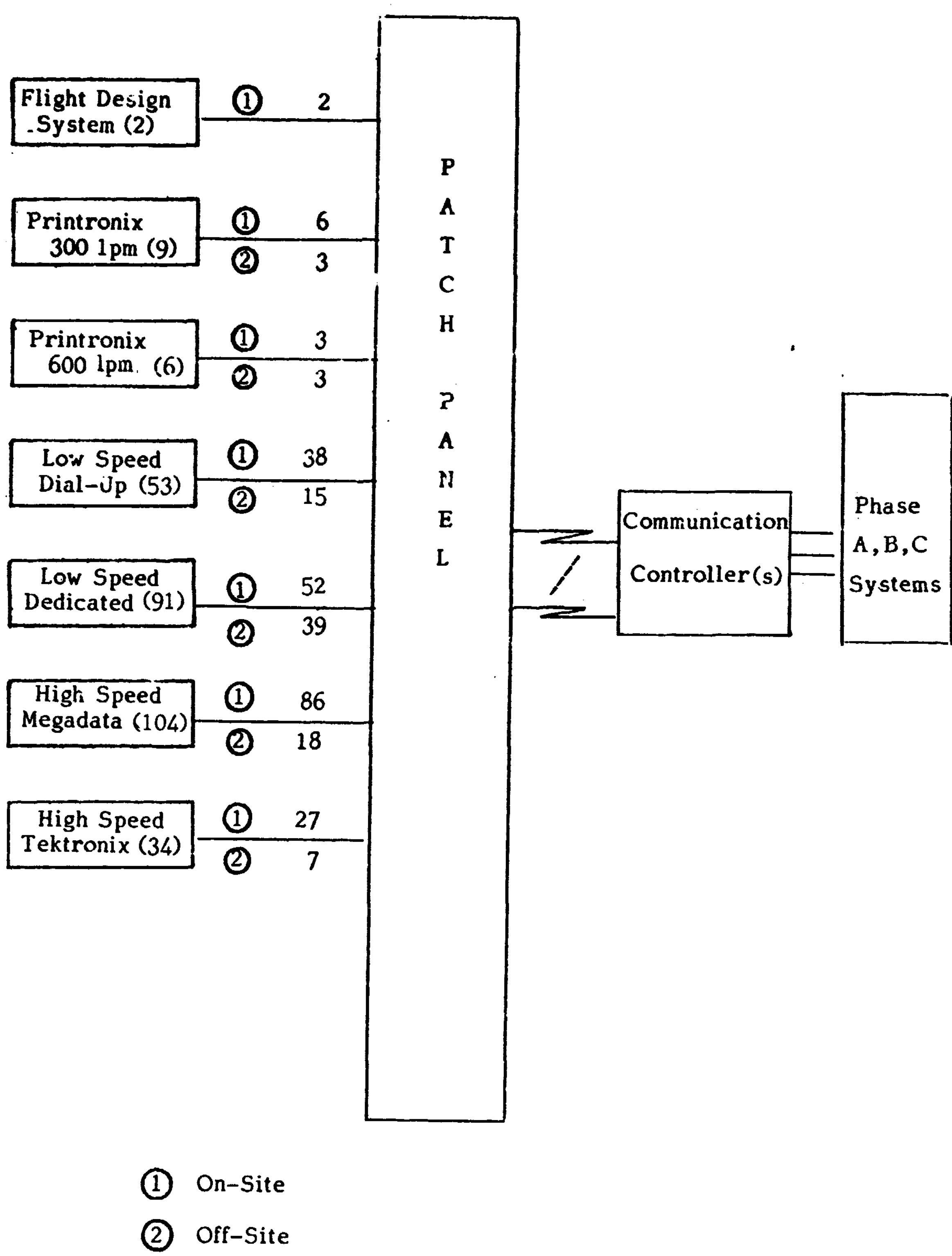


Figure 3.3-1 Modified FY83 Replacement System Configuration

Table 3.3-1 Replacement Systems Device Characteristics

DEVICE	MODE	SPEED	COMMENTS
Low Speed Terminals	asynchronous	300 bps	several manufacturers
Megadata Terminals	synchronous	to 9600 bps	emulating terminal
Tektronix 4014	asynchronous	4800 bps	graphics terminal
Flight Design System	synchronous	19200 bps	link to Interdata 8-32 in bldg. 30.
Remote Printers:			
PRINTRONIX 300 LPM	asynchronous	4800 bps	300 line/minute printer. Uses synchronous lines with sync to async converter.
PRINTRONIX 600 LPM	synchronous	9600 bps	600 line/minute printer.

This would require a spare parts inventory at JSC for the replacement of a failed component while the faulty component is sent to the vendor for repair. Since the actual maintenance costs under these circumstances would vary, a flat 1% per month (12% per year) of the equipment purchase price is added in determining the ten year life cycle costs.

3.4 Communication Options

The communication subsystem designs will be presented in two stages. First, individual subsystem components will be described. Next, using various component groupings, total subsystem designs will be evaluated

Four distinct types of subsystem components were investigated in this study. All but one of these types of components analyzed were available from more than one vendor. The four communication subsystem types presented are:

- port contention devices
- hardwired controllers
- front-end communication processors
- 'listen-while-talk' data bus

3.4.1 Port Contention Devices

The function of a port contention device is to switch 'N' input lines to 'M' communication ports where 'N' is usually greater than 'M'. Its functions are similar to an automated switchboard where the number of phones that could request service exceed the number of phone lines available. The exact contention ratio is a function of the average connectivity of the user terminals.

With this type of system, a terminal user establishes a connection with the port contention device and asks for service to a certain port type. Different port types are used for each host and for various terminal modes of operation. If a port of the requested type is available, a session is established and the terminal to port circuit is kept for the entire session.

This type of system provides several benefits:

- Since there is a virtual circuit to the host's port from the user's terminal, there is no added delay for message transmission.
- Terminals have access to all host computers attached to the port contention device.
- The port contention device is transparent to the host system.
- Since the number of input lines exceeds the number of output ports, the complexity and number of the host computer interfaces to the user terminal population are reduced.

Two types of port contention devices are described in the following paragraphs.

3.4.1.1 Gandalf Dual PACX III. The Gandalf Dual PACX (Private Automatic Computer Exchange) III is the largest of Gandalf's line of PACX systems. It has the capacity to service up to 510 input lines that will contend for up to 254 output ports. The output ports can be divided into several port groups (up to 63). These port groups can be dedicated to one host or spread out over several host systems.

The minimum Dual PACX III system contains one terminal board and one port board. This provides an interface for four input terminals to eight output ports. As needed, terminal boards and port boards are added until the maximum configuration is reached. With this system, synchronous support of up to 9600 bps and asynchronous support of up to 4800 bps can be provided.

Other Dual PACX III features include a statistics port to which an operator's terminal can be attached. An operator may then request system status reports or line activity reports, and can broadcast messages to the active user terminals. Initial connect time to a host port requires less than one second. After the circuit is established, no additional delays other than modem and line propagation delays are evident.

There are three methods available for a terminal to be routed to a port group. First, a default setting can be set in the PACX. Here, when the terminal is activated, an automatic request for a port group is issued. The terminal to port group default settings are stored in the PACX logic board memory. The memory can be loaded via the operator's console or can be down loaded from one of the host systems. This default setting can easily be changed by a directive from the operator's console. The second method available for port requesting is via a thumbwheel select unit. A port group number is selected on this unit and a toggle switch is set. The PACX will sense the thumbwheel settings and request an available port. Communications to passive polled terminals may require some type of thumbwheel unit to initiate communications with the PACX. The third method is the PACX keyboard select. Here the terminal user simply types in a coded series of characters to request a port group. Due to the differences between synchronous protocols, this third method is available only to asynchronous terminals.

Other options available to the PACX user include access restrictions and automatic queuing. Using the access restriction feature, specified user terminals can be prevented from accessing certain port groups. If a user's request for service cannot be satisfied because there are no available ports in the requested port group, a status message is sent to the user's terminal. With the automatic queuing option, the user may choose to go into a FIFO queue for service to the requested port group.

Figure 3.4.1.1-1 illustrates a possible CCF system configuration utilizing the Dual PACX III. Since the total number of ports required for all host systems would exceed the capacity of the Dual PACX III, full port selection would be available to the UNIVAC 1110 and UNIVAC 1108 replacement systems only. The CYBER 74 and IBM 360/65 would retain their own local networks. The PACX input lines would, however, be able to be linked to port groups dedicated to these other two systems. In this illustration, the communication lines for the remote printers, Adage terminals, and the Flight Design System by-pass the PACX and are directly connected to their dedicated host computer system.

The Dual PACX III system from Gandalf does not come with a service contract. Its modular design allows for substitution of parts to repair a failure. If a port board failed (8 ports) or a terminal board failed (4 terminals), it could be replaced in a few minutes without disrupting other communications. The failed

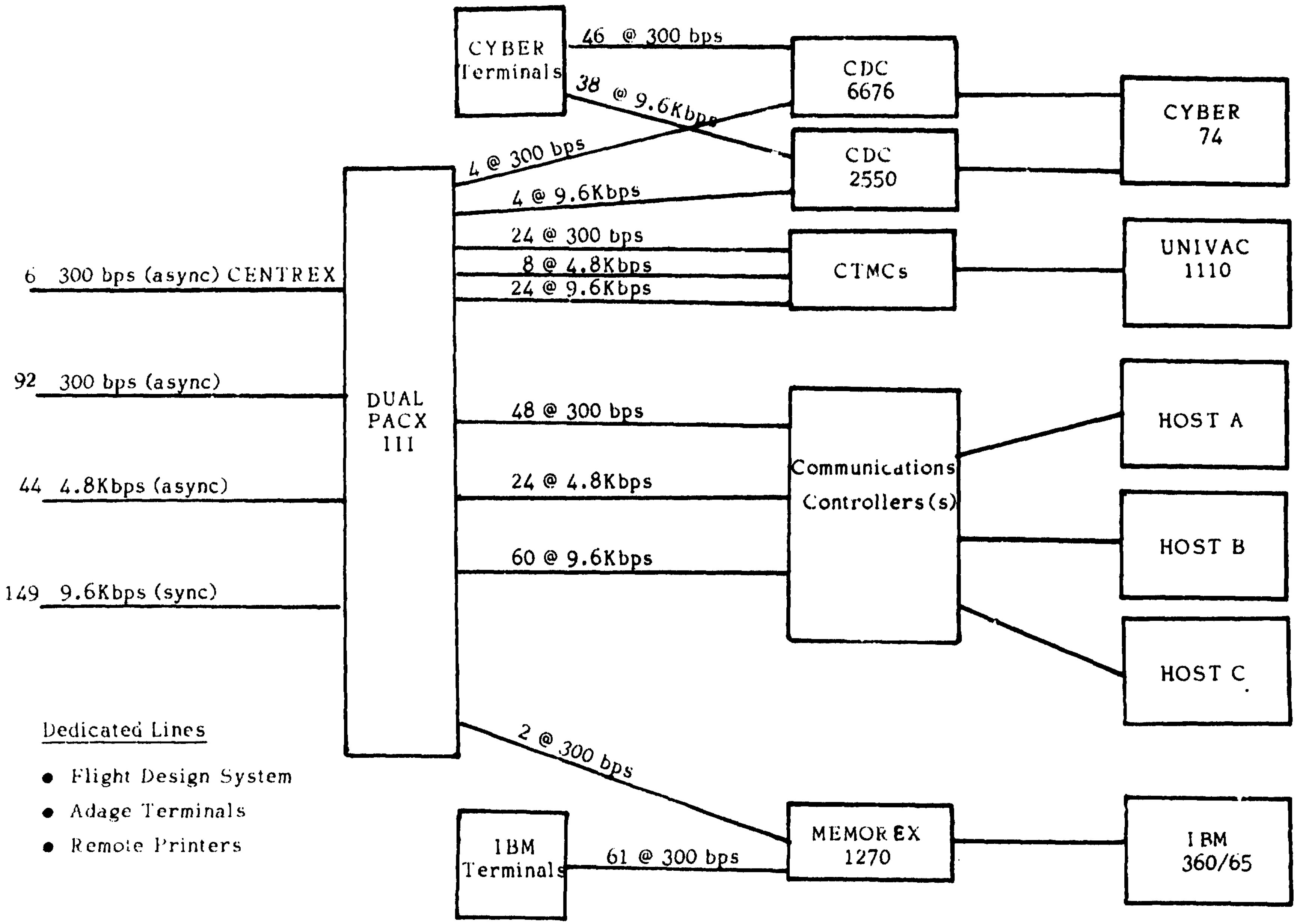


Figure 3.4.1.1-1 Dual PACX III Design

board would then be sent back to Gandalf for repair. There are two critical points of failure. If a power supply fails or the central logic board fails, all operations of the PACX would stop until the affected unit could be replaced. Again, with nearby spares this should take 5-10 minutes.

The cost figures for support of the configuration pictured in Figure 3.4.1.1-1 are presented in Table 3.4.1.1-1. The total cost, including spare parts and along with an available 5% discount, is approximately $119K. Referring to Table 3.4.1.1-1, the KCS/8 option provides the keyboard select option and allows up to eight users to request service simultaneously. It is assumed that the asynchronous terminals will use the keyboard select feature to request service. Since this feature is not available to the synchronous terminals, thumbwheel select units are used for those terminals that would require frequent access to more than one host system (estimated at 1/3 of the synchronous terminal population). The other synchronous terminals would default to specified port groups and, if necessary, could be routed to another port group via a directive on the PACX operator's console.

Other available port contention devices are similar to the Gandalf PACX system. Both Micom Systems and Develcon Electronics manufacture such systems. However, currently for both systems,full support is available to asynchronous terminals only. Synchronous terminals can be given limited support through special engineering modifications. Both manufacturers do expect to provide full support for synchronous terminals in future systems.

In addition to the PACX system, Gandalf also manufactures limited distance modems and provides terminal boards with built in modems that would interface to the user terminal via an external limited distance modem.

3.4.1.2 TRAN M3201A-2 Data Switch. The Computer Transmission Corporation (TRAN) M3201A-2 Data Switch performs the functions of a port contention device and network controller. Many of the features are functionally the same as those on the Gandalf PACX system. Features of the M3201A-2 include:

Table 3.4.1.1-1 Dual PACX III Costs (with spares)

ITEM	NUMBER REQUIRED	UNIT COST	TOTAL COST
Dual PACX III (KCS/8)	1	$21.2K	$21,2K
Port Boards			
APB II (asynchronous)	20	800	16.0K
SFB (synchronous)	15	1.1K	16.2K
Terminal Boards			
AMTB II (asynchronous)	45	600	27.0K
SMTB (synchronous)	40		27.0K
Thumbwheel Select			
TCU	50	250	12.5K
Spares and Options			
Queuing	3	500	1.5K
CB II logic board	1	1.7K	1.7K
KCS/SO-8	1	3.0K	3.0K
Battery	2	50	.1K
Power Supply	1	2.0K	2.0K
Total Cost			$125K
Cost with 5% Discount			$119K

- synchronous switching
- asynchronous switching
- port contention
- automatic queuing
- automatic speed recognition
- management statistics

The M3201A-2 was designed to be a node in TRAN's PACUIT network. This network combines distributed PACket with circUIT switching. It can, however, be used as a more localized port contention device as was the Gandalf PACX system.

User terminals can either be asynchronous or synchronous. A keyboard select feature is available for asynchronous terminals only. Synchronous terminals can either be dedicated to a port group or may be interfaced to any port group via on RTIU (Remote Terminal Interface Unit) in a manner similar to the Gandalf thumbwheel select unit.

The support design utilizing the TRAN M3201A-2 is pictured in Figure 3.4.1.2-1. Due to capacity and throughput limitations, two switches are required. These switches are connected via a high speed communication trunk line. The costs for this design are presented in Table 3.4.1.2-1. As with the Gandalf PACX design, one third of the synchronous terminals are provided with a port requesting device (RTIU). Total costs for this design including installation is $558K. TRAN would provide maintenance to this system at the rate of .9% per month of the purchase price ($59K per year).

The TRAN M3200 series of switching equipment provides wider networking capabilities than does the Gandalf PACX system. However, for the IDSD requirements, the PACX system would satisfy the requirements at much less cost.

3.4.2 Hardwired Controllers

The availability of hardwired controllers for future terminal support depends upon the manufacturer chosen to replace the U1108 systems. Most mainframe vendors are de-emphasizing the use of hardwired controller. Neither

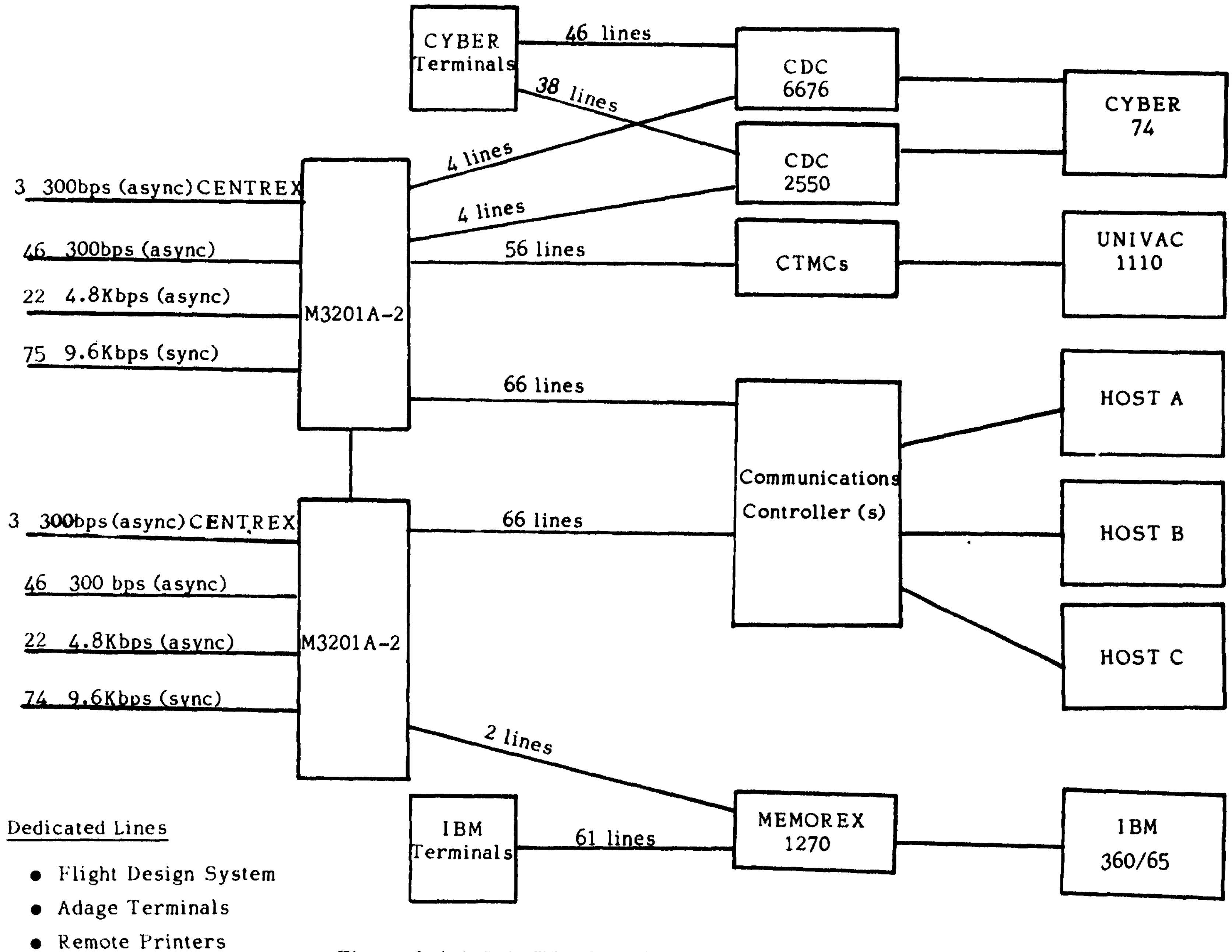


Figure 3.4.1.2-1 TRAN M3201A-2 Design

Table 3.4.1.2-1 TRAN M3201A-2 Costs

ITEM	NUMBER REQUIRED	UNIT COST	TOTAL COST
M3201A-2	2	$107.0K	$214.0K
Lime Modules			
Asynchronous	252	300	75.6K
Synchronous	237	525	124.4K
Cabinets	14	6.2K	86.8K
RTIU	50	900	45.0K
Trunk Card	1	1.2K	1.2K
TOTAL COST			$547K
Cost with 2% Installation Charge			$558K
Yearly Maintenance 10% of Total Cost			$59K/Yr.

IBM nor Burroughs Corporation could supply terminal support via such controllers. IBM's 2703 Communications Controller is currently under status D support. This means that the item is withdrawn from marketing.

If the replacement systems are Control Data Corporation mainframes, the 6676 Data Set Controller could service low speed asynchronous terminals while the 6671-3 Data Set Controller could service the high speed synchronous lines. However, neither device has been in production since 1976 and are supplied on an 'as available' basis. For the mix of terminals expected for future support the initial cost of the hardware would range from $1.9K to $2.0K per attached terminal.

UNIVAC Communications Terminal Module Controllers (CTMCs) are no longer being manufactured; however, its replacement,the General Communications Subsystem (GCS),is still under full UNIVAC support. The cost of CTMC or GCS subsystems to support the expected terminal mix would average $3.2K to $3.4K per attached terminal.

Hardwired controllers are cost efficient in low volume terminal systems. In large scale communications systems with the future IDSD terminal mix, the costs for hardwired controllers, if available at all, would actually be greater than that of programmable communications processors. Using a port contention device would reduce the number of ports required and, thus, the controller costs.

In addition to the above disadvantages of hardwired controllers being used for terminal support on the replacement computer systems, other disadvantages include:

- added host communication overhead
- no centralized control for terminal routing
- no redundant communication paths.

3.4.3 Front-End Communications Processors

Front-end communications processors (FECP) are used to replace hardwired controllers as the interface between the user terminals and the host computer system. These systems are programmable by the vendor to assume many of the communication functions previously performed by the host CPU. Some FECP also provide facilities for the user to add special purpose programs.

Among the FECP functions are included:

- communication line interfacing to the host
- off-load many communication functions from the host
- data conversion
- error detection and correction
- status monitoring
- statistics recording
- providing redundant data links to the host systems
- providing terminal access to multiple host systems

In the following subsections, FECP from five vendors will be described. The configurations and costs should be considered as guidelines only. Direct comparisons will not always be valid due to different FECP options included in the designs. Some FECP are user programmable, some can share host memory and disc storage, still others may have automatic switchover if a component fails. While several of the FECP attributes may vary, of the five FECP systems investigated four are functionally equivalent. The other system has unique features and is presented separately.

The FECP shoud not be considered as a special item but rather as part of the UNIVAC 1108s replacement. The FECP works in conjunction with the host system. FECP systems of one computer mainframe manufacturer generally are not compatible with those of other manufacturers. There are, however, independent FECP manufacturers that will interface their equipment to various host systems.

3.4.3.1 <u>FECP System Designs</u>. Four FECP systems will be considered in the following paragraphs. While there are several differences in the electronics involved and in some of the features and peripheral devices that may be connected, the conceptual designs of these systems are very similar. Line adapters interface the user terminals to the processing unit via a high speed scanning unit. The line adapters are dedicated to a single FECP and cannot be directly routed to another. Inter-FECP communications may, however, take place via a high speed data link. The processors themselves are linked to one or more host computers by channel adapters.

The terminal support requirements are illustrated in Figure 3.3-1. In the following four FECP system designs, it is assumed that there will be three host computers supported by two FECP units. As illustrated in Figure 3.4.3.1-1, the user terminals would be connected from the patch panel to the two FECP units, half directed to each unit. With this configuration, any terminal may communicate with any host. In the event of an FECP unit failure 50% of the user terminal population would become unavailable for support.

3.4.3.1.1 Comten. Comten Inc. is a manufacturer of IBM compatible FECP. These FECP will interface via channel adapters to the various IBM mainframes. Operating as a front end system, it relieves the host CPU from such processing functions as line control, polling, addressing, code translation, and error recovery.

For the projected terminal population Comten model 3670-F1 was configured using data provided by Comten. Table 3.4.3.1.1-1 lists the components and associated prices of this system. The total initial cost of this configuration would be $369K with a yearly maintenance and software cost of $20K.

Each asynchronous line controller, A-MIM, can handle up to 8 line adaptors each with two attached line. Asynchronous support via the A-MIM is limited to 1800 bps. Therefore, for Tektronix asynchronous support at 4800 bps, F2053-C1 start/stop adapters were used in conjunction with the synchronous line controller, BSC-MIM.

3.4.3.1.2 Control Data Corporation. The Control Data Corporation 2552-2 Network Processing Unit (NPU) consists of a communications processor, memory, multiplex loop controller, and interface adapters. Throughput is nominally rated at 25000 characters per second. Maximum connectability is 127 Communication Line Adapters supporting up to 254 communication lines.

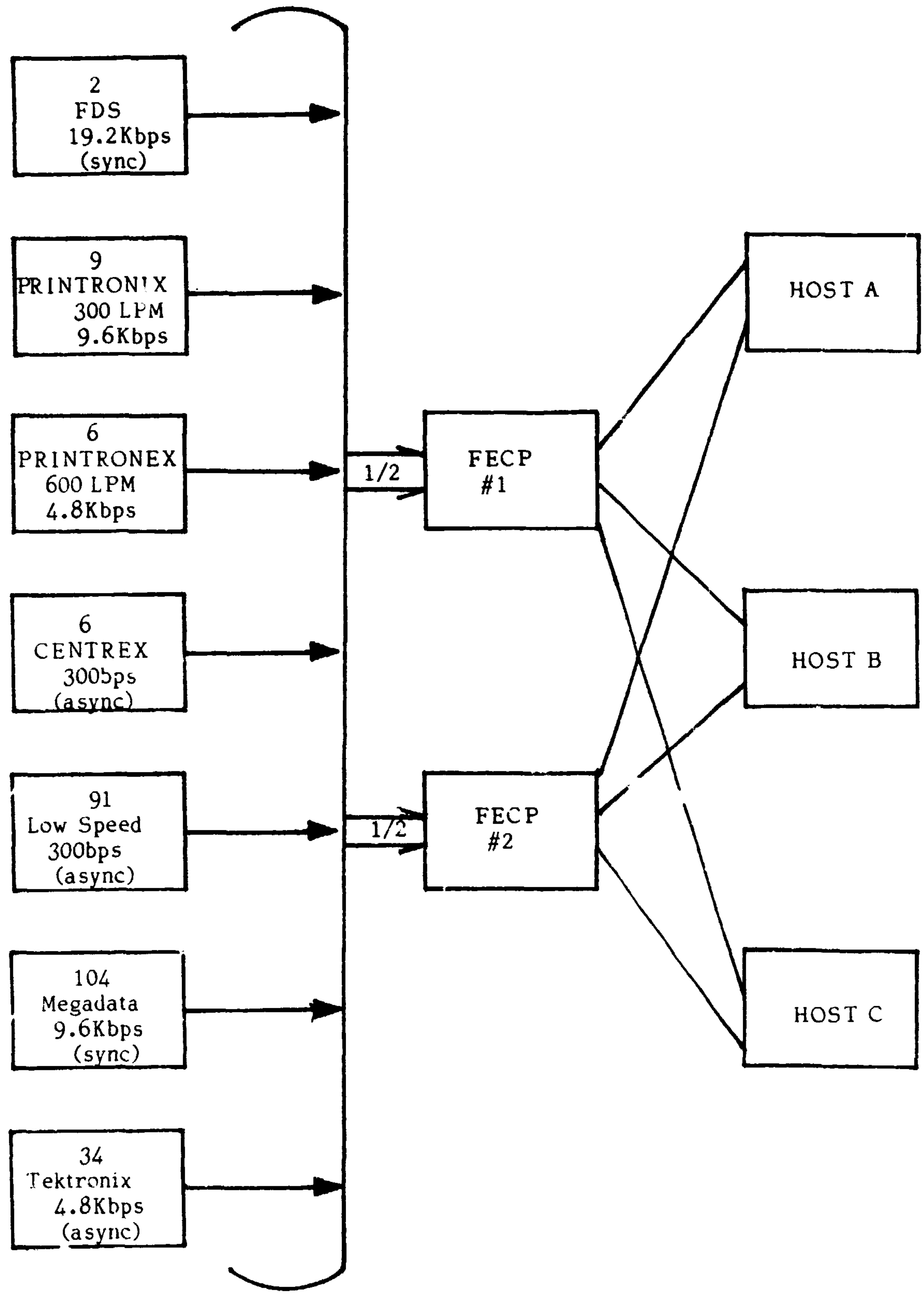


Figure 3.4.3.1-1 Standard FECP Design

Table 3.4.3.1.1-1 Comten FECP Costs

ITEM	NUMBER REQUIRED	UNIT COST	TOTAL
T3670-F1	2	$ 83.5K	$167.0K
F3602-A1 (memory expansion)	4	9.3K	37.0K
T3018 (channel adapter)	4	7.4K	29.7K
F1034-A1 (program loader)	2	1.3K	2.5K
T4008 (console)	1	3.5K	3.5K
F0002 (console switch)	1	.1K	.1K
F1027 (interface module)	2	2.1K	4.2K
Asynchronous Control			
T2016-A2 (A-MIM)	7	3.6K	25.2K
F2072-A1 (line adapter)	49	.2K	9.3K
Synchronous Control			
T2018-A2 (BSC-MIM)	10	6.5K	65.0K
F2053-A1 (sync)	60	.3K	19.2K
F2053-C1 (async → sync)	17	.3K	5.4K
F2064-A1 (wideband)	2	.6K	1.2K
TOTAL COST			$369K
Maintenance and Software Costs			$ 20K/Yr.

Table 3.4.3.1.2-1 lists the 2552-2 NPU system components required to support the projected FY83 replacement system configuration. Total initial cost for hardware is $375K and the service costs amount to $34K per year.

3.4.3.1.3 IBM Corporation. The IBM 3705 Communications Controller can contain up to 512K bytes of memory and can control up to 352 half-duplex communications lines (176 full-duplex). The maximum line speed serviced is 57.6K bps. Depending upon the number and type of communication lines to be serviced, varous combinations of communication scanners and line interface bases can be configured.

The network control program (NCP) is loaded into the 3705 and relieves the host of much of the communications and network control functions such as:

- polling and addressing
- data link control
- error recovery
- buffer control
- character assembly and disassembly.

A licensed version of the network control program is the ACF/NCP/VS (advanced communications function for the network control program/virtual storage). This software product works with the host access method to provide networking in accordance with the concepts of the system network architecture (SNA).

Using their in-house network configurator, IBM's estimate of the FY83 network cost is $447K initially and $27K per year for software products and maintenance. It was pointed out by IBM consultants that by multidropping the 104 Megadata communications lines into twenty-six lines with four drops each, the resulting network costs would be reduced to $350K initially and $24K per year. With multidropping, communication lines effectively share the FECP line adapter and transmit only in response to a polling request from the FECP. With only four terminals multidropped per line, total polling delays should be small. This multidropped terminals would have to be dedicated to the replacement systems and could not individually access the U1110 and CYBER 74, the comparisons in this section will use point-to-point communications only.

Table 3.4.3.1.2-1 CDC 2552 Costs

ITEM	NUMBER REQUIRED	UNIT COST	TOTAL COST
CDC 2552-2 NPU	2	$ 73.4K	$146.8K
2554-32 (memory expansion)	6	9.9K	59.4K
2556-10 (expansion cabinet)	2	6.0K	12.0K
2556-11 (line expansion)	4	4.0K	16.0K
2558-3 (host connect)	6	3.9K	23.6K
752-10 (console)	1	1.7K	1.7K
753-10 (printer)	1	2.5K	2.5K
Line Adapters (2/unit)			
2560-1 (sync)	60	.9K	51.2K
2560-1 (wideband)	1	.9K	.9K
2561-1 (async)	66	.7K	43.4K
Cables			
10401 (sync)	119	72	8.6K
10402 (wideband)	2	350	.7K
10400 (async)	131	64	8.4K
TOTAL COST			$375K
Maintenance and Software Costs			$34K/Yr.

Table 3.4.3.1.4-1 UNIVAC DCP Costs

ITEM	NUMBER REQUIRED	UNIT COST	TOTAL COST
8579-83 DCP	2	$40.7K	$81.4K
F2224-00 memory expansion	6	3.6K	21.6K
-01 memory expansion	6	1.8K	10.8K
F2223-01 (multiport)	2	4.0K	8.0K
8406-99 (diskette)	2	5.0K	10.0K
3536-86 (console)	1	7.0K	7.0K
8541-76 (printer)	1	2.6K	2.6K
F2691-00 (RIOC)	2	18.0K	36.0K
1928-03 (Type II Scanner)	4	23.0K	92.0K
F2263-00 (line adapter chassis)	4	2.4K	9.6K
F1801-01 (line base)	16	.6K	9.6K
F1825-02 (line indicator)	16	.4K	7.0K
Line Adapters			
F1828-00 (async)	131	.6K	78.6K
F1826-00 (sync)	119	.8K	90.4K
F1830-00 (wideband)	2	.9K	1.8K
TOTAL COST			$ 466K
Maintenance			$35K/Yr

3.4.3.1.4 UNIVAC. UNIVAC's Distributed Communications Processor (DCP) supports a direct channel interface to a host system and provides software controls for the transfer of data between the host and the communications network. The DCP also relieves the host system of much of the network management functions.

A DCP system consists of a processor, memory, line multiplexor, and other communication components. The RIOC (remote input/output controller) controls data transfer between the main memory and external equipment. Up to 128 half-duplex lines (64 full-duplex) can be attached to each of the three possible Type II Scanners available with each DCP. This makes the total line capacity 384 half-duplex (192 full-duplex) lines. With either the Type II Scanner or the RIOC the multiport feature is required.

As seen in Table 3.4.3.1.4-1 the total DCP system costs would be $466K with yearly maintenance costs of $35K per year.

3.4.3.2 Burroughs DCP. The Burroughs Data Communications Processor (DCP) performs the same function as do the other FECP investigated. However, its architecture and special features differentiate it from the previously discussed systems. Figure 3.4.3.2-1 illustrates the system configuration for the FY83 replacement system support. For this design it is assumed that host system is one of the Burroughs multiprocessor B7800 computer systems. Equivalent support could be provided to multiple B6800 computer systems. The various subsystem components are described below.

Each DCP can connect to a host I/O processor and contains four cluster control positions. A cluster position can control four Adapter Cluster II's or one Basic Control. In the FY83 design, each of the four DCPs uses two cluster controls in a primary mode and the other two as secondary connections to two other clusters. For example, DCP 1 and DCP 2 have the same four clusters attached and likewise for DCP 3 and DCP 4. This scheme provides for full cluster backup control. In the event of the failure of DCP 1, DCP 2 would automatically assume control of all attached clusters. With the previous FECP examples, if one FECP unit failed, 50% of the terminal support would be lost.

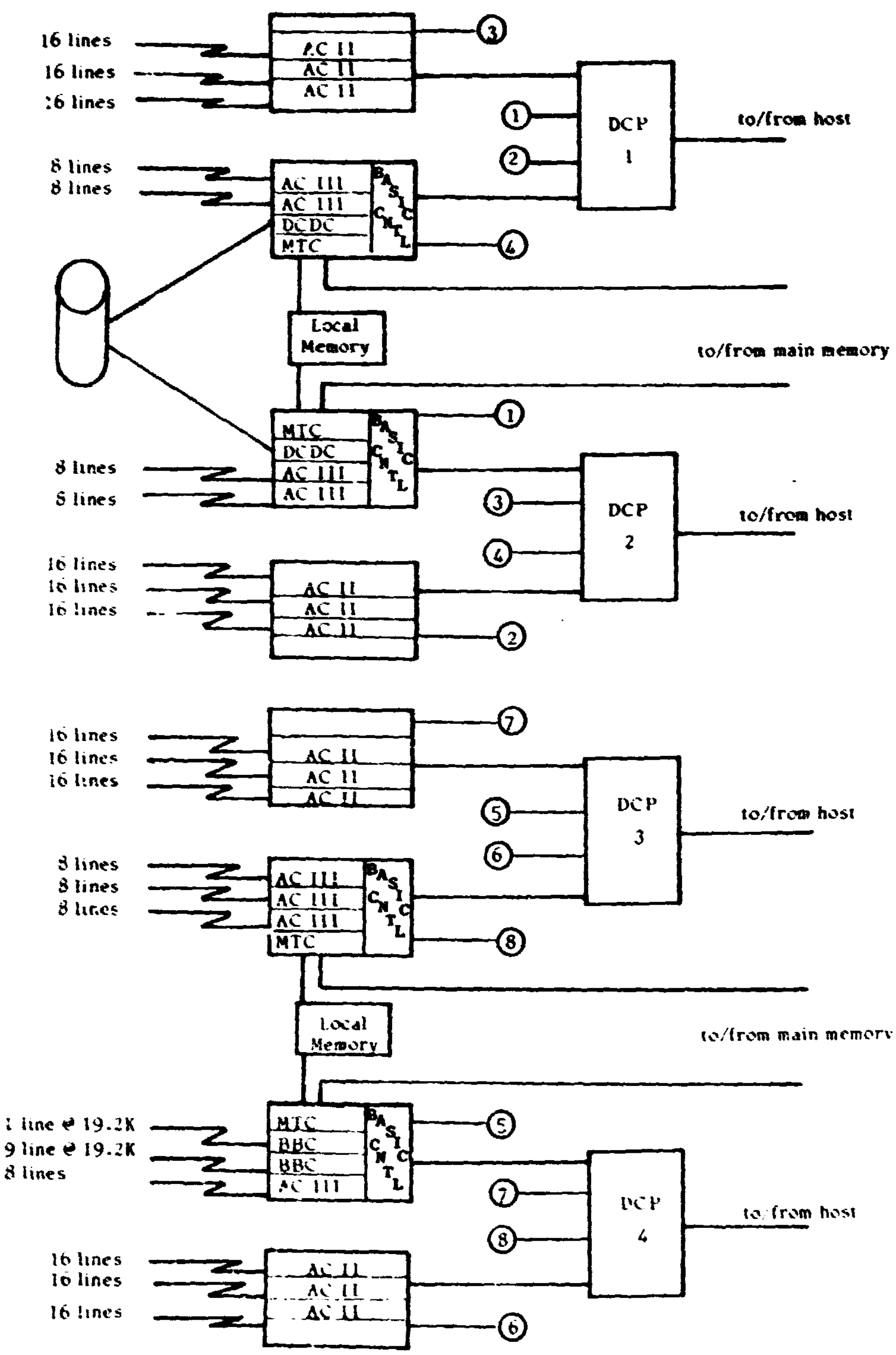


Figure 3.4.3.2-1 Burroughs DCP Design

The Adapter Cluster II is used to interface line adapters to a DCP module. Without the backup scheme described above, one DCP could interface to sixteen Adapter Cluster II's. A full-duplex line requires 2 line adapters while a half-duplex line requires only one.

Basic Control provides an interface between various front-end controls and the DCP. Each Basic Control requires one of the four available interface positions in the DCP.

Data Communication to Disk Control (DCDC) allows a DCP to access one of the host system's disk units. This feature is useful for message logging and for system backup.

Memory-to-Memory Control (MTC) provides the DCP access to local memory and allows block transfer between local and host memory without DCP control. This is designed to improve system throughput.

The Adapter Cluster III can control up to eight full or half-duplex data lines. This feature operates under Basic Control not directly under DCP control.

Broadband Control (BBC) also operates under Basic Control and handles one data line ranging in speed from 19.2K bps to 1344K bps.

The ACII and ACIII line adapters can communicate with lines ranging in speed from 300 bps to 9600 bps with either asynchronous or synchronous operation. The line adapters are programmable by the DCP for the specified mode of operation.

The cost figures for the design proposed in Figure 3.4.3.2-1 are contained in Table 3.4.3.2-1. The initial cost of this design is $1511K with yearly maintenance costs of $64K. The costs could be significantly reduced by eliminating some of the optional features as the DCDC and reducing the full backup capabilities.

3.4.3.3 FECP Redundancy Considerations. Except for the Burroughs FECP design which offered built in redundancy features, with any of the other four designs presented, a loss of one of the two FECP units would result in a 50%

Table 3.4.3.2-1 Burroughs DCP Design Costs

ITEM	NUMBER REQUIRED	UNIT COST	TOTAL COST
DCP	4	$ 35.8K	$143.4K
B7359-3 (local memory)	2	148.3K	296.6K
B7353 (Basic Control)	4	8.3K	33.2K
B7353-7 (MTC)	4	9.9K	39.6K
B7353-6 (DCDC)	2	12.4K	24.7K
B7353-1 (BBC)	2	10.4K	20.8K
B7353-8 (AC III)	8	10.9K	87.0K
B7359-5 (AC II)	12	9.9K	118.7K
B7353-3 (BSC adapter)	2	2.2K	4.5K
B7353-9 (AC III adapter)	64	2.2K	142.4K
B7353-11 (AC II adapter)	192	2.2K	427.2K
B7359-6 (expansion cabinet)	10	17.3K	173.0K
TOTAL COST			$1511K
Maintenance (40 hours/week)			$ 64K/Yr.

network loss. If this loss potential is too great other means could be applied to reduce the maximum loss due to any single FECP failure. Three methods are described below.

Since two FECP units provide 50% failure protection, by adding more FECP units each handling a certain portion of the communications lines any desired percentage of failure protection can be implemented. For example,to achieve a 90% failure protection, a system of ten FECP units would be needed. If one of the ten units failed,90% of the communication lines would be unaffected. The problems with such a solution are, first, the total system cost and, second, the physical space required for ten such FECP units.

A second method to provide backup would be to use the two FECP design but now use a third unit to act as standby. If one of the two primary FECP fails, the standby unit would be switched into the network to support the communication lines of the failed FECP. The backup design is illustrated in Figure 3.4.3.3-1.

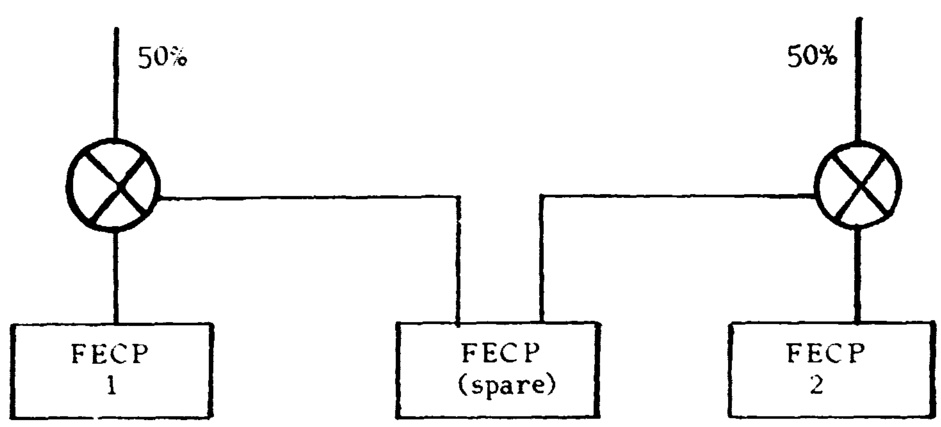


Figure 3.4.3.3-1 Spare FECP Design

In this design FECP units 1 and 2 each support half of the communications lines. If one unit fails, its lines would be switched over to the spare FECP.

The third backup design is similar to the second, using backup switching. However, with this design a spare FECP is not used, instead each of the two FECP are configured to support the entire set of communications lines. At any time only half of the lines are directed to either FECP unit. In the event of a failure, the lines from the failed FECP would be switched over to the other unit. This backup design is illustrated in Figure 3.4.3.3-2.

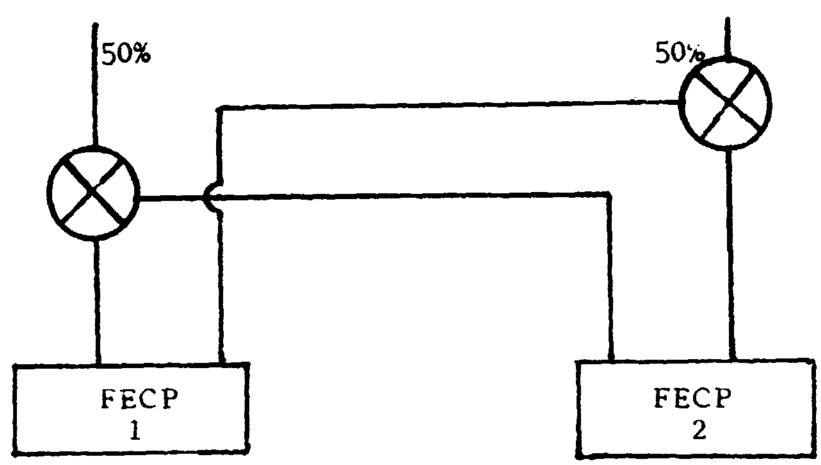


Figure 3.4.3.3-2 FECP Backup Design

The added cost of this design would be in line adapters and scanners for the two FECP. Additional costs for the banks of manual fallback switches would be approximately $200 per switch. Such vendors as T-bar and Atlantic Research manufacture RS232-C compatible fallback switches.

Of the three backup designs presented, the last one would be the least expensive to implement. However, its added costs would be approximately 60% to the initial system costs and 40% to the yearly maintenance costs. In subsection 3.5 which presents complete communications subsystem designs, it will be shown that added backup reliability can be obtained for no extra cost by using one of the port contention devices described earlier.

3.4.4 <u>CSMA Bus</u>

The Carrier Sense Multiple Access (CSMA) bus communication system was developed by the MITRE Corporation to satisfy the requirements of communications systems consisting of a large number of subscribers. Such a system is currently operational at MITRE headquarters in Bedford, Mass. and will be installed in such government facilities as the new Walter Reed Medical Center in Washington, D. C. The Trend Monitoring System (TMS) located in building 30 at JSC utilizes this technology to link several graphics systems to a MODCOMP IV/35 computer. The TMS will be used during OFT to monitor certain space shuttle operating parameters.

Multiple access means that all bus subscribers share the data channel and have access to all information on that channel. Carrier sense means that before a subscriber starts a message transmission the channel must be checked. If the channel is busy the subscriber waits before transmitting. Even after the channel is checked and found free for transmission, two subscribers could initiate transmission at approximately the same time. For such a possibility, a listen-while-talk feature is employed. After transmission is started each subscriber listens to the channel for their own message for at least the maximum propagation delay of the system. If two transmissions have had a collision the messages would be garbled; recognizing this, both subscribers would wait random intervals before transmitting again.

Some of the features of such a bus system are:

<u>Standard network interface:</u> All subscribers, terminals and host computers, have a standard network interface. The BIU, bus interface unit, interfaces the communication lines to the bus. The bus side interface is identical for all BIUs, however, the subscriber interface is matched to the subscribers operating mode and protocol.

<u>High bandwidth:</u> Channel bandwidth of one mega-bit per second will be available. Due to the CSMA with listen-while-talk feature the availability of this bandwidth will be high.

No single point of failure: If a BIU fails, the subscriber loses access to the bus. For critical subscribers, such as the host computers, dual BIUs can be used.

Centralized network control: The NCE, network control element, is a minicomputer system that has the function of regulating network operations. It would contain subscriber and application information, handle log-on/log-off functions, log errors, and provide network statistics.

Reduction in host FECP complexity: The bus would require only two FECP ports to each host, one primary and one backup. Special software would have to be produced for the FECP to interface to the BIU.

Easy expansion: To add additional subscribers to the bus system, an additional BIU is all that is needed.

Expanded JSC support: The transmission media for the bus system is CATV cable. This cable system could be run to any building in the JSC complex. The bus could then be used for computer-to-computer transmission, electronic mail, and various functions associated with the 'office of the future' concept. In addition, only a very small portion of the cable bandwidth would be needed for data communications, the remainder could be used for voice and video traffic.

Two bus designs for JSC support are considered. The first, Figure 3.4.4-1, is integrated into the communications system between the existing patch panel and the various host FECPs. All lines terminate at the patch panel as today and are then interfaced to the network via a BIU. The CATV cable is connected to all IDSD hosts in both building 12 and building 30.

The second bus design, Figure 3.4.4-2, is equivalent to the first for all off-site lines. All on-site buildings requiring service, approximately fifteen, would be directly wired into the bus system. For the terminals in these buildings the BIUs would directly link them to the bus, eliminating the need for pairs of modems to link a terminal to the bus via the patch panel. This design would also facilitate expansion to other computer systems in these buildings.

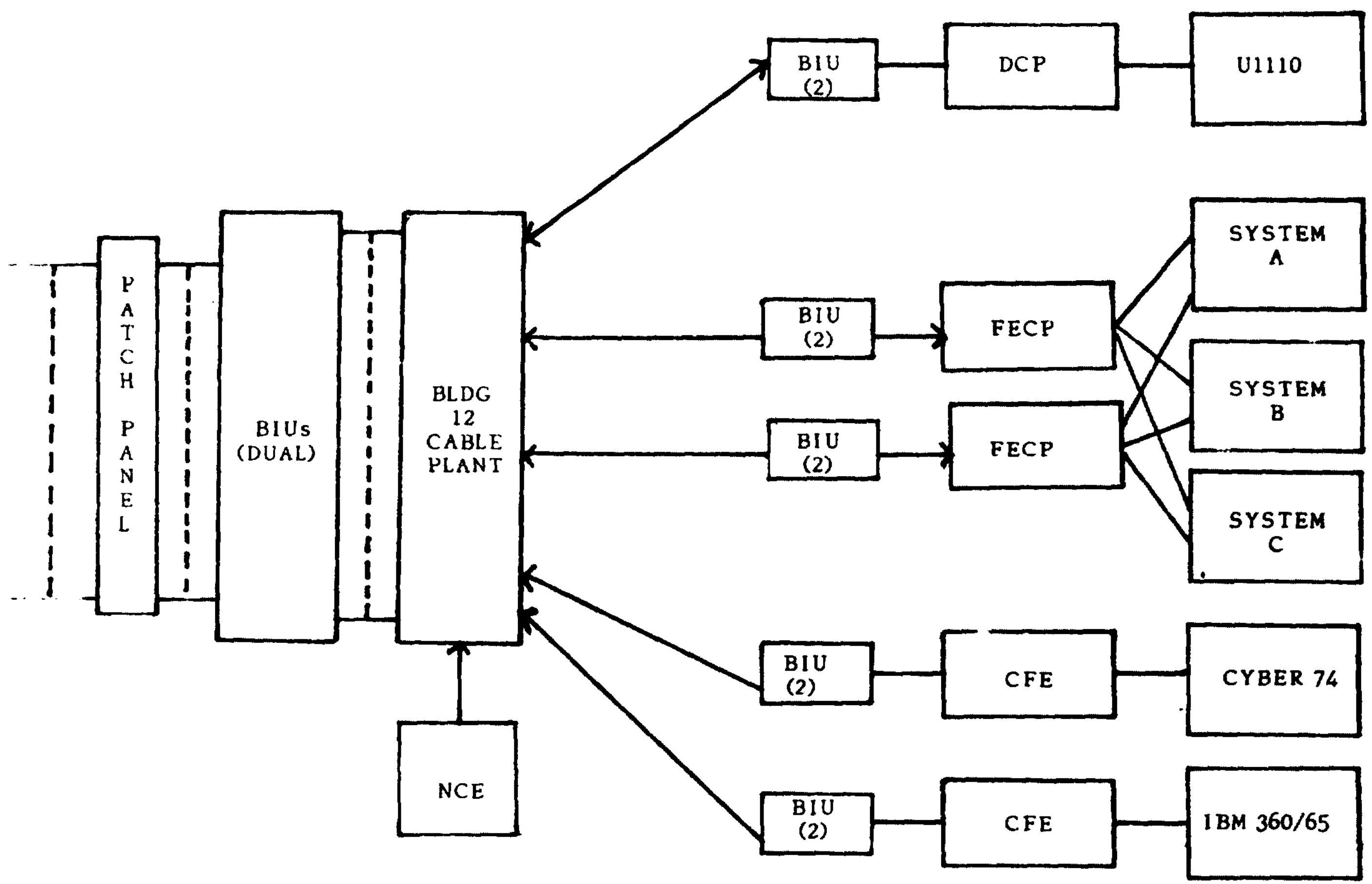


Figure 3.4.4-1 CSMA Bus Design – Limited On-Site

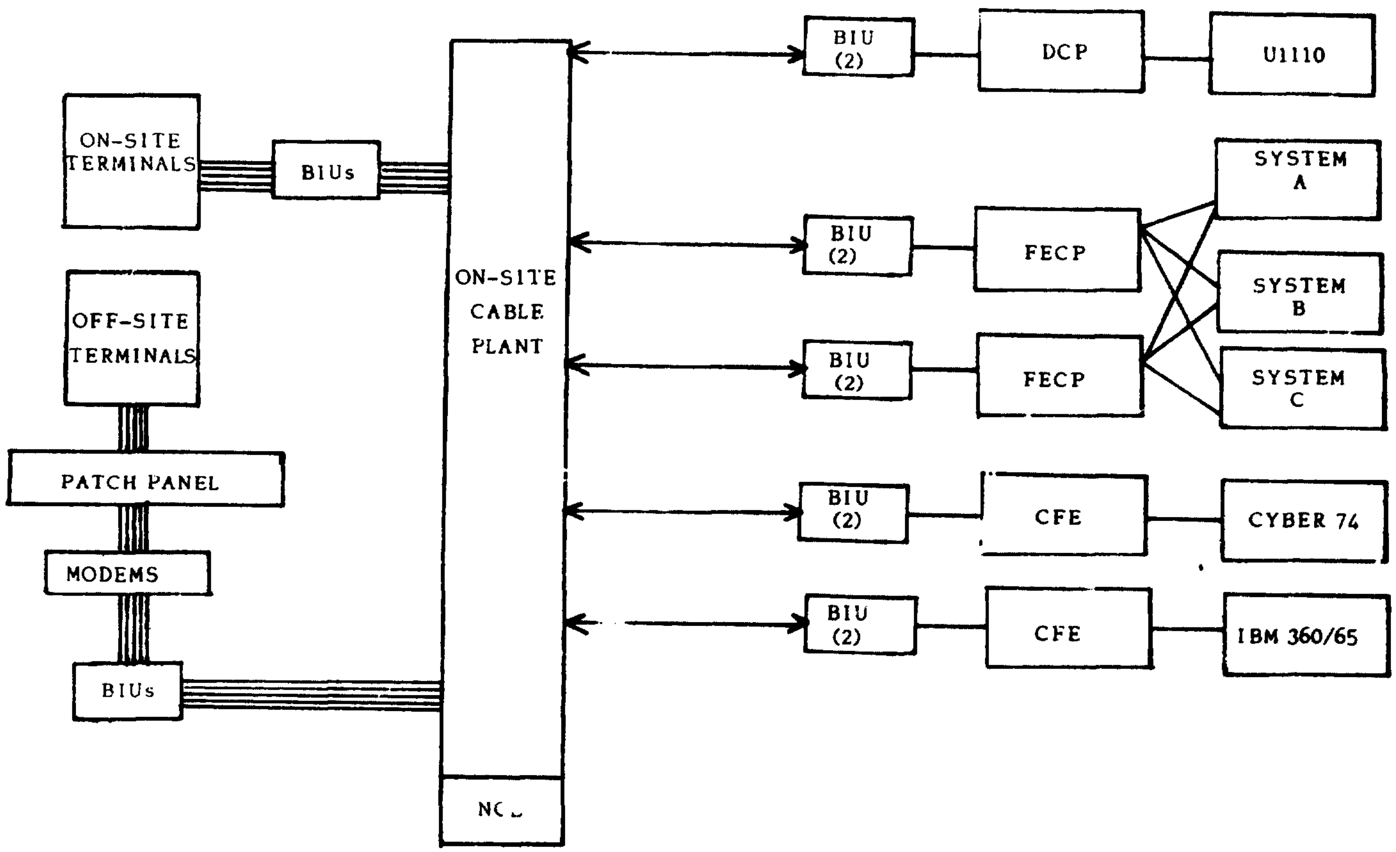


Figure 3.4.4-2 CSMA Bus Design - Full On-Site

Since the UNIVAC CTMCs are not programmable, bus service to the U1110 would require either bus software to reside in the U1110 or that the CTMCs be replaced with a programmable front-end processor. For these designs, it is assumed that the residual value of the three CTMCs would be sufficient for the purchase of a UNIVAC DCP. Another option would be to utilize one of the existing UNIVAC Communications/Symbiont Processor (CS/P) as a front-end to the U1110.

The costs of the two network designs are listed in Table 3.4.4-1. Each BIU has two ports available for user data lines. The BIU population of 290 provides for isolated terminals using only one port and for available spares. The host BIUs would require some special engineering and are priced separately. Cable costs include the costs of the physical CATV cable, amplifiers, and cable drops along with cable installation. NCE hardware costs are for a fully redundant minicomputer system with peripheral devices. The system engineering costs include NCE software, BIU software, FECP software, cable engineering, and system integration costs. The cable enginnering cost of the full on-site design is larger than the limited design.

Since maintenance on the bus system would be performed by NASA personnel or contractor personnel, certain maintenance costs must be included. An initial investment of approximately $50K would be needed to fully equip a bus test facility. This would be a test and repair facility for the various bus components. Digital test equipment such as a logic analyzer would be required for servicing the microprocessor controlled BIUs. A recurring expense for a four person maintenance group is estimated to be $175K per year. Two people would be responsible for software maintenance and development and two others for hardware maintenance and development (one engineer and one technician).

The cost of the limited bus system is substantially less than the full on-site design. However, with the on-site system, there would be much savings in line and modem leasing costs. Estimates of these and other savings will be detailed in subsection 3.5.3.

3.5 Integrated System Design

After having analyzed several communication system design options,

Table 3.4.4-1 CSMA Bus Costs

ITEM	ON-SITE OPTION LIMITED	FULL
BIUs		
Terminal (290 @ $1100)	$ 319K	$ 319K
Host/FECP (10 @ $2000)	20K	20K
Cable Costs	30K	220K
Network Control Element (redundant)	100K	100K
System Engineering	450K	480K
• NCF software	(120K)	(120K)
• BIU software (terminal)	(60K)	(60K)
• FECP and BIU software	(180K)	(180K)
• Cable engineering	(30K)	(60K)
• System integration	(60K)	(60K)
Test Facility	50K	50K
Total Cost	$ 969K	$ 1189K
Maintenance	$ 175K/yr	$ 175K/yr

the next step is to integrate the available options with each other and with the host computer systems. In the following paragraphs several such full system designs will be considered.

3.5.1 FECP Design

This design is basically the same as that presented in subsection 3.4.3. Here the patch panel is retained to connect terminals to the various host front-end processors. This design is used for illustrative purposes since it does not satisfy the communication concept that the patch panel be retained for test purposes only. With this design a full time operator to manually patch communication lines is required.

The costs for these types of systems are listed in Table 3.5.1-1 for the various vendor types. Also included in the ten year life cycle costs is the cost of the operator services for ten hours per day (1.25 shifts). An additional cost added is the cost of system integration. Included here is $100K for actual one-time costs associated with generating the first operational network. An extra cost of $100K is added to all systems, except UNIVAC, for protocol handling software. This software is currently operational on the U1108 systems to support such remote I/O devices as the Flight Design Systems and the remote printers. In addition,a maintenance charge of 1%/month (12%/year) is added to all systems for support of this software.

Software for the systems to be retained (U1110, CYBER 74, and IBM 360/65) would not have to be developed. Support of these systems would continue as is performed today.

3.5.2 Port Contention Device/FECP Design

By using a port contention device to link the user data lines to the host front-end processors, the need for an operator for manual line patching is eliminated. Additionally, since the number of FECP ports required will be reduced, the cost of the FECP will be lowered. For the pricing comparison in Table 3.5.2-1 the cost of the Gandalf Dual PACX III system is included. Included is a yearly 12% maintenance charge.

Table 3.5.1-1 FECP Full Support Costs

VENDOR	FECP	OPERATOR	SYSTEM INTEGRATION	10-YEAR COST
Burroughs	$1511K 64K/yr	--- 25K/yr	$200K 12K/yr	$2721K
Comten	$ 369K 20K/yr	--- 25K/yr	$200K 12K/yr	$1139K
Control Data Corp.	$ 375K 34K/yr	--- 25K/yr	$200K 12K/yr	$1285K
IBM	$ 447K 27K/yr	--- 25K/yr	$200K 12K/yr	$1287K
UNIVAC	$ 466K 35K/yr	--- 25K/yr	$100K 12K/yr	$1286K

Table 3.5.2-1 PACX/FECP Full Support Costs

FECP VENDOR	FECP COST	DUAL PACX III	SYSTEM INTEGRATION	10-YEAR COST
Burroughs	$1136K 48K/yr	$119K 14K/yr	$200K 12K/yr	$2195K
Comten	$ 292K 16K/yr	$119K 14K/yr	$200K 12K/yr	$1031K
Control Data Corp.	$ 302K 27K/yr	$119K 14K/yr	$200K 12K/yr	$1151K
IBM	$ 341K 23K/yr	$119K 14K/yr	$200K 12K/yr	$1150K
UNIVAC	$332K 24K/yr	$119K 14K/yr	$100K 12K/yr	$1051K

From Table 3.5.2-1 it can be seen that, the added cost of such a port contention device is more than offset by the associated reduction in FECP port requirements. This cost savings is in addition to the benefits obtained from port contention devices as described in subsection 3.4.1. The major benefit is the flexibility for one terminal to access multiple host systems. For most FECP, the reduced complexity allowed for reductions in memory, scanner and line adapter requirements.

3.5.3 CSMA Bus/FECP Design

In subsection 3.4.4 two CSMA bus options were presented. The initial cost of the limited on-site support option was $200K less than the more flexible full on-site support option. However, as will be shown below, the resulting savings in communication equipment leasing and maintenance costs realized with the full support option more than offsets the added initial costs. For this reason, the full on-site support option is used in Table 3.5.3-1 for system costing.

BIUs interface all devices to the bus and only one BIU is needed per device. To provide added backup capabilities two BIUs were connected to each FECP. As a result, only two ports were required per FECP unit, greatly reducing the complexity and costs of the FECP subsystem. Because the FECP interface to the BIU must be user programmable, IBM proposed in their design to have each bus BIU connect to IBM Series/1 computers which would then be linked to the IBM 3705 FECP. The Series/1 computers are easily user programmable while the IBM 3705 is not. This added complexity adds considerably to the final IBM design cost.

The 10-year cost of the bus system ranges from $3.3M to $3.9M depending upon FECP type. Because with the full support on-site bus design, terminals on-site are directly linked to the bus eliminating the need for modem and line leasing, a large savings will be realized over 10 years. This savings will be a minimum of $745K and could be substantially greater. This reduces the 10-year costs to a range of $2.6M to $3.2M.

Section 4 of this document presents a detailed perspective of the many factors affecting communication costs. Full analysis of the communication savings

Table 3.5.3-1 On-Site Bus Full Support Costs

FECP VENDOR	FECP COST	FULL ON-SITE BUS COST	10-YEAR COST	MODEM AND LINE SAVINGS	NET 10-YEAR COST
Burroughs	$692K 29K/yr	$1189K 175K/yr	$3921K	$745K	$3176K
Comten	$236K 22K/yr	$1189K 175K/yr	$3395K	$745K	$2650K
Control Data Corp.	$240K 13K/yr	$1189K 175K/yr	$3309K	$745K	$2564K
IBM	$417K 45K/yr	$1189K 175K/yr	$3806K	$745K	$3061K
UNIVAC	$228K 13K/yr	$1189K 175K/yr	$3297K	$745K	$2552K

expected after implementation of the full support on-site bus system will be presented there. For now,Table 3.5.3-2 lists the breakdown of the expected line and modem savings of $745K. Here, it is assumed that all data lines and low speed modems are leased from S. W. Bell and all high speed modems are owned limited distance modems.

The $745K savings would be the minimum expected savings with such a bus design. Other areas of expected savings include:

- After the Phase A (FY81) replacement system implementation, enough of the owned high speed limited distance modems would be made available to avoid additional purchases for terminal increases on the other U1108 systems.
- After the Phase C (FY83) replacement system implementation, the owned modems should have residual value for use elsewhere.
- If the high speed line count to the CDC CYBER 74 increases as estimated, the CDC 2550 NPU would have to be expanded. With the bus system, only two ports are required in the NPU and expansion would not be necessary.
- The estimated cost of adding an expansion terminal post-Phase C to the bus system would be $550 (one port in a two port BIU). Depending upon terminal mode the cost would range from $800 to $1550 with a conventional network.

3.5.4 Centralized Message Switched Systems

Two centralized message switched systems will be discussed. The first utilizes a Comten FECP to interface to the user terminals and then to the replacement computer systems. In addition, communication lines to the other systems (U1110, CYBER 74, and IBM 360/65) are also provided. The second design was furnished by IBM and uses 3705 FECP as the centralized message switch.

3.5.4.1 Comten Message Switching. The Comten message switching design is illustrated in Figure 3.5.4.1-1. All communications lines are terminated at the large scale Comten 3690-E4 FECP system. To provide sufficient backup

Table 3.5.3-2 Projected Communication Savings with On-site Bus

ITEM	NUMBER	10-YEAR COST
Line Leasing	286 lines	$86K
Low Speed Modem Leasing	202 (101 pairs)	351K
High Speed Modem Maintenance	370 (185 pairs)	308K
Total Savings		$745K

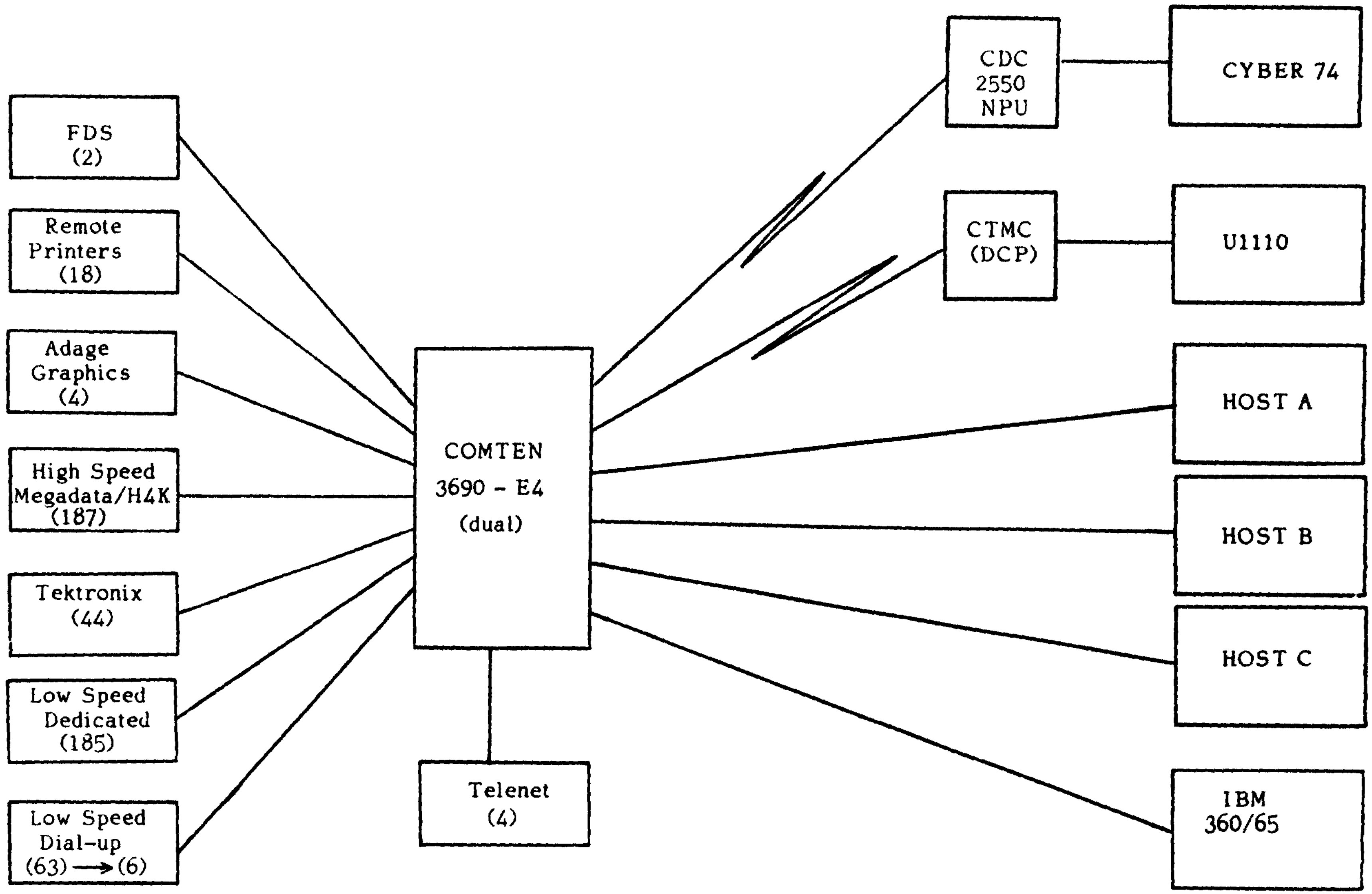


Figure 3.5.4.1-1 Comten Message Switching

protection dual 3690-E4s are configured. Since Comten equipment is IBM compatible, it is assumed in this design that the replacement hosts are IBM systems. This also means that the existing IBM 360/65 could be linked to the FECP via a channel adapter and could utilize existing communications software.

The two non-IBM systems (CYBER 74 and U1110) would be linked to the FECP via high speed communications lines. Special software would be required in both the FECP and the non-IBM systems. This software would be needed to handle non-IBM terminal protocols and to pack and unpack the data traffic between FECP and host system. The software for the CYBER 74 would be placed in the 2550 NPU, a programmable FECP. For the U1110, since the CTMC is not programmable, communications software would reside in the host. If the three CTMCs were replaced by a UNIVAC DCP or CS/P, the communications software could be kept out of the UNIVAC host and into the front-end device.

The costs of such a system are presented in Table 3.5.4.1-1. The initial costs are $1276K with yearly recurring costs of $143K. This results in a 10-year cost of $2706K. If a full-time system operator is required to oversee the operation of the dual 3690s, then the yearly costs would significantly increase. This design is in the same price range as the CSMA bus system but does not have the potential for added savings as the bus design nor does it have the expansion capabilities of the bus.

3.5.4.2 IBM Message Switching. The IBM centralized message switching design is illustrated in Figure 3.5.4.2-1. Half of the communication lines are routed to each of the two 3705 controllers. Network control is in the IBM 4331 computer. This computer system has a dual function of providing network control to the SNA hosts (HOST A,B,C) and that of routing data to the non-SNA hosts.

Each non-SNA host (IBM 360/65, U1110, and CYBER 74) is connected to the network via two IBM Series/1 computers. Software in the Series/1s handles message preparation into and out of the hosts.

If one of the 3705 FECP units fail, support to half of the user terminals would cease. Increased reliability could be added with a backup 3705 with switchover capabilities. In the event of a failure in the network control computer,

Table 3.5.4.1-1 Comten Message Switching Costs

ITEM	COST
<u>Initial Costs</u>	
Comten 3690 hardware	$776K
System design and integration	250K
Software:	
Comten	100K
U1110 (or DCP)	75K
CDC 2550 NPU	75K
Subtotal	$ 1276
<u>Recurring Costs</u>	
Comten maintenance	$ 43K/yr
Software maintenance (two people full time)	100K/yr
Subtotal	$ 143K/yr
Total 10-year Costs	$2706K

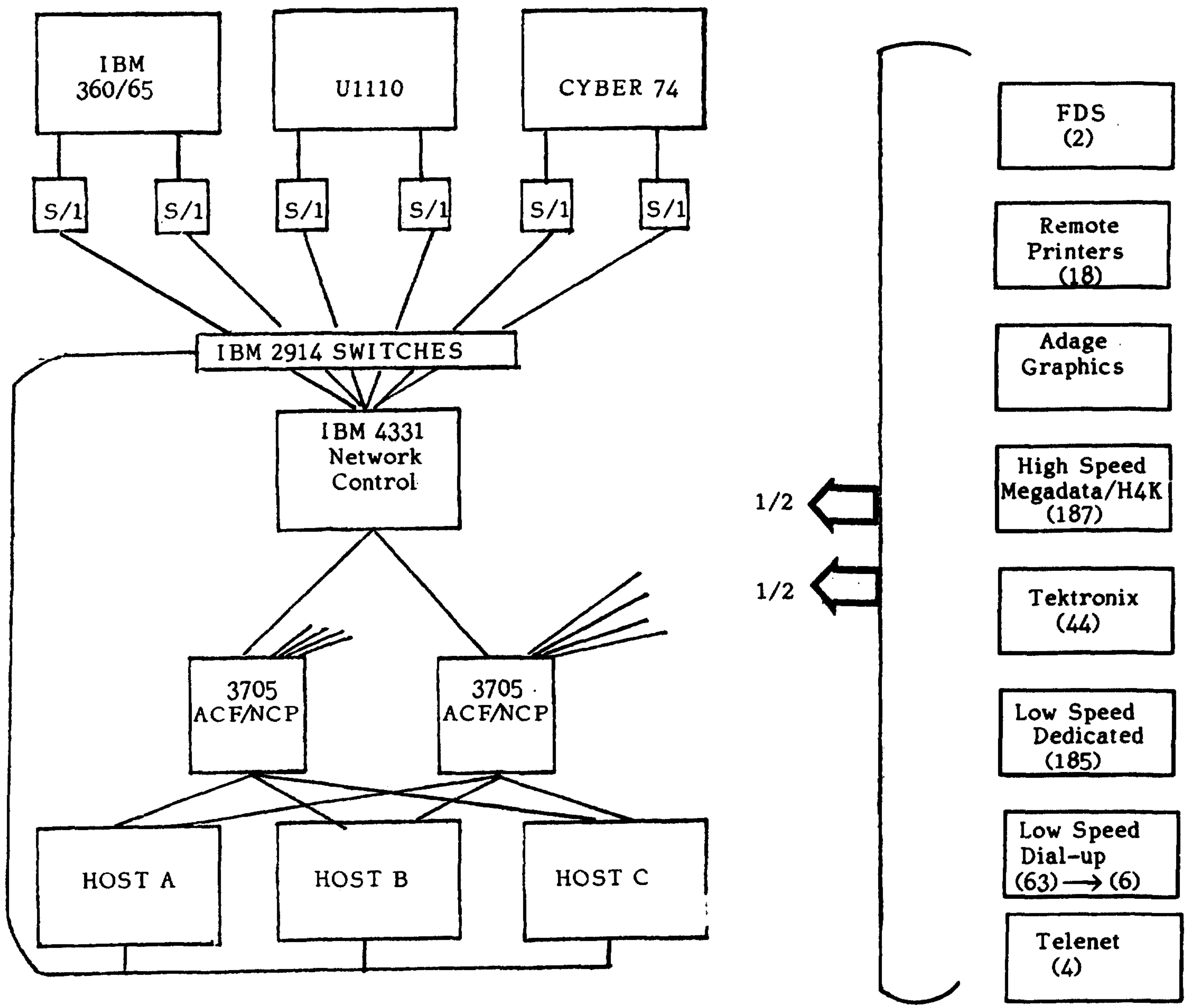


Figure 3.5.4.2-1 IBM Message Switching

IBM 4331, any of the other IBM SNA hosts could assume network control. The IBM 2914 switching unit would route the data traffic from the new network controller to the non-SNA hosts.

Table 3.5.4.2-1 lists the costs associated with this IBM proposed design. It is assumed that the high speed terminals are multidropped at four per line. Operator costs were not included in the IBM design and are estimated to be $100K per year. The operators would be responsible for the control of the IBM 4331 and Series/1 computer systems. The total 10-year cost would be approximately $2914K.

Adjustments to the above costs should be expected. The cost of [illegible] a third 3705 to the network in a standby mode would be significant. Ho[illegible]er if network control functions do not saturate the capabilities of the IBM 4331, it may be possible to transfer the functions of the IBM 360/65 to the IBM 4331. If this could be done, the cost of adding the IBM 360/65 to the network would be eliminated as would the cost of operating this system.

3.6 Communication System Redundancy

The major questions dealing with communications system redundancy are:

- What is the maximum network loss anticipated if any component in the network fails?
- When operating in such a degraded mode, can all high priority users be serviced?
- What is the expected mean time to repair (MTTR) of the system?

These questions will be addressed in the following paragraphs.

3.6.1 Gandalf PACX/FECP Network

In a communications network utilizing the Gandalf Dual PACX III port contention device and front-end communication processors, there can be two areas of failure, in the PACX or in the FECP. The treatment of component failures in the PACX were addressed in paragraph 3.4.1.1. Basically stated, if a port or terminal board fails only those attached communications lines are affected. Total points of failure are the central logic board and power supply.

Table 3.5.4.2-1 IBM Message Switching Costs

ITEM	COST
Initial Costs	
Hardware:	
3705 (two units)	$ 460K
IBM 4331 (one unit)	175K
Series/1 (six units)	240K
2914 (one unit)	59K
Software:	
Series/1 programming	150K
Systems prc ramming	100K
Subtotal	$1184K
Recurring Costs	
Software Products:	
3705	$ 6K/yr
IBM 4331	12K/yr
Series/1	10K/yr
Maintenance:	45K/yr
Operations:	100K/yr
Subtotal	$ 173K/yr
Total 10-year Costs	$2914K

With a suitable spare parts population, any failed component can be replaced within ten minutes. Terminal and port boards can be replaced without interrupting other network service.

Table 3.6.1-1 lists the expected number of high priority user terminals and remote I/O devices that would have to be serviced in the event of an FECP failure. Using these requirements, the number of ports required on each FECP in a two FECP network can be determined. In the table the terminal type and associated organization is listed. Also included is the expected FY83 terminal count to the replacement systems (reference Figure 3.3-1). The number of concurrently average active (CAA) terminals totals ninety terminals which is the maximum number of terminals the Phase C replacement systems can handle and still meet goal response. This CAA figure requires 32% of the terminals to be active.

High priority users must have service restored in under 10 minutes in the event of a network failure. Sixty percent of the remote I/O devices fall into this high priority class (10 of 17 devices). The 42 high speed CAA terminals all fall into the high priority class while half of the 48 CAA low speed terminals are in this class. In the event of an FECP failure the remaining FECP must be capable of handling at least:

- 10 remote I/O devices
- 12 high speed Tektronix terminals
- 30 high speed Megadata terminals
- 24 low speed terminals.

Any high priority device serviced by the failed FECP would have to be linked to the remaining FECP. For any of the 66 high priority terminals, the re-routing procedure would simply require logging on to the second FECP via the PACX. For the remote I/O devices, not handled by the PACX, manual patch panel intervention would be required. Depending upon the total number of ports available on each FECP and on the actual number of attached high priority users, some lower priority users may be forced to sign-off to free up ports for higher priority users.

Table 3.6.1-1 Priority Terminal Service Requirements

TERMINAL CLASS	ORG	NUMBER 8/78	NUMBER FY83	CAA[1]	TIME TO RESTORE ≤10 Min	TIME TO RESTORE >10 Min	NO. PORTS EACH FECP	REMARKS
FDS	FM	1	2	NA	1	1	1	TWO (2) 19.2kbps LINES CONNECTED DIRECTLY TO TWO (2) FECPs
REMOTE PRINTERS	FD			NA				FIFTEEN (15) PRINTERS CONNECTED DIRECTLY TO TWO FECPs. THREE ADDITIONAL PRINTER PORTS ARE PROVIDED SO THAT NINE (9) OF THE FIFTEEN (15) PRINTERS CAN BE SUPPORTED IF ONE OF THE FECPs MALFUNCTION.
300 LPM		4	9		5	4	5	
600 LPM			6		4	2	4	
REMOTE TOTAL			17		10	7	10	
MEGADATA @9.6kbps			(104)					
	EM	3	0					PMATS MOVED TO U1110
	BA	5	24	8	8		8	MANAGEMENT
	FD2	3	3	1	1		1	OPERATIONS
	FD6	10	20	6	6		6	DEVELOPMENT
	AH	0	2	1	1		1	MANAGEMENT
	JA	0	6	2	2		2	MANAGEMENT
	LSR	0	12	4	4		4	REPLACEMENT OF WORN OUT LS TERMINALS
	GRW	0	17	4	4		4	GROWTH @ 10%/YR (FY83-FY85)
	FLT	0	20	4	4		4	FLOAT
TEKTRONIX @4.8kbps			(34)					
	CA	0	14	4	4		4	
	LA	1	6	2	2		2	
	SA	5	5	1	1		1	
	FM	3	9	5	5		5	
HS SUB-TOTAL			138	42	42		42	

Table 3.6.1-1 Priority Terminal Service Requirements continued ...

TERMINAL CLASS	ORG	NUMBER		CAA[1]	TIME TO RESTORE		NO. PORTS EACH FECP	REMARKS
		8/78	FY83		≤ 10 Min	> 10 Min		
LOW SPEED								
	FD	19	4	4	2	2	2	
	CSC	0	37	17	9	8	9	
	EA	19	18	5	2	3	2	
	FM	5	5	4	4	0	4	
	SA	13	13	4	1	3	1	
	EM	1	1	1	1	0	1	
	LA	6	6	2	1	1	1	
	FD2	14	14	7	4	3	4	
	TS	23	38	2	0	2	0	TIME SHARING USERS
	FLT	40	20	2	0	2	0	FLOAT
	WO		-12					WEAROUT OF LS TERMINALS
LS SUBTOTAL			144	48	24	24	24	
TERMINAL TOTAL			282	90	66	24	66	

1 90 CAA / 282 TERMINALS = 32% BUSY

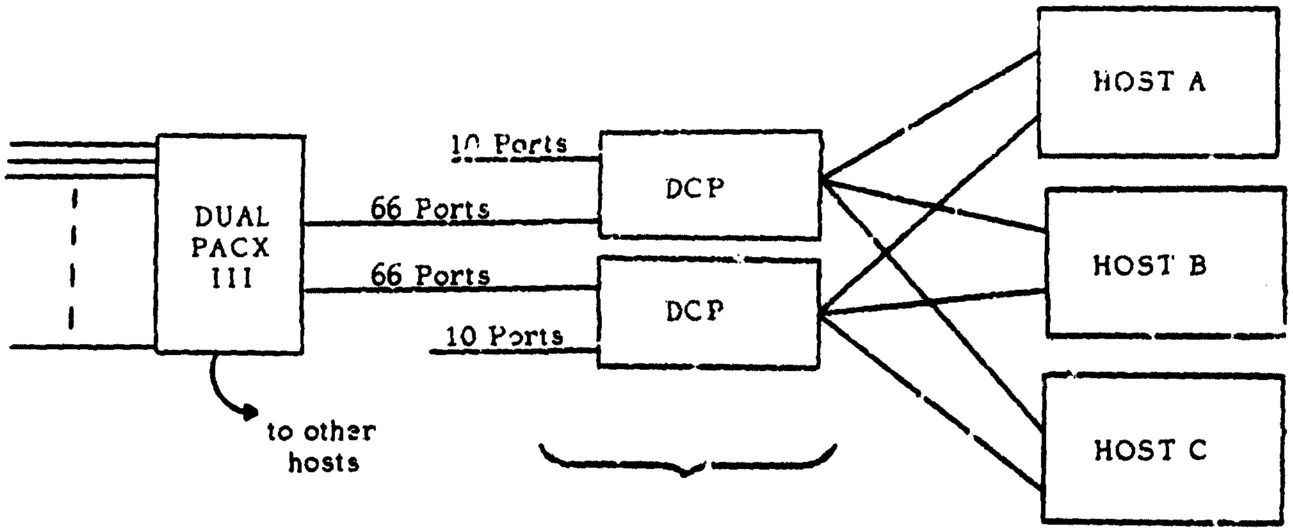
Figures 3.6.1-1,-2,-3 illustrate three methods of providing the required high priority backup support. These designs are priced for the UNIVAC DCP. The first design uses two DCP each with 66 terminal ports and 10 remote I/O device ports. The costing information is only for the DCP hardware purchase and maintenance. These costs are slightly higher than those previously listed in Table 3.6.2-1. This is due to the addition of three extra remote I/O device ports (twenty total ports for seventeen devices).

The design of Figure 3.6.1-2 uses three DCPs to support the terminal population. Each DCP requires fewer terminal and remote I/O device ports. The seventeen remote I/O devices can now be serviced with seventeen ports (not twenty) to obtain the needed backup. This design adds $136K to the 10-year network costs.

The third design, Figure 3.6.1-3 uses totally redundant ports on each DCP and fallback switches to switch all lines on a failed DCP to the operational DCP. With this design all attached terminals could be serviced in the event of a FECP failure. The added cost of this design over that of the first design is $379K over ten years. This fallback switching would not be transparent to the user. After the switches are manually reset, each affected user would have to re-establish the computer session.

Table 3.6.1-2 summarizes the redundancy features of the three designs and presents the estimated added cost. For design one,two additional options are investigated; increasing the number of terminal ports per DCP from 66 to 80 and then to 90. Three terminal mixes are also investigated. The 'BEST' mix has the same ratio of ports in each category (high/low speed, synchronous/asynchronous) active. The 'WORST' mix has 60 of the 90 CAA using high speed Megadata terminals. This leaves a sparse Tektronix and low speed terminal CAA. The 'PRIORITY' mix is that in Table 3.6.1-1.

In all designs, the 'PRIORITY' terminal mix has 100% backup. For the 'BEST' design the basic two DCP 66/66 port configuration provides 73% terminal backup. Adding more ports increases this to any desired figure. Adding more ports increases the terminal backup of the 'WORST' case but not as rapidly as with the 'BEST' mix.



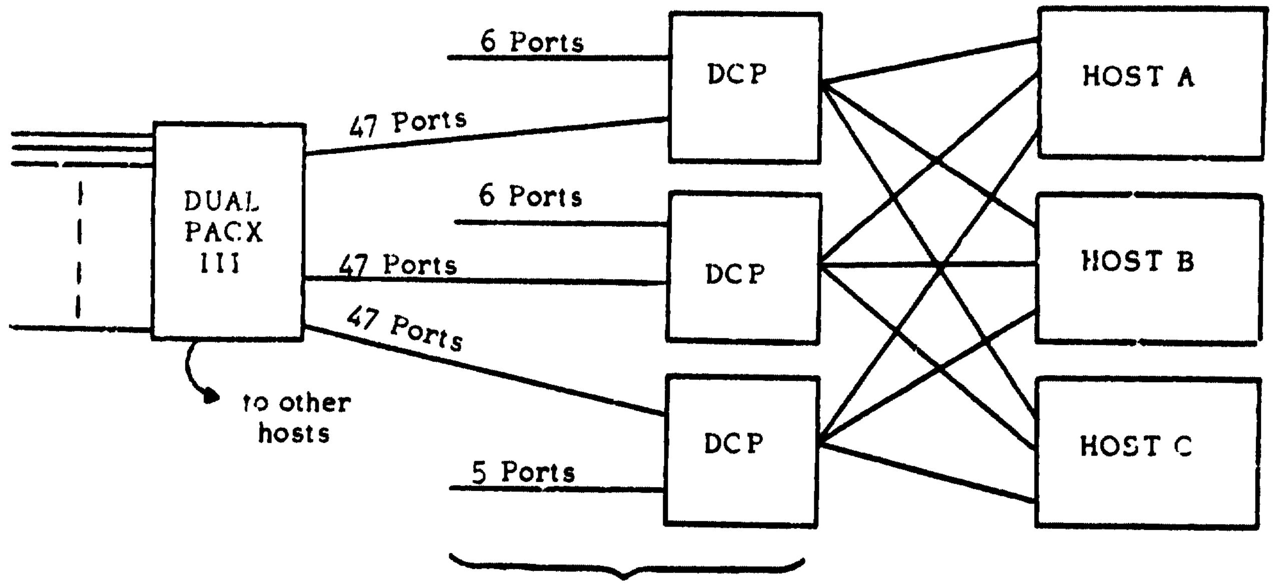
COST: DCP Hardware $335K

Maintenance $ 25K/yr

Dedicated Ports

- 2 FDS (1/1)
- 6 600LPM Printers (4/4)
- 9 300LPM Printers (5/5)

Figure 3.6.1-1 Dual FECP Backup Design



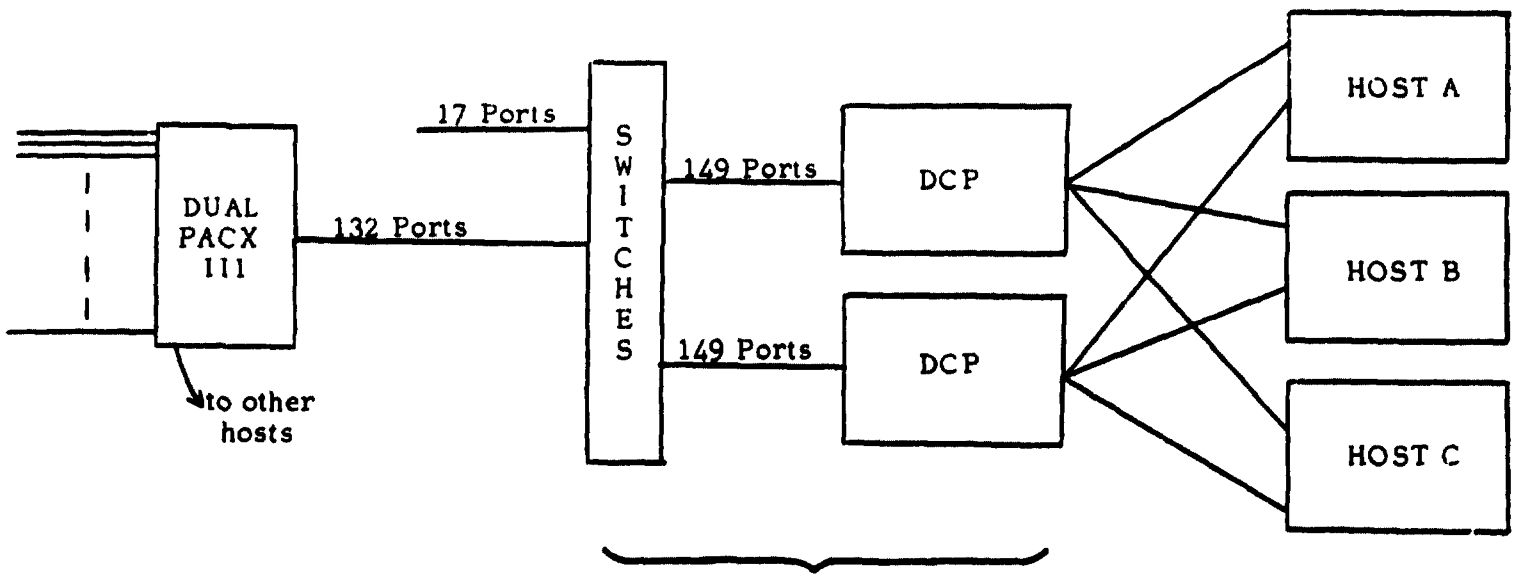
COST: DCP Hardware $421K

Maintenance $ 30K/yr

Dedicated Ports

- 2 FDS
- 6 600 LPM Printers
- 9 300 LPM Printers

Figure 3.6.1-2 Three FECP Backup Design



COST:	DCP Hardware	$504K
	Fallback Switches	30K
		$534K
	DCP Maintenance	$ 39K/yr
	Switch Maintenance	4K/yr
		$ 43K/yr

Dedicated Ports

- 2 FDS
- 6 600 LPM Printers
- 9 300 LPM Printers

Figure 3.6.1-3 Dual FECP Backup Design with Switching

Table 3.6.1-2 Expected Backup with 90 CAA

BACKUP MODE	EXPECTED BACKUP WITH TERMINAL MIX			COST			
	TOTAL						
	BEST	WORST	PRIORITY	INITIAL	YEARLY	10-YEAR	Δ
50% (two DCPs)							
66/66	73%	67%	100%	$335K	$25K	$585K	—
80/80	89%	73%	100%	$369K	$28K	$649K	+$64K
90/90	99%	79%	100%	$399K	$30K	$699K	+$114K
67% (three DCPs)							
47/47/47	100%	80%	100%	$421K	$30K	$721K	+$136K
FULL (two DCPs)							
132/132	100%	100%	100%	$534K	$43K	$964K	+$379K

As seen in Table 3.6.1-2 any terminal backup capability up to 100% is available if it is worth the extra cost to achieve such a backup figure. For this analysis it was assumed that 90 CAA would be used. The Phase C replacement system should have the ability to service 90 terminals and still meet goal response. The actual peak number of concurrently active terminals based upon the user projections (paragraph 2.2.2) is 96 user terminals to both the replacement system and the U1110. The actual peak load of the replacement system is expected to be approximately 60 terminals in FY83 not 90. Over the course of the next few years, additional requirements could be identified but the requirements should not reach 90. For this reason the basic design with two FECP units each with 10 remote I/O device ports and 66 terminal ports should be considered. If the number of CAA increases additional ports could be added.

3.6.2 CSMA Bus/FECP Network

The CSMA Bus/FECP network design presented in paragraph 3.5.3, has no single point of failure that could cause serious network availability problems. A failure of a terminal BIU would affect at most two terminals. Since each FECP is connected to the network by two BIUs, the loss of any one of these would have no effect. The network control element (NCE) continuously monitors the network and would automatically identify any malfunction. The NCE itself is a redundant system.

Since the CYBER 74, IBM 360/65, and U1110 would each have only one front-end processor, a failure of one of these processors would drop all network communications to the affected host system. This single point of failure is not unique to just the bus network but to all network designs considered. The only way around it would be to purchase redundant FECP for these hosts.

3.6.3 Centralized Message Switched Network

The Comten message switching design presented in paragraph 3.5.4.1 has approximately the same backup capabilities as the CSMA bus design. The Comten network controller is a redundant system interfaced to individual terminals or to individual host systems.

As mentioned in paragraph 3.5.4.2, with the IBM design, a failure of one of the 3705 FECP units would drop 50% of the entire network (not just to the U1108 replacement system). A third 3705 would have to be added to serve as a backup unit. Any of the IBM SNA compatible host systems could assume network control if the primary controller failed. A loss of one of the Series/1 computers linking the non-SNA hosts to the network would drop half of the communications support to the affected host.

3.7 Design Conclusions

In subsection 3.1 a communications concept that described the level of support required in the future CCF communications subsystem was presented. The lowest cost option considered that would satisfy this concept would utilize a port contention device to connect the user terminals to the host computer systems FECP. Such a system could be expanded to additional host systems by adding new port groups. Increases in the user terminal population could be implemented by simply adding additional terminal boards to the port contention device without affecting the FECP at all. It was also shown that with this type of configuration, all high priority terminals would have full backup and adequate backup could be provided for all other users.

The Gandalf Dual PACX III port contention device was used for the designs presented in this section. Any failure to a component in this device can be rectified in minutes by component substitution. A port contention device is transparent to the host FECP, data lines appear to be directly connected to the terminals. As a result, such a device could be installed in the CCF before, during, or after the Phase A,B,C U1108 computer system replacement. At the time of procurement, other vendors besides Gandalf such as Micon Systems and Develcon Electronics should be able to offer full terminal support.

All other communication design options considered were significantly higher in cost than the port contention device/FECP design. Of the other designs, the CSMA data bus provided the most flexible and powerful option. Besides meeting the communications concept, the bus design offers the potential for full JSC networking capabilities, easy expansion to additional hosts and terminals, no single point of failure, electronic mail, and office of the future service. In addition, the unused bandwidth of the CATV cable could be used for video and voice communications. However, due to added cost of such a bus system, requirements for the extra capabilities offered must be identified to justify procurement. The installation of a port contention device will not prevent future implementation of a bus system. It should be possible to attach the BIUs on the port side of such a device to interface the user terminals to the bus network.

SECTION IV

COST OF COMMUNICATIONS

4.0 INTRODUCTION

In Section III, the communications subsystem to connect data lines from the buildings 12 and 30 patch panels to the various host computer systems was considered. Several designs were proposed and their relative cost and performance characteristics were analyzed. Just as there are several alternatives to connect the data lines from the patch panel to the host systems, there are several methods available to connect the user terminals to the patch panel.

In the following paragraphs the current method of providing on-site, within JSC, and off-site, outside of JSC, communication to user terminals will be presented. Next, methods to reduce the cost of communications will be analyzed and judged for performance and reliability. Guidelines for future communication schemes will then be offered.

4.1 Current Communication Operations

Communication lines to the patch panel are handled differently for on-site and off-site lines. Currently all off-site lines use S. W. Bell switched communications. Each terminal is connected point-to-point via S. W. Bell leased modems over S. W. Bell lines. The majority of off-site terminals use dedicated leased lines as opposed to the dial-up facilities. The proposed communications medium connecting the Computer Sciences Corporation (CSC) building to building 12 will use a S. W. Bell wideband communication line with wideband multiplexing.

Various methods are used to connect on-site terminals. If the terminal is in close proximity to the patch panel, it may be possible to directly connect it instead of using a modem pair. The other terminals are connected via modems over leased data lines. Low speed terminals (300 bps asynchronous) use leased lines and S. W. Bell 113A/B modems while higher speed terminals use leased lines and NASA owned limited distance modems. These limited distance modems cannot operate over the S. W. Bell switched network but can operate over the point-to-point lines connecting the on-site terminals to the patch panel.

4.2 FY83 Projections

For the communication cost comparisons in the following paragraphs a few assumptions were made to simplify the computations. Included are:

- Cost comparisons will use the expected FY83 terminal projections
- Post - FY83 terminal increases will not be included
- Communications conditions in FY83 will be the same as today. On-site data lines will be connected point-to-point over S. W. Bell leased lines. Low speed terminals will use leased S. W. Bell modems while high speed lines will use purchased limited distance modems. Off-site lines will be point-to-point using S. W. Bell leased lines and modems.
- Six CENTREX ports will be available for dial-up service to the building 12 patch panel.

The one exception to the above assumptions will be the off-site terminals in the CSC building which will be multiplexed over a wideband data line.

Table 4.2-1 lists the expected terminal population in FY83. The 20 high speed and 20 low speed floats are not included in the number since they are not permanently assigned to a specific location.

The following communication cost comparisons will utilize the terminal configuration in Table 4.2-1 and will use the initial condition assumptions stated previously. The initial conditions are those expected if operations continue as today. Any recommendations made could be implemented prior to FY83 providing pre-Phase C replacement benefits.

4.3 Communications Component Costs

Several factors contribute to the total cost of communications. For end-to-end connections with S. W. Bell leased components, the costs include leasing the voice grade data line and the modems plus a one time installation cost of each item. Using non-S. W. Bell equipment over leased lines replaces the leased modem costs with a one time purchase cost plus recurring maintenance costs. These various types of costs are described in the following paragraphs.

Table 4.2-1 FY83 Terminal Status

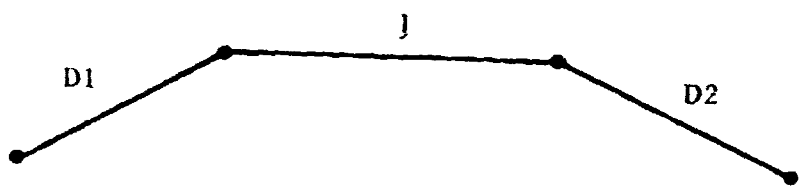
	ON-SITE	OFF-SITE	TOTAL
UNIVAC			
High Speed			
Hazeltine 4000	34	3	37
Megadata	74	18	92
Tektronix	37	7	44
Remote I/O			
Adage	4	0	4
FDS	2	0	2
300 LPM Printers	6	3	9
600 LPM Printers	5	4	9
Low Speed			
Dedicated	28	39	67
Dial-up	8	12	20
CDC CYBER 74			
High Speed			
Hazeltine 4000[1]	23	15	38
Low Speed			
Dedicated	34	2	36
Dial-up	0	6	6
IBM 360/65			
Low Speed			
Dedicated	34	23	57
Dial-up	0	4	4
Time Sharing			
Low Speed			
Dedicated	5	0	5
Dial-up	30	3	33
Total Population[2]	324	139	463

1. Either Hazeltine 4000 terminals or Megadata terminals emulating Hazeltine 4000 terminals.

2. Floats not included (20 high speed, 20 low speed)

4.3.1 Line Leasing Costs

S. W. Bell line leasing rates are tariffed by the Federal Communications Commission (FCC), intrastate leased lines have higher tariff rates than to interstate lines. In gene: ı: . the cost of a circuit is a function of several line attributes; including, the length of the two local exchange drops, the inter-exchange distance, whether the line is 2-wire or 4-wire, and the t_pe of terminating equipment. The figure below illustrates the local drops (D1, D2) and inter-exchange distance (J). The charge per mile for the 'ocal drop is much greater than the charge per mile for ınter-exchange communications.



The current costs associated with leasing an intrastate line from S.W. Bell for JSC service are contained in Table 4.3.1-1. Most modems can operate only in half-duplex mode over 2-wire lines and require 4-wire lines for full duplex service. The added cost to the local drop rates to go from a 2-wire line to a 4-wire line is only 16%. Terminating non-S. W. Bell equipment to the phone lines results in a 7% reduction in local drop monthly rates. All non-S. W. Bell equipment attached to S. W. Bell phone lines must comply with various interface and power limitation requirements.

To illustrate the method of computing monthly rates, two examples will be used. The first circuit connects building 12 to LXI in Nassau Bay and the second connects building 12 with the Alpha building in Clear Lake City. For leasing purposes, the 483 NASA exchange is considered to be part of the 488 exchange, resulting in a longer (and more expensive) initial drop, D1, of 14 quarter miles. Tabl 4.3.1-2 lists the pertinent distance data and related line costs for the two ex... es. Each circuit has the same D1 drop from building 12 to the 488 exchange. The circuit to LXI travels inter-exchange to the

Table 4.3.1-1 Leased S.W. Bell Voice-grade Line Rates

TERMINATING EQUIPMENT	2-WIRE DROP	4-WIRE DROP	EXCHANGE JUMP
S.W. BELL			$3.75/month per mile
First 1/4 mile	$6.80/mo	$7.90/mo	
Additional 1/4 miles	3.40/mo	3.95/mo	
Installation	20.00	20.00	
NON-S.W. BELL			$3.75/month per mile
First 1/4 mile	$6.30/mo	$7.30/mo	
Additional 1/4 miles	3.15/mo	3.65/mo	
Installation	20.00	20.00	

Table 4.3.1-2 Line Rates to L XI and Alpha

SERVICE	DISTANCE IN QUARTER MILES				TERMINATING EQUIPMENT	
	D1	J	D2	Total	S.W. Bell	Non-S.W.Bell
L XI	14	12	1	27		
2-Wire					$69.05/mo	$64.80/mo
4-Wire					78.40/mo	73.30/mo
ALPHA	14	0	9	23		
2-Wire					$8[illegible]00/mo	$78.75/mo
4-Wire					98.75/mo	91.25/mo

Continental Telephone 333 exchange while the line to Alpha building is entirely within the 488 exchange. It is interesting to note that even though the total circuit distance is one mile less to Alpha than to LXI, the monthly lease cost is approximately 25% greater. This is due to the fact that a large part of the circuit to LXI uses inter-exchange lines at rates lower than local drop rates.

The on-site communication costs are computed differently. The cost of 2-wire or 4-wire circuit between two JSC building is set at $.50/month per 0.1 mile with a minimum line rate of $2/month. The following rates are examples of on-site monthly line costs:

- Building 12 to building 30 .... $2.00
- Building 12 to building 222 .... $2.50
- Building 12 to building 415 .... $5.50

One other type of S. W. Bell line is used in the communication comparisons. The type 101 channel is a 2-wire metallic line with DC continuity. Since this circuit is 2-wire only, a 4-wire line would require two separate circuits. Table 4.3.1-3 presents the cost of this circuit and the equivalent cost of a 4-wire circuit.

Item	2-Wire	4-Wire
First ¼ mile	$1.50/mo	$3.00/mo
Additional ¼ mile	.75/mo	1.50/mo
Installation	20.00	40.00

Table 4.3.1-3 Type 101 Circuit Rates

4.3.2 Communications Equipment Costs

Many alternatives exist to point-to-point communications over S. W. Bell lines and modems. Independent manufacturers produce modems which may have different operating characteristics than similar S. W. Bell modems. Maintenance is included with S. W. Bell leased equipment and must be added to other cost factors when considering purchased equipment. These considerations will be detailed in the next paragraphs.

4.3.2.1 Costing Assumptions. When leasing communications equipment a set rate is paid monthly. However, with the purchase of such equipment, the purchase price is paid prior to delivery. This money is now not available for future use and, in theory, there is an associated cost penalty equivalent to the amount of interest this money could earn if invested elsewhere. The penalty added to the purchase price is computed as:

$$\frac{\sum_{j=1}^{N} j}{N} * i\% \equiv \frac{N+1}{2} * i\%$$

where: N is the amortization period and i% is the interest rate. With an 8% interest and a ten year amortization, an additional 44% must be added to the purchase price over the ten year life cycle.

Many vendors of communications equipment offer service contracts, others do not. The average monthly rate for maintenance is approximately 1% of the purchase price per month (12% per year). Therefore, for all purchased equipment an additional charge of 12% per year of the purchase price will be added for maintenance. This is regardless of whether the equipment would be maintained by the vendor, by NASA personnel, or by NASA contractor personnel.

As a result of the above two cost factors, over the ten year equipment life cycle, 164% of the purchase price is included for interest (44%) and maintenance (120%). For leased lines and modems from S. W. Bell no assumptions are made concerning changes in tariffs, current rates are used throughout.

4.3.2.2 Equipment Costs. Before analyzing specific communication designs the individual equipment components must be identified. The following paragraphs describe several such components.

4.3.2.2.1 Modem Costs. Several of S. W. Bell modems are listed in Table 4.3.2.2.1-1 along with associated installation and monthly leasing rates,

Table 4.3.2.2.1-1 S.W. Bell Leased Modem Costs

MODEM	SPEED	MODE	INSTALLATION	MONTHLY UNIT COST		MONTHLY CIRCUIT
				LEASE	CONDITIONING	COST (2 MODEMS)
103 F	Low	async	$ 25	$ 29	-	$ 58
108	Low	async	25	29	-	58
113 A[1]	Low	async	25	15[3]	-	29
113 B[2]			25	14[3]	-	
202 T	to 1200 bps	async	50	30	-	60
201 C	2400 bps	sync	100	54	-	108
208 A	4800 bps	sync	100	135	-	270
209 A	9600 bps	sync	100	205	7.80 (D1)	426

1. Originate - only
2. Receive - only
3. Estimated costs - not tariffed

line leasing costs are not included. The modems commonly used at JSC are the 113A/B, 208A, and 209A. The 113A/B are used both on-site and off-site for low speed asynchronous communications. These modems require special engineering and are not tariffed. As a result, the monthly lease rate may vary. The high speed synchronous modems, 208A and 209A, are used for off-site communications. The 208A modem requires no additional line conditioning while the 209A requires D1 conditioning on each end of the circuit. The cost of D1 conditioning is $7.80/month for each end. To provide service to an off-site Tektronix graphic terminal operating asynchronously at 4800 bps. transmission would have to be synchronous via 208A modems with synchronous/asynchronous converters on both ends. The approximate cost of such a converter is $300 per line.

Table 4.3.2.2.1-2 lists comparative prices for non-S. W. Bell modems available from independent vendors. The long haul modems are not S. W. Bell compatible but are similar in that they can be used to transmit data long distances over the switched telephone network. Medium distance modems are much less expensive than the long haul modems and can transmit data over the switched telephone network for distances of up to fifty miles. Limited distance modems are the least expensive communications method but also have the most restrictions. The distance such devices can transmit is a function of the modem bit rate and the gauge of the communications line, the thicker the line the greater the acceptable distance. The line itself must meet three restrictions; it must be a metallic line, have DC continuity, and be unloaded. S. W. Bell Type 101 lines meet the first two restrictions. Telephone lines typically have loading coils spaced every 6000 feet to reduce signal attenuation over the voice frequency range. Beyond the voice range, these coils have much greater attenuation than unloaded lines and interfere with the operation of limited distance modems. Obtaining communications lines off-site to service limited distance modems can be difficult. For on-site communications, such unloaded lines are standard.

Any non-S. W. Bell modem attached to the switched phone system must meet the power restriction standards listed in Bell Publication 43401. When comparing S. W. Bell monthly leased costs with the price of purchased equipment, an equivalent monthly cost including maintenance and interest can be obtained

Table 4.3.2.2.1-2 Purchased Modem Costs

MODEM TYPE	SPEED	MODE	INSTALLATION	COST EACH	EQUIVALENT MONTHLY COST (per pair)	S.W. BELL MONTHLY COST (per pair)
LONG HAUL	low	async		$ 350	$ 15	$ 29
	4800 bps	sync	$200	3000	132	270
	9600 bps	sync	200	4500	198	426
MEDIUM DISTANCE	4800 bps	sync		$1200	$ 53	
	4800 bps	sync		1200	53	
LIMITED DISTANCE	to 9600 bps	async		$ 500	$ 22	
	to 9600 bps	sync		700	31	

using the formula below:

$$\text{monthly cost} = \left[\frac{m}{100} + \frac{\frac{i}{100}}{1 - \frac{1}{\left(1 + \frac{i}{100}\right)^{n}}} \right] * P$$

where: m = monthly maintenance 1%/month

i = monthly interest 8%/year
0.64%/month

n = amortization period .... 10 years
120 months

P = initial purchase price

The resulting monthly cost is approximately 2.2% of the initial purchase price.

The prices used in Table 4.3.2.2.1-2 represent the lower price ranges found for the modem types listed. Recent advances in LSI circuitry have reduced the cost for such modems as the 9600 bps long haul modem from $8000-$9000 to as low as $4500. The equivalent monthly cost for a pair of purchased long haul modems is approximately half of the S. W. Bell costs. Utilizing medium distance or limited distance modems reduce the equivalent monthly rate further. Some of the non-Bell equipment will be installed by the vendor, other equipment may have to be installed and tested by the purchaser.

4.3.2.2.2 Multiplexors. Several types of multiplexors are available to support a variety of user needs. Time division multiplexors (TDM) are used to service several low speed asynchronous terminals over one data line. Concentrators are becoming available at TDM prices through the use of microprocessors. Instead of assigning fixed time slots to each attached terminal as do TDMs, concentrators use statistical multiplexing to allocate modem bandwidth to only the active terminals. This allows the device to provide an effective bandwidth in excess of the actual bandwidth. The concentration of bit rates usually ranges from 2 : 1 to 4 : 1. Wideband modems operate over wideband data lines and can service various combinations of high and low speed, synchronous and asynchronous terminals.

Table 4.3.2.2.2-1 lists average costs of low speed TDMs and concentrators. As the line capacity increases, so do the costs. In the cost comparisons that follow in later paragraphs, low speed terminals are multiplexed with TDMs but concentrators can be substituted instead. Concentrators are useful in reducing modem costs, for example, if the total bit rate of all attached terminals was 6000 bps, a TDM would require a 7200 bps or 9600 bps modem while a concentrator could use a 4800 bps modem.

Wideband multiplexors operate over wideband data lines and usually can service combinations of synchronous and asynchronous terminals. The costs used for wideband multiplexors are:

base cost $4650
asynchronous board (3 lines) $730
synchronous board (3 lines) $260

These costs are equivalent to those on the TRAN 2111-3 wideband multiplexor purchased to service the CSC building.

A Megadata multiplexor can be used to multidrop several Megadata terminals when in Uniscope 200 emulation mode. Here, the terminals are polled and can share a single modem and communications line. In such a mode the terminals would be dedicated to a single port in one FECP and would not be general purpose with the ability to access all CCF hosts.

4.4 On-Site Communications

Currently on-site communications is all point-to-point. High speed terminals utilize purchased limited distance modems while low speed terminals use leased S. W. Bell modems. High speed communications are handled in a cost efficient manner and should continue to operate as today. However, alternate low speed communications offer a savings potential over current methods.

Table 4.3.2.2.2-1 Multiplexor Costs

MULTIPLEXOR TYPE	NUMBER OF CHANNELS	COST
TIME DIVISION	2	$1200
	4	1500
	8	3000
	12	3600
	16	4200
CONCENTRATOR	2	$1250
	4	1750
	8	2750
	12	3900
	16	4800

4.4.1 Low Speed

From Table 4.2-1 it is seen that approximately 101 dedicated low speed terminals will be on-site in FY83. These terminals will be distributed throughout several buildings. Table 4.4.1-1 list comparisons for three available low speed options. The requirement is for 4 and 8 collocated low speed terminals to be linked to building 12. Three options are considered. The first is the current method of operations, point-to-point with S. W. Bell leased modems. In the second option, leased modems are replaced by purchased medium distance modems. The last option uses a low speed multiplexor with a single pair of purchased modems. In all cases,the current option using leased modems is most expensive while the point-to-point option with purchased modems is least expensive. Increasing the number of terminals beyond 8 will eventually cause the multiplexed option to be least costly. The switchover will occur at approximately 11 terminals. Even when the multiplexed option is less costly, consideration must be given to the reliability of each system. Multiplexors have a single point of failure for all attached lines while point-to-point communications do not.

4.4.2 Other On-Site Options

Because of the underground tunnels connecting most of the on-site buildings, options not available for off-site communications can be used. The next paragraphs discuss two such options.

4.4.2.1 Fiber Optics. A newly emerging technology for point-to-point data communications is fiber optics. Such a medium offers very low transmission error rates free of electrical interference. Such a system is the VALTEC fiber optics modem and cable. To the user terminal the interface is RS-232C compatible requiring no wiring modifications.

Two modem models are available, each of which can transmit up to 20000 bps asynchronously. Model RSH-D1 has a maximum range of 100 meters and model RSK-D1 has a range of 1000 meters. The cost of these modems are $500 and $600 respectively. A major cost in constructing a circuit is the cable cost of $3 per meter. The initial cost of a 300 meter circuit would be:

Table 4.4.1-1 Low Speed Terminal Support - On-Site

OPTION	10-YEAR COSTS[1]	
	4 LOW SPEED TERMINALS	8 LOW SPEED TERMINALS
1. Point-to-point with S.W. Bell leased modems	$ 15K	$ 30K
2. Point-to-point with purchased modems	$ 9K	$ 17K
3. Multiplexed terminals with purchased equipment	$ 12K	$ 20K

[1] Costs include maintenance and interest

2	RSK-D1	$1200
4	connectors	200
300	meter cable	900
		$2300

Including maintenance and interest would increase the cost by 164% over ten years.

Such fiber optics systems cannot be currently justified for on-site use since more conventional options are less expensive. However, for those circuits requiring error rates less than 1 in 10^9 bits, this would be a useful alternative.

4.4.2.2 CSMA Bus. The listen-while-talk CSMA Bus design for on-site communications was described in subsection 3.4.4. It offered many advantages over conventional communication methods in terms of flexibility and capacity. Although the bus option is more costly than others described, it did result in a large savings in on-site communication costs. Using the FY83 terminal projections in Table 4.2-1 the ten year savings in communication costs can be calculated.

Ignoring the dial-up lines, the on-site lines connected to the bus in FY83 can be listed as:

low speed (async)	101 lines
high speed (async)	37 lines
high speed (sync)	142 lines
wideband (sync)	6 lines
	286 lines

With all the on-site lines connected to the bus the savings over ten years would result in a $745K savings as described below.

Line Savings:	
286 lines @ $2.50/month (ave)	$ 86K
Low Speed Modem Leasing:	
101 pairs @ $29/month per pair	$351K
Maintenance on Limited Distance Modems:	
1%/month of purchase price of 185 pairs of high speed LDM (LDM value $257K)	$308K
Total savings	$745K

If the leased low speed modems had been replaced with purchased modems the $745K savings would be reduced to $581K over the ten year span.

Four other areas of bus savings can be identified:

- After Phase A replacements, enough high speed LDMs would be made available to negate the need to purchase LDMs for projected increases.
- The LDMs would have some post-Phase C residual value for use elsewhere.
- With the projected increase in CYBER 74 terminals, expansion of the 2550 NPU would be necessary. With the bus system only two ports are required and expansion would not be necessary.
- The cost of adding a new terminal to the bus system would be the cost of a BIU ($550 per port in a two port BIU) plus the cost of a short cable drop. The costs using low speed modems and high speed LDMs would be much higher as seen below.

Low Speed:	modem pair	$700
	¼ Gandalf PACX board	100
		$800
High Speed (async):	LDM pair	$1000
	¼ Gandalf PACX board	100
		$1100
High Speed (sync):	LDM pair	$1400
	¼ Gandalf PACX board	150
		$1550

The addition of the monthly line leasing and maintenance charges would increase the total cost of the modem option.

4.5 Off-Site Communications

Current off-site communications utilize point-to-point circuits with S. W. Bell leased modems. The CSC wideband multiplexor will be an exception to this when it is operational. Several design configurations will be identified.

4.5.1 Low Speed Terminal Concentrations

Using the same low speed terminal example presented in Table 4.4.1-1 for on-site terminals, the results are different when the terminals are off-site. Table 4.5.1-1 presents the example of having 4 and 8 collocated low speed terminals off-site connecting to the building 12 patch panel. It is assumed here that the terminals are located in the Alpha building. Again the option using point-to-point communications with S. W. Bell leased modems is most costly. However, for both cases the multiplexed option is less expensive than the others. As the number of terminals increase, the savings with multiplexing grows.

The on-site and off-site low speed terminal examples illustrate the fact that on-site the hardware cost is the driving factor while off-site the line cost is most important.

4.5.2 Alpha/Beta Buildings

Other than the CSC building, only two off-site buildings will have large concentrations of terminals. Table 4.5.2-1 lists the FY83 expected configuration of each building. These configurations should be used for illustration only since tenants in the Alpha or Beta building could relocate to another site prior to FY83. The comparisons made to these two buildings will apply to any off-site building with a variety of terminals.

4.5.2.1 Point-to-Point. Three point-to-point communications options to connect the Alpha and Beta buildings to building 12 were investigated. These options are:

A-1 Continue as today, lease lines and modems from S. W. Bell. Table 4.5.2.1-1 lists the related costs to each building. It is assumed that the equipment will be installed prior to FY83 so no

Table 4.5.1-1 Low Speed Terminal Support - Off-Site

OPTION	10-YEAR COSTS[1]	
	4 LOW SPEED TERMINALS	8 LOW SPEED TERMINALS
1. Point-to-point with S. W. Bell leased modems	$ 58K	$ 115K
2. Point-to-point with with purchased modems	$ 45K	$ 90K
3. Multiplexed terminals with purchased equipment	$ 25K	$ 33K

[1] Costs include maintenance and interest

Table 4.5.2-1 FY 83 Terminal Configuration - Alpha and Beta Buildings

TERMINAL TYPE		BUILDING	
Speed	Mode	Alpha (22 Lines)	Beta (20 Lines)
9600 bps	Sync	4 Megadata (UNIVAC) 5 Megadata (CDC)	3 Megadata (UNIVAC) 3 Printronix 600 LPM
4800 bps	Sync	1 Printronix 300 LPM	
	Async	2 Tektronix	
Low Speed	Async	10 to Bldg. 12	14 to Bldg. 12
Maximum Data Rate		104K bps	62K bps

Table 4.5.2.1-1 Option A-1 Costs

ITEM	ALPHA		BETA	
	Number	Cost	Number	Cost
Installation		-		-
Converters (sync/async)[1]	5	$ 4K	0	$ 0
Line Leasing				
2-wire	10	102K	14	143K
4-wire	12	142K	6	71K
Modem Leasing (pairs)				
113A/B	10	35K	14	49K
208A	3	97K		
209A	9	460	6	306K
Total 10-year Cost	$840K		$569K	
Cost if Megadata operate at 4800 bps	$674K		$514K	

[1] With interest and maintenance

additional installation changes are added. The Tektronix terminals operate at 4800 bps asynchronously; this requires a S. W. Bell 208A modem (4800 bps, synchronous) with sync/async converters on both ends. The 300 LPM printer requires one such converter to interface the synchronous line to its asynchronous interface. If the slower speed of 4800 bps was acceptable to the Megadata terminal users, a large savings could be realized over the 10-year cycle.

A-2 Lease S. W. Bell lines and purchase modems from independent manufacturers. High speed 9600 bps communications utilize long haul modems while 4800 bps communications can utilize medium distance modems. The 10-year costs are in Table 4.5.2.1-2. Again it is seen that by operating all Megadata terminals at 4800 bps a large savings can be realized.

A-3 Lease S. W. Bell Type 101 lines and purchase limited distance modems. Type 101 lines are metallic with DC continuity and may not be readily available from S. W. Bell. To make a 4-wire circuit two 2-wire lines must be used and these lines cannot have loading coils.

4.5.2.2 Multiplexed Data Lines. Various types of multiplexing options are available to support the Alpha/Beta to building 12 communications. With the use of multiplexing, line costs are greatly reduced but single component failures may now affect many terminal users. Three multiplexing options are described below.

B-1 This option is similar to the proposed wideband link between the CSC building and building 12. The communications circuit is a special engineering item and is not tariffed. The estimated CSC monthly modem and wideband line cost of $630 is used for both Alpha and Beta buildings. In addition, an engineering and installation cost of $2000 is added. The cost analysis for Alpha and Beta is contained in Table 4.5.2.2-1. One wideband multiplexor is

Table 4.5.2.1-2 Option A-2 Costs

ITEM	ALPHA		BETA	
	Number	Cost	Number	Cost
Installation				
9600 bps modems	18	$ 4K	12	$ 2K
Converters (sync/async)[1]	1	1K		
Line Leasing				
2-Wire	10	95K	14	132K
4-Wire	12	131K	6	66K
Modem Purchase (pairs)[1]				
low speed	10	18K	14	26K
medium distance @ 4800 bps	3	19K		
long haul @ 9600 bps	9	214K	6	143K
Total 10-Year Cost	$482K		$369K	
Cost if Megadata operate at 4800 bps	$321K		$315K	

[1] With interest and maintenance

Table 4.5.2.1-3 Option A-3 Costs

ITEM	ALPHA		BETA	
	Number	Cost	Number	Cost
Installation				
Type 101 lines	44	$ 2K	40	$ 2K
Converters (sync/async)[1]	1	1K		
Line Leasing				
Type 101 (2-wire)	44	99K	40	90K
Modem Purchase (pairs)[1]				
Async. LDM	12	32K	14	37K
Sync. LDM	10	37K	6	22K
Total 10-Year Cost	$170K		$151K	

[1] With interest and maintenance

Table 4.5.2.2-1 Option B-1 Costs

ITEM	ALPHA		BETA	
	Number	Cost	Number	Cost
Installation				
Line and modems[1]		$ 2K		$ 2K
Converters (sync/async)[2]	1	1K		
Circuit Leasing[1]		76K		76K
Wideband Multiplexors[2]	2	37K	2	39K
Connection to Bldg. 30				
Line installation	5	—		
Line leasing	5	1K		
LDM (sync) pairs[2]	5	18K		
Total 10-Year Costs	$135K		$117K	

[1] Estimated cost, not a tariffed item

[2] With interest and maintenance

needed on each end to interface to the user terminals and patch panel. Since all lines terminate in building 12, the five Megadata terminals dedicated to the CYBER 74 require limited distance modems and communication lines from building 12 to building 30. Due to the clocking sequence between the wideband multiplexor and the terminals, Hazeltine 4000 terminals have difficulties in interfacing to the multiplexor. However, Megadata terminals emulating Hazeltine 4000s would not have such difficulties. For this reason, the off-site CYBER 74 high speed terminals are assumed to be Megadata terminals. The estimated time required to plan and install such a wideband line is 28 weeks.

B-2 In this option, two multiplexing schemes are used. All the low speed lines are multiplexed via a TDM and the Megadata terminals emulating UNISCOPE 200s use a single Megadata multiplexor. Once the Megadata terminals are multiplexed in this manner, they are no longer general purpose with access to all hosts. Conceptually the Megadata multiplexor is more similar to a multidropped modem sharing unit than to an actual multiplexor. Table 4.5.2.2-2 contains the associated costs. All 9600 bps communications require purchased long haul modems while 4800 bps communications can utilize medium distance modems. Since the total bit rate to each low speed TDM is under 4800 bps, the medium distance modems are used. If more low speed lines were added and the bit rate exceeded 4800 bps (16 terminals), a higher speed long haul modem could be used. Another option would be to use a concentrator to keep the output bit rate under 4800 bps. All printers, Tektronix terminals, and CYBER 74 Megadata terminals are handled point-to-point. Additional savings can be realized if all 9600 bps Megadata terminals operate at 4800 bps.

B-3 As in option B-2, the low speed lines and the UNIVAC Megadata terminals are multiplexed while all other lines are point-to-point. For this option, limited distance modems with Type 101 lines are utilized. The costs are presented in Table 4.5.2.2-3.

Table 4.5.2.2-2 Option B-2 Costs

ITEM	ALPHA		BETA	
	Number	Cost	Number	Cost
Installation				
9600 bps modems	12	$ 2K	8	$ 2K
Converter (sync/async)[1]	1	1K		
Line Costs				
4-wire	10	110K	5	55K
Modem Purchase (pairs)[1]				
medium distance @ 4800 bps	4	25K	1	6K
long haul @ 9600 bps	6	143K	4	95K
Multiplexors[1]				
Low speed TDM	2	17K	2	21K
Megadata Multiplexor	1	5K	1	5K
Total 10-Year Costs	$303K		$184K	
Costs if Megadata operate at 4800 bps	$218K		$166K	

[1] With interest and maintenance

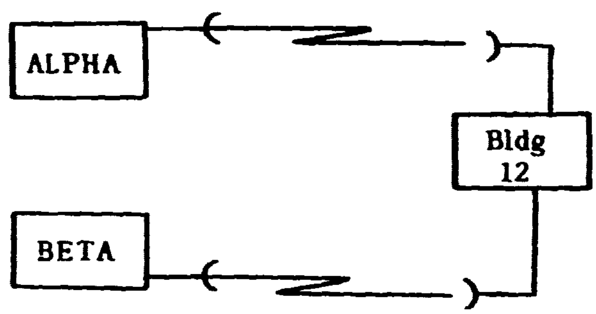
Table 4.5.2.2-3 Option B-3 Costs

ITEM	ALPHA		BETA	
	Number	Cost	Number	Cost
Installation				
Type 101 lines	20	$ 1K	10	$ —
Converters (sync/async)[1]	1	1K		
Line Leasing				
Type 101 (2-wire)	20	45K	10	23K
Modem Purchase (pairs)[1]				
Async. LDM	2	5K		
Sync. LDM	8	30K	5	18K
Multiplexors[1]				
Low Speed TDM	2	17K	2	21K
Megadata Multiplexor	1	5K	1	5K
Total 10-Year Costs	$104K		$67K	

[1] With interest and maintenance

4.5.2.3 Microwave Communications. As an alternative to conventional communications over leased phone lines, microwave communication was considered. Such a communications subsystem is manufactured by the Cushman-Electronics, Inc. One radio system can handle up to twelve 1.544 Mbps data links. Through the use of appropriate multiplexors, a variety of data speeds can be handled. In addition, voice and data transmissions can be mixed on the same system. Two microwave configurations are described.

Option 1: In this option separate microwave systems connect Alpha to building 12 and Beta to building 12 as pictured below:



The cost breakdown for the two systems is in Table 4.5.2.3-1. Discounting the initial survey and installation costs, most costs are for hardware purchases to which 44% interest and 120% maintenance charges must be added over the 10-year life cycle. The unprotected radio signifies a single radio link with single point of failure. With the protected system a second radio is used as a backup.

Two other costs must be included in the microwave design. The first is for a wideband multiplexor to interface to a 256 Kbps data line on the microwave multiplexor. The second cost is required for connection of the five data lines from building 12 to building 30 as listed in Table 4.5.2.2-1.

If both systems were to be installed the total cost would not be the sum of both separate systems. A $49K savings would be realized since the transmission survey, test equipment, and spares would not have to be duplicated.

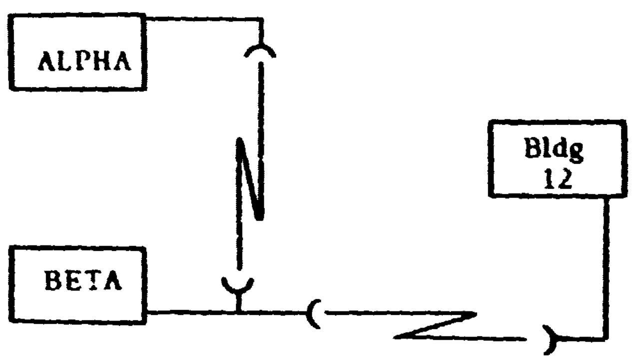
Table 4.5.2.3-1 Microwave Option 1 Costs

ITEM	ALPHA	BETA
Microwave System Costs		
Installation	$ 8K	$ 8K
Frequency search	1K	1K
Transmission survey	3K	3K
Test equipment [1]	32K	32K
Radios – unprotected [1]	169K	169K
(protected) [1]	(290K)	(290K)
Multiplexors [1]	53K	53K
Antenna and mounts [1]	18K	18K
AC power supplies [1]	5K	5K
Spares [2]	14K	14K
Microwave Subtotal		
unprotected	$303K	$303K
(protected)	($424K)	($424K)
Other Costs	$ 57K	$ 39K
Wideband multiplexors (2) [1]	(38K)	(39K)
Connection to bldg 30	(19K)	
Total Costs – unprotected	$360K	$342K
(protected)	($481K)	($463K)

[1] With interest and maintenance

[2] With interest only

Option 2: Unlike the previous design, this design has one integrated system not two separate ones. Here, all traffic to/from Alpha is routed through Beta and combined with the traffic from Beta to building 12 as pictured below.



The total costs of this design are listed in Table 4.5.2.3-2.

The unprotected service cost to Alpha and Beta building are $653K with option 1 and are reduced to $538K with option 2 (protected service $895K vs $721K). Another possible design could be a fully redundant loop system with transmission possible between any two of the three buildings. Further designs could include the terminal population in the CSC building.

4.5.2.4 Alpha/Beta Summary

Utilizing the terminal populations listed in Table 4.5.2-1, several communications options were analyzed. A summary is presented in Table 4.5.2.4-1 with the cost of service to Alpha added to the cost of service to Beta. The least expensive option, B3, utilizes unloaded, metallic Type 101 lines with limited distance modems. The practicality of this design is dependent upon the availability of the unloaded transmission lines. Special engineering costs may have to be added to provide such unloaded lines. This type of transmission may not be available for JSC support at all.

The next most cost efficient design utilizes a wideband multiplexor similar to the proposal CSC multiplexor circuit. Since this circuit is not a tariffed item, cost estimates based upon the CSC wideband cost were used.

Table 4.5.2.3-2 Microwave Option 2 Costs

ITEM	COST TO ALPHA/BETA
Microwave System Costs	
Installation	$ 12K
Frequency Search	4K
Transmission Survey	3K
Test equipment [1]	32K
Radios – unprotected [1]	253K
(protected) [1]	(436K)
Multiplexors [1]	79K
Antenna and mounts [1]	37K
AC Power Supplies [1]	8K
Spares [2]	14K
Microwave Subtotal	
unprotected	$ 442K
protected	($ 625K)
Other Costs	$ 96K
Wideband multiplexors (4) [1]	(77K)
Connection to bldg 30	(19K)
Total Costs – unprotected	$ 538K
(protected)	($ 721K)

[1] With interest and maintenance

[2] With interest

Table 4.5.2.4-1 Alpha/Beta Cost Summary (10 Year Costs)

Option		Cost	Comments
A1	● Lease S.W. Bell equipment ● Point-Point	\$ 1409K \$ 1188K	All Megadata at 9600 BPS All Megadata at 4800 BPS
A2	● Lease S.W. Bell Lines ● Purchase Modems	\$ 851K \$ 636K	All Megadata at 9600 BPS All Megadata at 4800 BPS
A3	● Unloaded S.W. Bell Type 101 Lines ● Purchase Limited Distance Modems	\$ 321K	
B1	● Lease S.W. Bell Wideband Line ● Purchase Multiplexor	\$ 252K	
B2	● Lease S.W. Bell Lines ● Multiplex UNIVAC Megadata ● Multiplex Low Speed ● Printers & CDC Megadata point-to-point	\$ 487K \$ 384K	All Megadata at 9600 BPS All Megadata at 4800 BPS
B3	● Unloaded S.W. Bell Type 101 Lines ● Multiplex UNIVAC Megadata ● Multiplex Low Speed ● Purchase Multiplexors & Limited Distance Modems	\$ 171K	
Microwave	Option 1	\$ 653K \$ 895K	Unprotected Protected
	Option 2	\$ 538K \$ 721K	Unprotected Protected

Point-to-point communications are more costly than multiplexed communications but do provide isolation from single points of failure.

Because of the added interest (44%) and maintenance (120%) costs over 10 years, the two microwave communications designs are more costly than other designs except for the A-1 and A-2 point-to-point designs.

4.6 Conclusions

In this section the cost of communications were investigated for both on-site and off-site terminals. Using the projected FY83 terminal requirements as a basis of design, it was concluded that:

- On-site communications costs are driven by hardware costs.
- Off-site communication costs are driven by line leasing costs.
- High speed terminals on-site should continue to be handled as today in the order below:
  - direct wired to FECP
  - Megadata multiplexor if dedicated to one FECP
  - via limited distance modems
- Low speed terminals on-site should continue to be point-to-point, however, leased S. W. Bell modems should be replaced with purchased modems.
- Off-site communications designs are dependent upon terminal population and location. For high concentrations of terminals, the use of limited distance modems with unloaded lines is least expensive. If such lines are not available, the wideband multiplexing should be considered.
- Other off-site conclusions:
  - For small concentrations of low speed terminals (over two), it would save money to purchase a multiplexor and modem pair than to have point-to-point communications.
  - Multidropping collocated polled terminals on one FECP port will provide significant reductions in equipment costs.

- For point-to-point communications, it is more cost efficient to purchase modems rather than lease them from S. W. Bell.
- For 4800 bps communications over loaded lines, medium distance modems should be used.

- Any option other than leasing point-to-point equipment should be analyzed and tested thoroughly.
- The communications system operation should be re-evaluated periodically to reflect changes to the terminal population and to S. W. Bell leasing rates. Other future developments that could affect the communication design include:
  - digital communications provided by S. W. Bell
  - hardware cost reductions resulting from LSI circuitry
  - development of medium distance modems operating at 9600 bps
  - development of limited distance modems operating over loaded lines.

SECTION V

CONCLUSIONS AND RECOMMENDATIONS

5.0 INTRODUCTION

Many conclusions were drawn from this study of the communication subsystem requirements for future IDSD computer systems. Based upon these conclusions and upon cost factors, several recommendations can be made.

5.1 Conclusions

The following conclusions were reached from this study.

a. The FY83 terminal population is projected to be 60% greater than the September 1978 level. Most increases will be in high speed synchronous terminals and remote I/O devices.

b. Front-end communications processors will be required to interface the communication lines to the replacement computer systems.

c. The functional capabilities and costs of most FECP systems are quite similar.

d. Using a port contention device to connect the data lines from the patch panel to the various host FECP meets the need for network flexibility and reduces the complexity of the host FECP. In addition, this configuration allows the rerouting of communications from a failed FECP unit to an operational unit.

e. Communications costs on-site are driven by hardware costs.

f. Communications costs off-site are driven by line leasing costs.

g. On-site communications should be point-to-point. High speed terminals should use limited distance modems and low speed terminals should use purchased modems.

h. Off-site communications are driven by the particular terminal configuration of each building. Generally. it is more cost-efficient to purchase and maintain modems rather than lease from S. W. Bell. Multiplexing even small concentrations of low speed terminals can result in significant savings. Likewise, multidropping collocated polled terminals will provide great reductions in line and modem costs.

5.2 Recommendations

Based upon the results of the communications subsystem study, the following recommendations are made.

a. To provide terminal flexibility and reduce FECP complexity, a port contention device should be purchased to link the patch panel to the host computers.

b. Such a port contention device could be procured prior to, during, or after the UNIVAC 1108 computer replacement.

c. On-site communications to the patch panel should continue to be point-to-point, however, the leased S. W. Bell modems should be replaced by purchased modems.

d. Off-site communications to the patch panel are controlled by terminal concentrations in off-site buildings. However, where possible, multiplexing should be used to reduce costs.

e. The communications system operation should be re-evaluated periodically to evaluate changes in S. W. Bell leasing rates and changes in communications equipment resulting from new technologies.

APPENDIX A
TERMINAL PROJECTIONS

Table A-1 CCF Terminal Population by Category (August 1978)

Category or Organization	Low Speed (≤ 300 bps)		HIGH SPEED						TOTALS		
			Hazeltine 4000		Tekronix		Megadata				
	On-Site	Off-Site	On-Site	Off-Site	On-Site	Off-Site	On-Site	Off-Site	On-Site	Off-Site	Total
UNIVAC System											
● Engineering Analysis									22	7	29
ES	2	1	3		2						
EX	4				3	1					
EA (balance)	7	5	1								
● Flight Support									19	3	22
CG (GDP)			19	3							
● Mission Planning									12	1	13
FM	4	1	5		3						
● Science Support									11	7	18
SA	7	6			4	1					
● Management									9		9
EM (PMATS)	1						3				
BA (IBAS)							5				
● Others									4	7	11
FA	1										
JA	1										
LA		6				1					
other			2								

Table A-1 CCF Terminal Population by Category (August 1978) continued...

Category or Organization	Low Speed (≤ 300 bps)		HIGH SPEED						TOTALS		
			Hazeltine 4000		Tekronix		Megadata				
	On-Site	Off-Site	On-Site	Off-Site	On-Site	Off-Site	On-Site	Off-Site	On-Site	Off-Site	Total
● Operations									18	2	20
FD2	13	2	2				3				
● FD Development									11	25	36
FD6 Management							4	6			
FD Other Dev.											
FD1		14									
FD4	1										
FD6	3		2								
FD7	1										
MITRE		2									
TRW		2									
MRI		1									
● Total In Service	45	40	34	3	12	3	15	6	106	52	158
● Float	40								40		40
● Total Terminals	85	40	34	3	12	3	15	6	146	52	198
● Remot I/O											
Adage									2		2
Flight Design System									1		1
U9300										1	1
Mohawk									1		1
Printronix									3	1	4
● Total Remote									7	2	9
● UNIVAC Total									153	54	207

Table A-1 CCF Terminal Population by Category (August 1978) continued...

Category or Organization	Low Speed (≤ 300 bps)		HIGH SPEED						TOTALS		
			Hazeltine 4000		Tekronix		Megadata				
	On-Site	Off-Site	On-Site	Off-Site	On-Site	Off-Site	On-Site	Off-Site	On-Site	Off-Site	Total
CYBER SYSTEM											
• CG				2						2	2
• EC	1								1		1
• FD	13	8	12	7					25	15	40
• LA	1	1							1	1	2
• CYBER TOTAL	15	9	12	9					27	18	45
• IBM 360/65 TOTAL	19	15							19	15	34
• TIME SHARING TOTAL	21	2							21	2	23
ALL SYSTEMS											
• TERMINALS	140	66	46	12	12	3	15	6	213	87	300
• REMOTE I/O									7	2	9
• GRAND TOTAL									220	89	309

Table A-2 Terminal Population Projections

Category or Organization	Sept. 1978		POPULATION PROJECTIONS													
			FY79		FY80		FY81		FY82		FY83		FY84		FY85	
	LS	HS	LS	HS	LS	HS	LS	HS	LS	HS	LS	HS	LS	HS	LS	HS
UNIVAC SYSTEMS																
• Engineering Analysis EA LEC	19	10	18 8	14	18 8	14	18 8	14	18 8	14	18 8	14	18 8	14	18 8	14
• Flight Support CA	0	22		26		30		32		34		36		36		36
• Mission Planning FM	5	8	5	14	5	14	5	14	5	14	5	14	5	14	5	14
• Science Support SA	13	5	13	5	13	5	13	5	13	5	13	5	13	5	13	5
• Management AH BA EM JA	1	5 3	1	16 6	1	2 20 8 6	1	2 24 8 6	1	2 24 8 6	1	2 24 8 6	1	2 24 8 6	1	2 24 8 6
• Other Open Shop FA JA LA Other	1 1 6	2	6	4 2	6	5 2	6	6 2	6	6 2	6	6 2	6	6 2	6	6 2

Table A-2 Terminal Population Projections continued...

Category or Organization	Sept. 1978		POPULATION PROJECTIONS													
			FY79		FY80		FY81		FY82		FY83		FY84		FY85	
	LS	HS	LS	HS	LS	HS	LS	HS	LS	HS	LS	HS	LS	HS	LS	HS
• Operations FD2	15	5	15	5	15	5	15	5	15	5	15	5	15	5	15	5
• FD Development FD6 Management Other Dev.		4		8		6		6		6		6		6		6
FD6	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2
FD1,4,7	16		1		1		1		1		[illegible]		1		1	
UNIVAC				2		3		3		3		3		3		3
MITRE	2		2		2		2		2		2		2		2	
TRW	2		2		2		2		2		2		2		2	
MRI	1		1		1		1		1		1		1		1	
CSC		6	24	6	24	6	24	6	24	6	24	6	24	6	24	6
OTHER				4		5		5		5		5		5		5
• Total In Service	85	73	99	114	99	133	99	140	99	142	99	144	99	144	99	144
• Float	40	0	35	5	30	10	20	20	20	20	20	20	20	20	20	20
• UNIVAC Terminals	125	73	134	119	129	143	119	160	119	162	119	164	119	164	119	164

Table A-2 Terminal Population Projections continued...

Category or Organization	Sept. 1978		POPULATION PROJECTIONS FY79		FY80		FY81		FY82		FY83		FY84		FY85	
	LS	HS	LS	HS	LS	HS	LS	HS	LS	HS	LS	HS	LS	HS	LS	HS
● Remote I/O																
Adage		2		2		4		4		4		4		4		4
Flight Design System		1		1		1		2		2		2		2		2
U9300		1		0		0		0		0		0		0		0
Mohawk		1		1		1		0		0		0		0		0
Printronix 300:																
On-Site		3		3		3		5		6		6		6		6
Off-Site		1		3		6		4		3		3		3		3
Printronix 600:																
On-Site								2		3		5		6		6
Off-Site								1		3		4		4		5
● Total Remote		9		10		15		18		21		24		25		26
● UNIVAC Total	125	82	134	129	129	158	119	178	119	183	119	188	119	189	119	190
CYBER SYSTEM																
● CYBER Total	24	21	36	27	46	32	46	38	46	38	46	38	46	38	46	38
IBM 360/65																
● IBM Total	34		41		46		51		56		61		66		71	

Table A-2 Terminal Population Projections continued...

Category or Organization	Sept. 1978		POPULATION PROJECTIONS													
			FY79		FY80		FY81		FY82		FY83		FY84		FY85	
	LS	HS	LS	HS	LS	HS	LS	HS	LS	HS	LS	HS	LS	HS	LS	HS
TIME SHARING																
● Time Sharing Total	23		25		28		31		34		38		42		46	
ALL SYSTEMS																
● Total	206	103	236	156	249	190	247	216	255	221	264	226	273	227	282	228

Table A-3 Adjustments to Projections

Category or Organization	Sept. 1978		POPULATION PROJECTIONS FY79		FY80		FY81		FY82		FY83		FY84		FY85	
	LS	HS	LS	HS	LS	HS	LS	HS	LS	HS	LS	HS	LS	HS	LS	HS
● UNIVAC Terminals Adjustments	125	73	134	119	129	143	119	160	119	162	119	164	119	164	119	164
● Low speed terminal wearout @ 5% per year									-6	+6	-12	+12	-18	+18	-24	+24
SUBTOTAL	125	73	134	119	129	143	119	160	113	168	107	176	101	182	95	188
● High speed terminal growth @ 10% per year												+17		+35		+54
● Adjusted UNIVAC Terminals	125	73	134	119	129	143	119	160	113	168	107	193	101	217	95	242
● Remote I/O		9		10		15		18		21		24		25		26
● UNIVAC TOTAL	125	82	134	129	129	158	119	178	113	189	107	217	101	242	95	268
● CYBER Terminals	24	21	36	27	46	32	46	38	46	38	46	38	46	38	46	38
● IBM Terminals	34		41		46		51		56		61		66		71	
● Time Sharing Terminals	23		25		28		31		34		38		42		46	
● TOTAL (all systems)	206	103	236	156	249	190	247	216	245	227	252	255	255	280	258	306