MCR-76-403
NAS8-31789

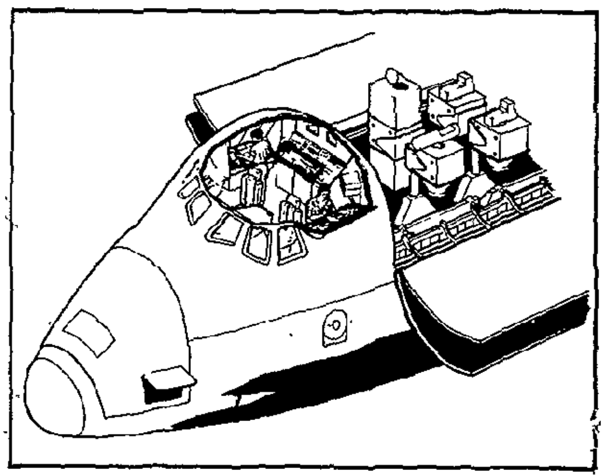
Volume I

Final Study Report

November 1976

Executive Summary

Payload Specialist Station Study



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Volume I | Final Study Report | November 1976

EXECUTIVE SUMMARY

PAYLOAD SPECIALIST STATION STUDY

Approved

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FOREWORD

This document was prepared by the Martin Marietta Corporation, Denver Division, for the National Aeronautics and Space Administration, Marshall Space Flight Center. This volume forms a part of the Final Study Report for Contract NAS8-31789, *Payload Specialist Station Study*, completed under the technical direction of Mr. William Lucero, Contracting Officer's Representative, MSFC.

The following documents form the complete Final Study Report:

Volume I	Executive Summary
Volume II	Technical Report
Part I	Preliminary Design Document
Part II	Contract End Item Specifications (Part I)
Part III	Program Analysis and Planning for Phase C/D
Volume III	Program Study Cost Estimates
Part I	Work Breakdown Structure
Part II	Cost Data

CONTENTS

CONTENTS (Concluded)

ABBREVIATIONS AND ACRONYMS

AFD	Aft flight deck
AMPS	Atmospheric, Magnetospheric, and Plasmas in Space
ATP	Authorization to proceed
BESS	Biomedical Experiment Scientific Satellite
CCD	Core control and displays
CCTV	Closed circuit television
C&D, C/D	Controls and displays; Procurement Phases C and D
CDR	Critical design review
CEI	Contract End Item
COR	Contracting Officer's Representative
CRT	Cathode ray tube
DBC	Data bus coupler
D/D	Design and development
DDU	Data display unit
DDT&E	Design, development, test, and engineering
DEU	Display electronics unit
DOD	Department of Defense
DSSM	Dedicated Solar Sortie Mission
DWS	Disaster Warning Satellite
EOS	Earth Observatory Satellite
EU	Electronics unit
FSMS	Foreign Synchronous Meteorological Satellite
FY	Fiscal year
G&A	General and administrative
GFE	Government furnished equipment
GPC	General purpose computer (Orbiter)
GRS	Gravity Relativity Satellite
GSE	Ground support equipment
ICD	Interface Control Document
IND	Indicator(s)

I/O, IOP	Input/Output Processor
IPS	Instrument Pointing System (Spacelab)
I/S	Interconnecting station (Spacelab)
IUS	Interim Upper Stage
KB	Keyboard
Kw	Kilowatt
LDEF	Long Duration Exposure Facility
LED	Light emitting diode
LH_2	Liquid hydrogen
LO_2	Liquid oxygen
Mb	Megabit (10^6)
MDM	Multiplexer-demultiplexer
MFDS	Multi-Function Display System
MMSE	Multi-use Mission Support Equipment
MPC	Manual pointing controller
MS, MSS	Mission Station, Mission Specialist, Mission Specialist Station
NSP	Network signal processor
OOS	On-orbit station
PCMMU	Pulse code modulation master unit
PDI	Payload data interleaver
PDR	Preliminary design review
PL, P/L	Payload
PS, PSS	Payload Station, Payload Specialist, Payload Specialist Station
PSP	Payload signal processor
RAU	Remote acquisition unit
SE&I	Systems engineering and integration
SIMS	Shuttle Imaging Microwave System
SIPS	Small Instrument Pointing System
SIRTF	Spacelab Infrared Telescope Facility
SL	Spacelab

SLC	Spacelab computer
SPHINX	Space Plasma High Voltage Interaction Experiment Satellite
SM	Systems management
SMM	Solar Maximum Mission
SS, S/S	Subsystem
ST	Space Telescope
STE	Space test equipment
STP	Space test project
STS	Space Transportation System
SUOT	Spacelab Ultraviolet Optical Telescope
SW, S/W	Software
TOBE	Teleoperator Orbiter Bay Experiment
TP	Twisted pair
TSP	Twisted shielded pair
WBS	Work breakdown structure

VOLUME I - EXECUTIVE SUMMARY

This document summarizes the results of the Payload Specialist Station Study (NAS8-31789), which was conducted in the one-year period between November 1975 and November 1976. The purpose of the study was to define an optimum aft flight deck (AFD) controls and displays (C&D) configuration concept for payload operations within the Shuttle Orbiter. The concept derived satisfies the large majority of identified payload C&D requirements through the 1980's, is cost effective, and utilizes existing technology.

The results of this study are directly applicable to Phase C/D activities. Programmatic analyses, phase C/D program definition and schedules, and economic analyses have been completed; and estimated phase C/D costs have been identified. These results are included in this summary.

Additional details are contained in the following documents, which also form a part of the Final Study Report:

Volume II - Technical Report;
Volume III - Program Study Cost Estimates.

The AFD control and display concept was defined by this study via panel layouts, CEI specifications, and programmatics for phase C/D. The study plan included the following six phases:

1) Derive control and display requirements;
2) Perform functional analyses;
3) Perform system synthesis;
4) Perform trade studies;
5) Perform preliminary design;
6) Provide programmatics.

1.0 SUMMARY DESCRIPTION - AFD C&D CONCEPT

Figure 1 shows the Orbiter aft flight deck within which the AFD C&D concept is configured. Payload-dedicated panel areas are indicated in the figure, as are the Orbiter controls and displays which payloads can utilize during on-orbit operation. Figure 2 shows a schematic representation of the controls and displays contained within the core AFD concept derived in this study. The core concept utilizes Spacelab equipment (CRT/keyboard at R12, instrument pointing system backup C&D, experiment remote acquisition unit, power distribution box) as government furnished equipment (GFE). This concept can be implemented by either of two AFD panel layouts, as shown in the composites depicted in Figures 3 and 4. One layout utilizes STS program qualified hardware at panels L10 and L11 (payload station) and the other utilizes new development hardware at those panels. The core concept also utilizes a set of multi-use mission support equipment (MMSE) which comprises all of panel L12 and portions of panels L11 and A7. The rationale for the use of MMSE and the analyses conducted to identify the MMSE is discussed in section 6.2 of this report. The figures identify the C&D components to be acquired in Phase I or Phase II of the program procurement cycle (see Section 2.0, Phase C/D Programmatics). Although the layouts are functionally identical, the new development option offers advantages over the STS option in overall program costs, electrical power requirements, and an increase in mission unique equipment panel area. In addition, the STS equipment option requires that the CRT/keyboard at panel L10 be supplied as GFE, whereas the new development option provides for the design of the entire PS (L10, L11, L12) as a complete unit.

Section 7.0 in this volume describes the preliminary design of these panels in more detail and identifies the primary interfaces between the core C&D and Orbiter or Spacelab systems. Section 2.0 summarizes Phase C/D programmatics.

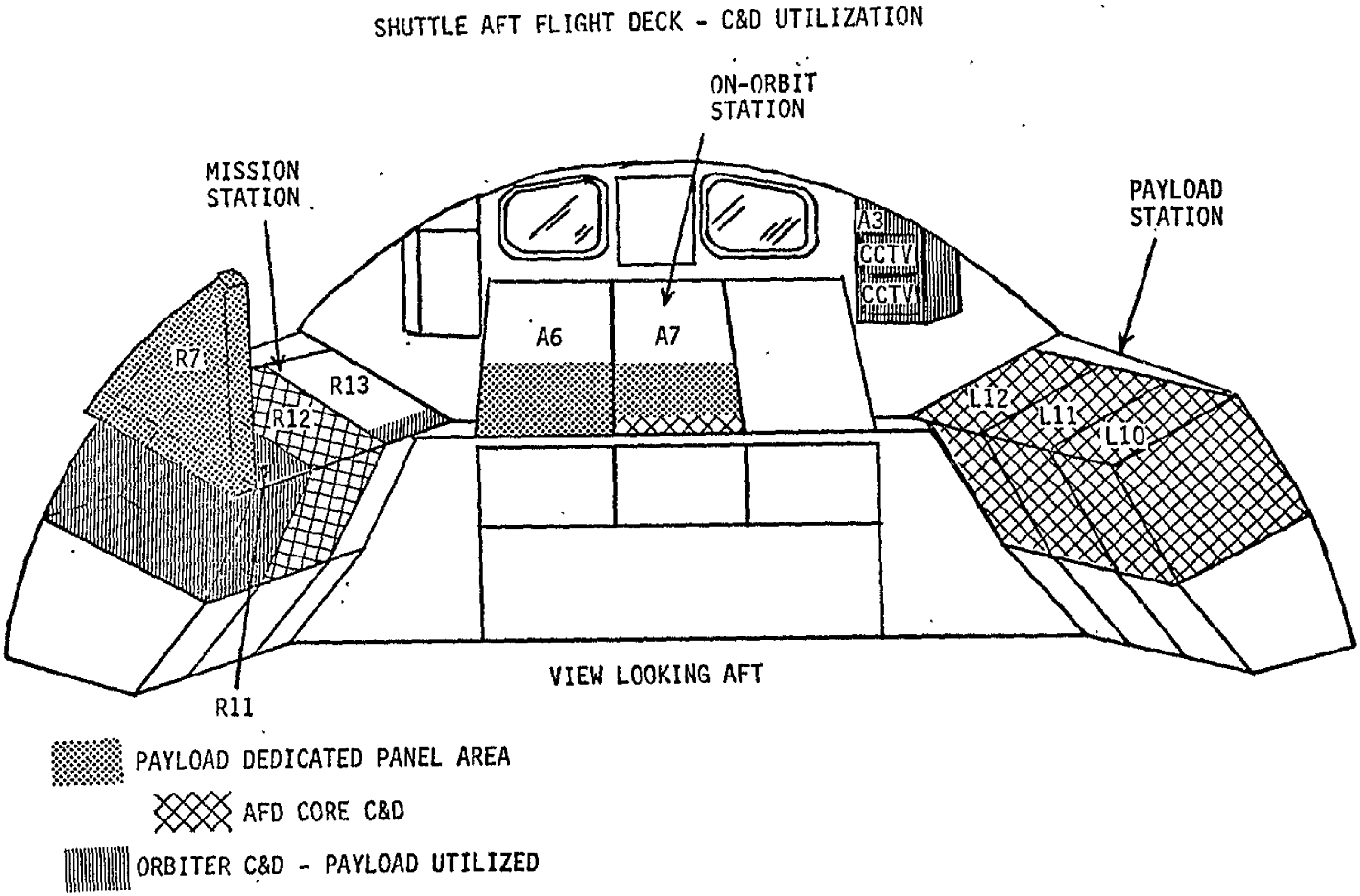


Figure 1 Payload Specialist Station Study (NAS8-31789)

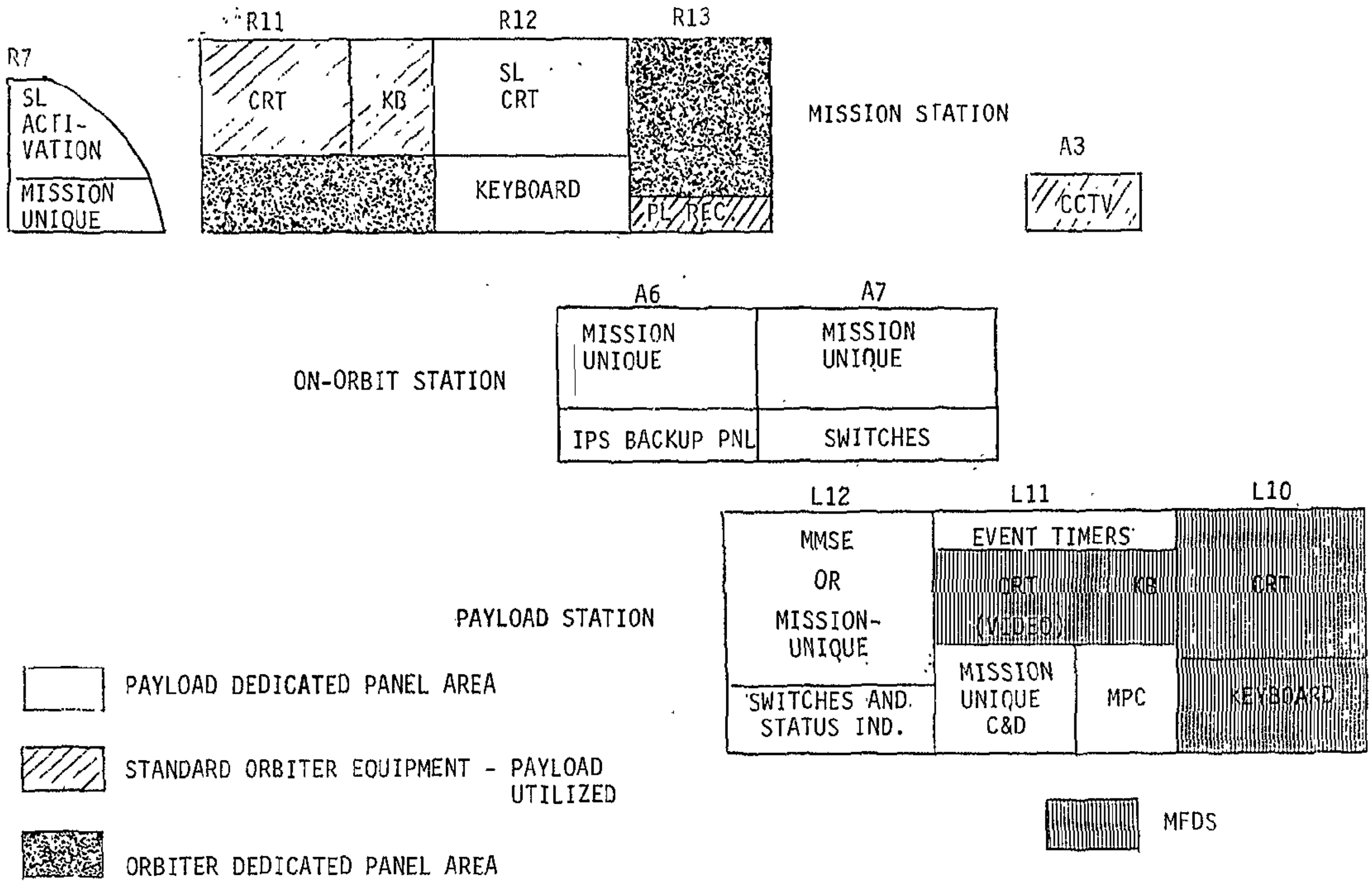


Figure 2 Aft Flight Deck C&D Concept

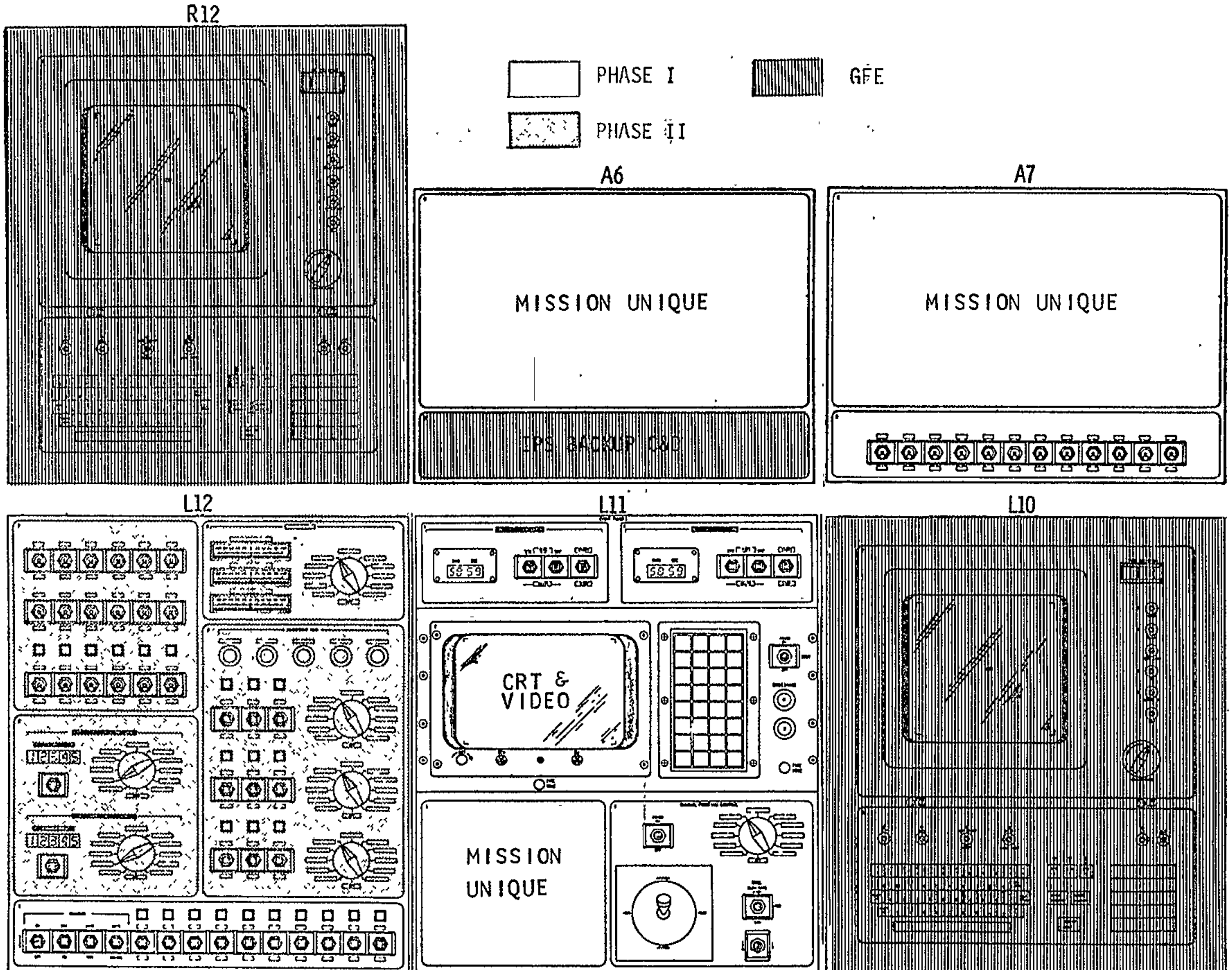


Figure 3 AFD Core C&D Concept (STS Hardware)

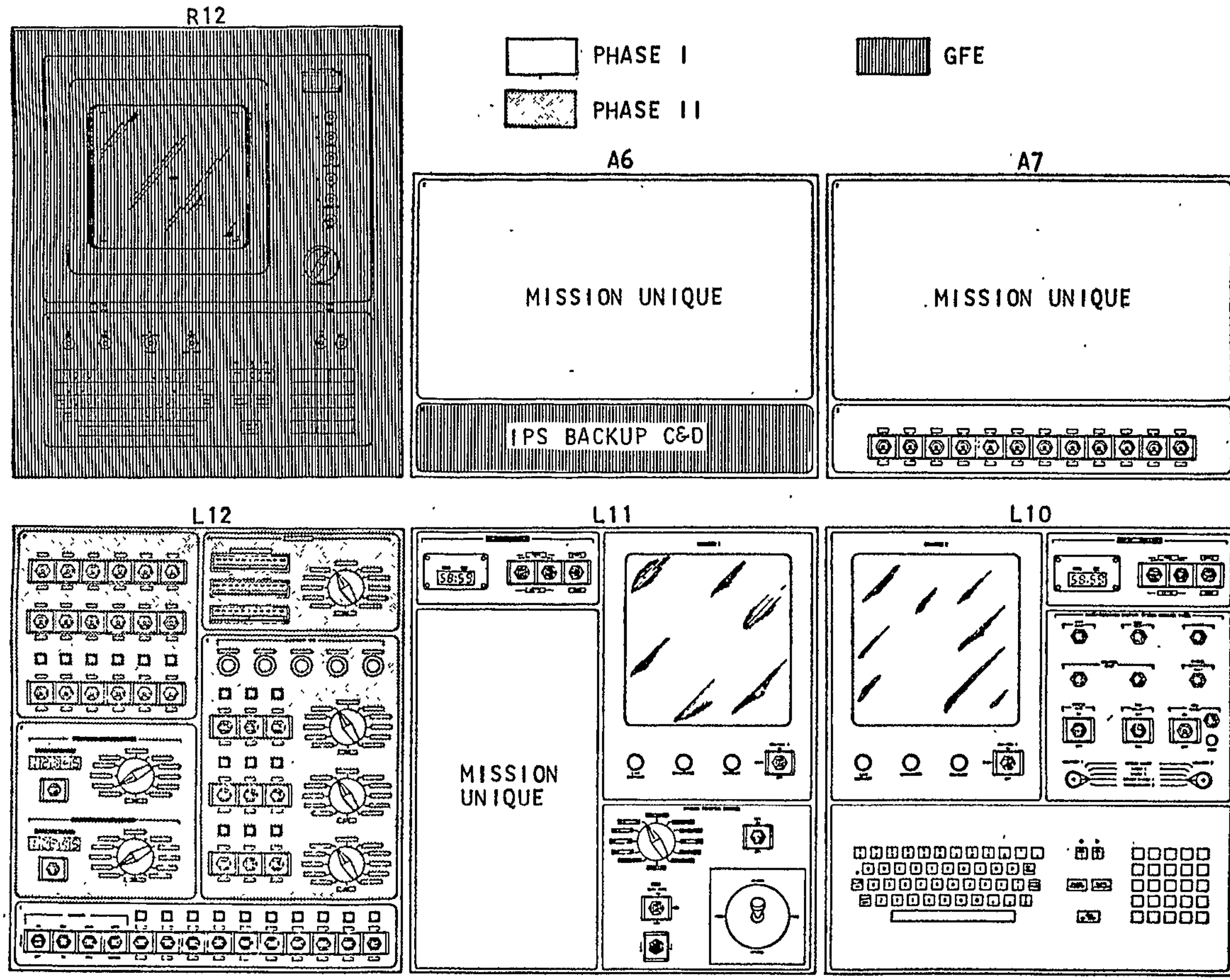


Figure 4 AFD Core C&D Concept--New Development Hardware

2.0 PHASE C/D PROGRAMMATICS

Programmatics analysis and planning played a significant role in the selection of the PSS core concept and in defining the approach to the acquisition process for phase C/D. Throughout the study the driving factor was to achieve a maximum C&D capability for the Aft Flight Deck Payload Specialist Station at minimum cost. Key to the programmatic analysis was an economic analysis conducted early in the study that showed maximizing the core PSS capability would--over the mission model--reduce significantly the total life cycle cost to the government and to the user community. Initial goals were to provide at least 65% of the C&D capability required by the payloads identified in the mission model. We determined that we could provide up to 90% coverage in an affordable PSS core design.

During the study the programmatic ground rules went through an evolutionary process to balance capability and cost. The program acquisition approach, cost, and schedule that resulted from this effort is described in the following paragraphs.

2.1 Ground Rules - The programmatic ground rules established the scope, conditions and framework for configuring the phase C/D program cost, schedule, and plans. The ground rules used for our final report are shown in Table 1. Costs and schedules presented in Volume III, Part II were developed to these requirements as were the plans presented in Part III of Volume II. Significant among these ground rules is the acquisition of the PSS core capability is divided between a PSS contractor and a mission contractor. Figure 5 shows the functional relationship between these two elements and their relationship to the payload user community and the STS program. The ground rules also identify a two-phased acquisition approach to the PSS core C&D system. This approach was selected in coordination with the COR and provides a means of meeting mission requirements and staying within funding constraints. The Phase C/D effort in each of the program acquisition segments is as follows:

Table 1 Programmatic Ground Rules and Assumptions

1) THE PSS CONTRACTOR WILL PROVIDE:
   1 FLIGHT ARTICLE
   1 DEVELOPMENT ARTICLE REFURBISHED FOR USE AT THE SDF
   1 QUALIFICATION ARTICLE REFURBISHED FOR P/L INTEGRATION
   2 SETS OF GSE
   COSTS TO INCLUDE "CORE" PSS AND PAYLOAD-PECULIAR PSS FOR THE SL-2 MISSION IN OCTOBER 1980.

2) COSTS OF "MAJOR ELEMENTS" (WBS LEVEL 4) TO BE PROVIDED IN ACCORDANCE WITH THE WBS AND WBS DICTIONARY. ALSO COSTS OF ALL MAJOR C&D EQUIPMENTS TO BE PROVIDED (WBS LEVEL 6).

3) ASSUME THE ORBITER RACKS AND SL C&D EQUIPMENTS ARE GFE.

4) THE PSS CONTRACTOR WILL BE RESPONSIBLE FOR THE FOLLOWING AS DIRECTED BY THE NASA:
   a. DEFINE THE PSS HARDWARE, SOFTWARE, GSE, AND PROGRAMMATIC REQUIREMENTS.
   b. PROVIDE THE NECESSARY SUBSYSTEM AND SYSTEM DESIGN/DEVELOPMENT.
   c. PROVIDE DESIGN VERIFICATION TESTING OF THE PSS CONSOLES/SYSTEMS.
   d. PROVIDE QUALIFICATION TESTING OF THE CORE C&D AND THE PAYLOAD-PECULIAR C&D AT THE CONSOLE LEVEL.
   e. INTEGRATE THE C&D EQUIPMENT INTO CONSOLES AND PERFORM THE NECESSARY ACCEPTANCE TESTING OF FLIGHT HARDWARE.
   f. PROVIDE THE NECESSARY TEST EQUIPMENT FOR DESIGN VERIFICATION, QUALIFICATION, AND ACCEPTANCE TESTING OF THE PSS CONSOLES.
   g. PROVIDE CREW TRAINING MANUALS AND INSTRUCTIONS (CREW TRAINING WILL BE CONDUCTED BY THE GOVERNMENT).
   h. MAINTAIN THE PART I CEI SPECIFICATIONS STARTED IN THE PSS STUDY. PROVIDE INTERFACE CONTROL DOCUMENTS (ICDs) AS REQUIRED. USE MSFC MANAGEMENT MANUAL 8040.12 AS A GUIDE IN STRUCTURING THE CEI SPECIFICATIONS AND ICDs.

5) A PLAN SHOULD BE FOLLOWED THAT WILL ASSURE THE PSS WILL BE COMPATIBLE WITH THE STS REQUIREMENTS FOR ELECTROMAGNETIC INTERFERENCE (MIL-STD-461-A, NOTICES 1, 2, AND 3; AND MIL-STD-462, NOTICES 1 AND 2 AND BONDING (MIL-B-5087B).

6) PHASE C/D ACTIVITIES WILL BEGIN IN JUNE 1977.

7) USE NASA NHB 5300.4(1D-1) AND SAFETY POLICY AND REQUIREMENTS DOCUMENT FOR PAYLOADS USING THE SPACE TRANSPORTATION SYSTEM (STS) AS A GUIDE WHEN DEVELOPING THE PLAN FOR SAFETY, RELIABILITY, MAINTAINABILITY, AND QUALITY PROVISIONS.

8) COSTS ARE TO BE IN CONSTANT 1976 DOLLARS.

9) THE NASA PROVIDES ALL FLIGHT SOFTWARE. THE PSS CONTRACTOR WILL IDENTIFY THE PSS SOFTWARE REQUIREMENTS.

10) PANELS R-11, R-12, AND R-13 ARE STANDARD ON ALL FLIGHTS; COSTS ARE NOT INCLUDED.

11) A TWO-PHASE ACQUISITION APPROACH WILL BE USED. THE FIRST PHASE (34 MONTHS) WILL PROVIDE THE PSS C&D REQUIRED FOR THE SL-2 MISSION IN OCTOBER 1980. THE SECOND PHASE (12 MONTHS) WILL COMPLETE THE PSS C&D CONFIGURATION BY ADDING THE MMSE SUBPANELS NEEDED TO COMPLETE THE CORE CONCEPT. THE SUBPANELS WILL BE FABRICATED ALONG WITH A REVISED GROUND TEST SOFTWARE PROGRAM, INTEGRATED INTO THE THREE DELIVERED ARTICLES IN THE FIELD AND A DEMONSTRATION ACCEPTANCE TEST PERFORMED.

12) ASSUME THAT A MISSION INTEGRATOR WILL BE AN ELEMENT IN THE PSS ACQUISITION AND OPERATION PROCESS. THE INTEGRATOR AS NASA's AGENT WILL PROVIDE PSS FLIGHT SOFTWARE, TRAINING, LAUNCH AND MISSION OPERATIONS SUPPORT.

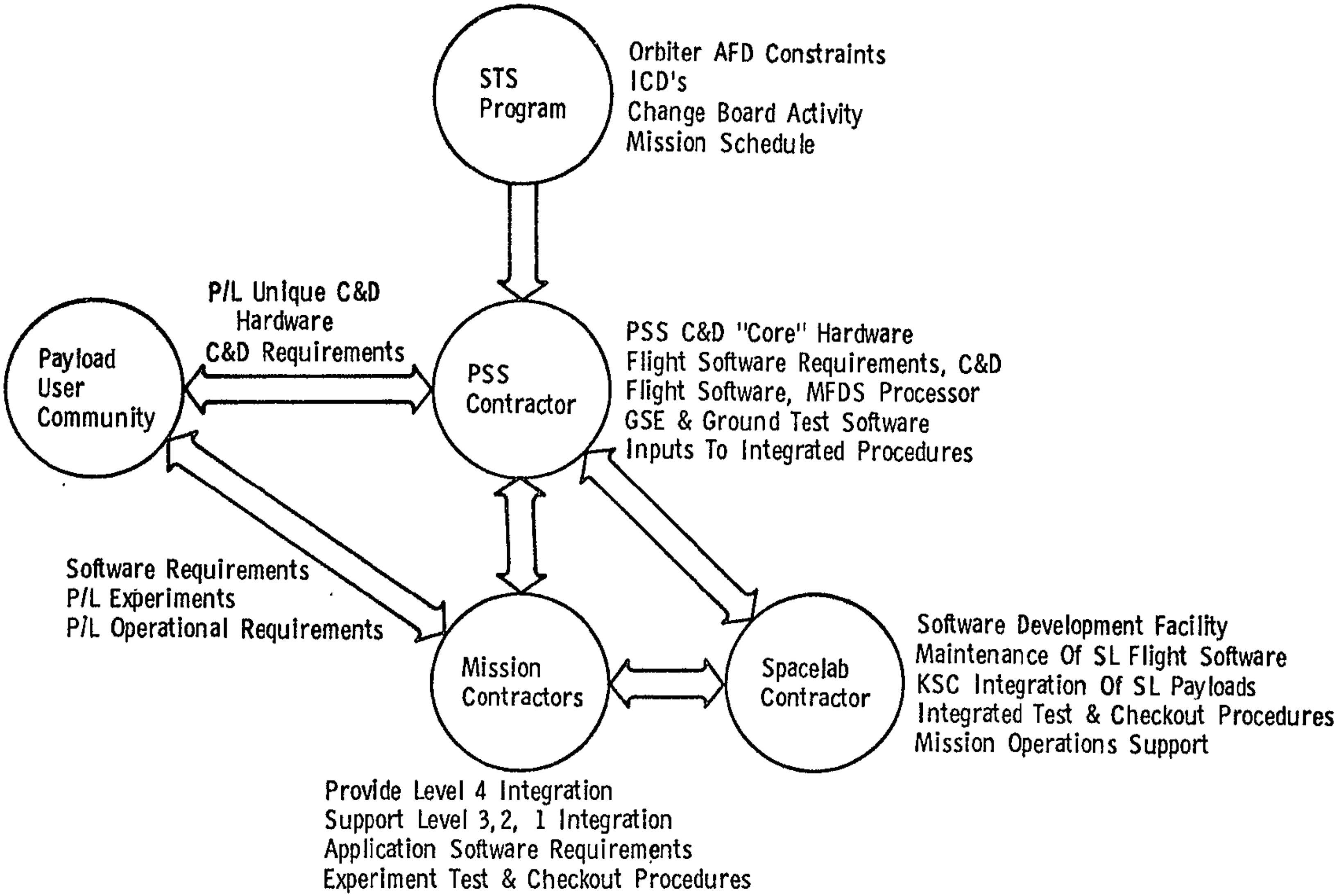


Figure 5 Contractor Structure for PSS Program

Phase I--Initial PSS Core Capability - During this phase the following activities occur:

1) The PSS core system (MFDS and elements of MMSE) is designed, developed, and tested in a 34-month period. The effort includes development of all specifications, ICDs, and drawings to define the core PSS design.

2) The systems engineering and integration will be performed to ensure the PSS design is compatible with all pertinent STS design requirements.

3) Required qualification testing and analysis will be performed to ensure the PSS core design meets STS environmental requirements.

4) GSE and associated ground test software will be developed.

5) Flight software requirements for both the MFDS processor and the payload computer will be developed. This will allow the Spacelab contractor to develop the flight software to support the AFD C&D and the mission contractor to supply the payload application software requirements.

6) Flight software for the MFDS processor will be developed.

7) Procurement will be made of a portion of the MMSE hardware needed for the PSS in support of early missions.

8) PSS core hardware will be fabricated for the first PSS mission. This includes panels L10, L11, L12, and A7. This configuration includes the MFDS and that portion of the MMSE C&D equipment required for the first mission. Phase I equipment does not require a Spacelab Experiment RAU interface at the PSS. In this phase the delivered PSS equipment includes one PSS C/D trainer, one PSS payload integration article, one flight article, critical component spares, and two sets of GSE.

Phase II--Complete PSS Core Capability - During this phase the following activities occur:

1) The detailed design drawings for the remaining portions of panels L11 and L12 will be developed and released in a twelve month period.

2) The additional quantities of MMSE and interfacing hardware will be procured; the additional capability provided requires a Spacelab experiment RAU at the PSS.

3) The additional L12 subpanels will be built and tested.

4) Delta flight software requirements will be defined and a new ground test software program to test the completed PSS core system will be developed and delivered.

5) The new subpanels will be acceptance tested at the factory, delivered and installed, and tested as a part of the PSS C/D development unit, the PSS payload integration article, and the flight article.

2.2 Program Definition - The PSS core acquisition was planned to provide a logical and affordable design, development, and fabrication of Aft Flight Deck Equipment and software that optimally meet the needs of the payloads identified in the mission model. The design definition effort of this study focused on the acquisition of the equipments and software defined below by a PSS contractor, since analysis showed over the long term this was the most economical.

PSS C&D Equipment

One (1) development article refurbished for use at the software development lab.
One (1) qualification article refurbished for payload integration
One (1) flight article.
Critical component spares.
Two (2) sets of GSE

PSS Software

Flight software requirements

Flight software for the MFDS processor

Ground test software

The program was defined for planning and cost estimating using a WBS for the PSS contractor. The fourth and fifth level elements of this WBS are shown in Table 2. Cost estimating was made to the sixth and seventh levels where appropriate and to the fifth level where design definition required and where cost estimating relationships assured acceptable accuracy.

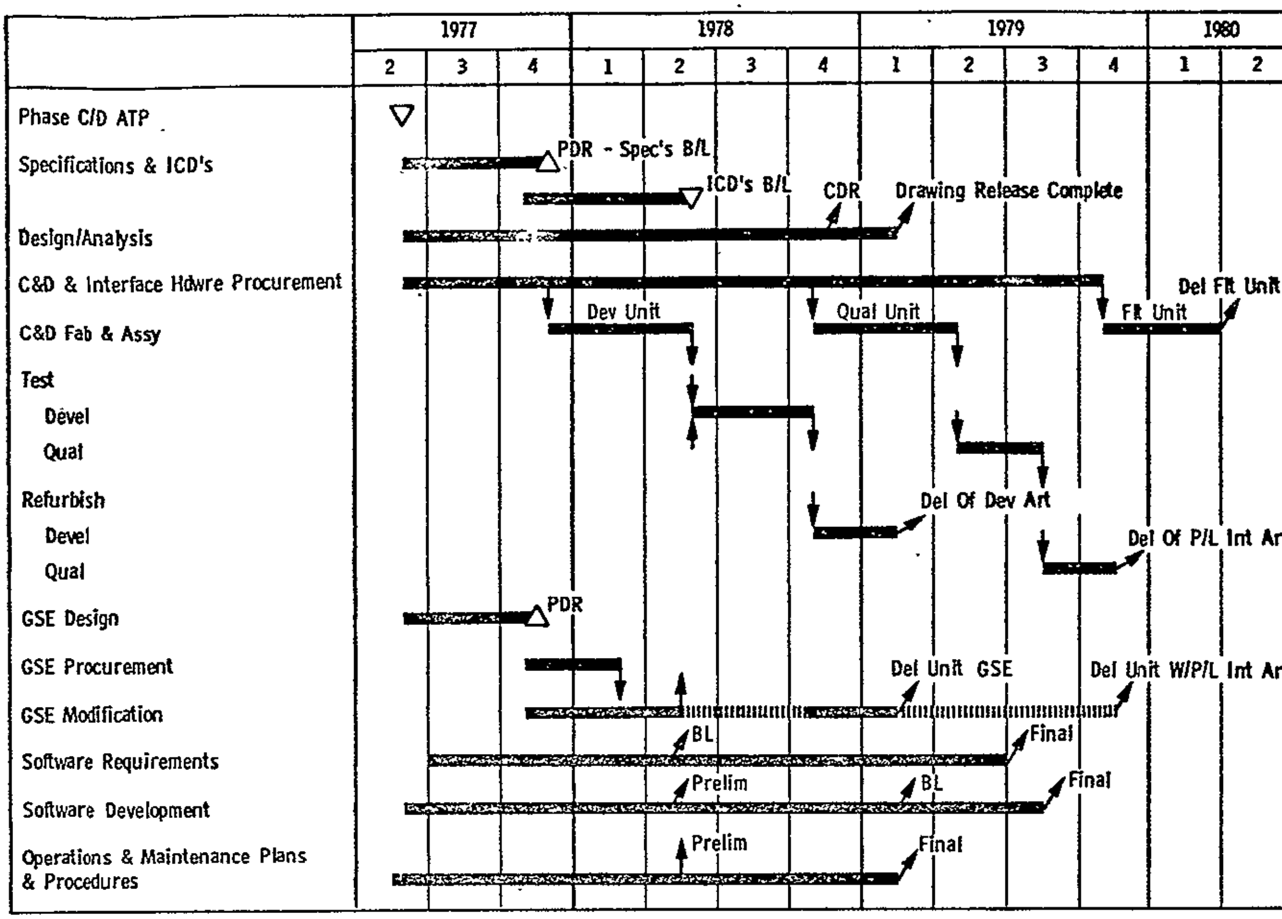
2.3 Cost and Schedule Summary - The Phase C/D program effort is planned in two subphases and the effort and schedule are summarized for each in the overview schedule in Figure 6. Cost summary by WBS and a funding schedule are presented in Figures 7 and 8. The funding schedule shows a peaking in FY '78. This is due to procurement orders for C&D equipment and a man-loading required to support a CDR eleven months after go-ahead. The procurement costs of MMSE are shown in Figure 9.

These elements together with a multifunction display system (not shown) constitute the core C&D equipment. Cost estimates were based on quotes from vendors conforming to Rockwell International (Shuttle Program) specifications so the majority of the MMSE is space-qualified and the costs are "hard". Two concepts of MFDS were assessed. One was a modified orbiter-qualified system and the other a new design which required STS qualification. Both approaches were technically adequate and attractive. Quotes were received from vendors and for the purpose of this study and the program cost estimates, a figure of $1 million was used for the MFDS procurement. The selection of STS qualified equipment would utilize the Spacelab CRT/KB and associated electronics unit, considered as GFE to the PS contractor, and represents an increase to the total program price of $600K.

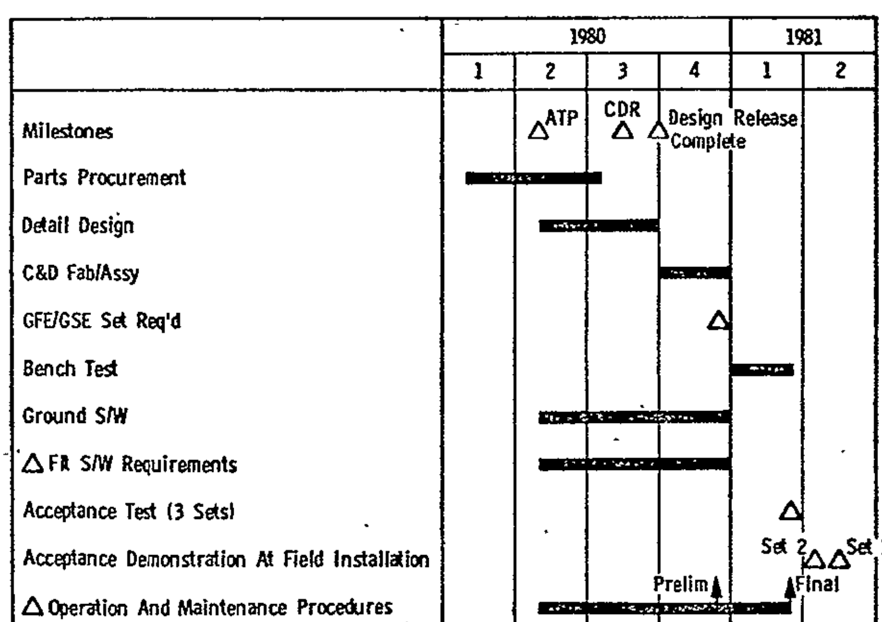
As part of the cost and planning for the study the future needs for a second flight unit were analyzed and the schedule and cost for a "build to print" article was derived and is shown in Figure 10. This assessment, like the program cost estimates, is in 1976 dollars and includes no allowance for modification or changes.

Table 2 PSS Contractor Work Breakdown Structure (WBS)

MAJOR ELEMENTS	SUBELEMENTS
01 Project Management	01 Project Administration 02 Project Planning and Control 03 Data Management 04 Procurement Management 05 Configuration Management 06 GFE Management
02 Systems Engineering and Integration	01 Mission Analysis and Requirements 02 System Analysis, Design, and Integration 03 Specification and ICDs
03 Control and Display Equipment Design and Development (including test hardware other than flight hardware)	01 Structures and Mechanical 02 Controls and Displays 03 Electronics 04 Electrical Power, Control, and Distribution 05 Thermal Control
04 Control and Display Equipment Manufacturing (Flight Hardware)	01 Structures and Mechanical 02 Controls and Displays 03 Electronics 04 System Assembly, Integration, and Checkout
05 GSE and STE D&D	01 Electrical 02 Mechanical
06 GSE and STE Hardware Manufacturing	01 Electrical 02 Mechanical
07 Software Development	01 Flight Software Requirements 02 Flight Software for MFDS Processor 03 Ground Test Software
08 Product Assurance	01 Quality and Reliability 02 Safety 03 Parts, Materials, and Processes
09 System Test	01 System Test Requirements 02 System Test Operations (Development Only) 03 System Test Verification
10 Ground Operations Support	01 PSS C/D Integration and Verification 02 Logistics 03 Maintenance & Refurbishment



A) Phase I



B) Phase II

Figure 6 PSS Schedule

WBS NO.	WBS IDENTIFICATION	COST (INCL G&A) IN MILLIONS PHASE I	PHASE II	REMARKS
01	PROJECT MANAGEMENT	0.45442	0.09152	PHASE I 34 MONTHS PHASE II 12 MONTHS
02	SE&I	0.62699	0.22184	FOR TOTAL "CORE" CAPABILITY
03	C&D DESIGN & DEVELOPMENT	0.69664	0.24531	
04	C&D MANUFACTURING	1.565	0.4280	ALL MFDS PROCUREMENT IN PHASE I
05	GSE & STE DESIGN & DEVELOPMENT	0.06252	0	
06	GSE & STE MANUFACTURING	0.17360	0	COMMON COMMERCIAL COMPUTER EQUIPMENT WITH MINOR MOD.
07	SOFTWARE DEVELOPMENT	0.48462	0.10610	PHASE I: FLIGHT SOFTWARE REQUIREMENTS, PROGRAMS FOR MFDS PROCESSOR AND GROUND TEST PHASE II: DELTA FLIGHT REQUIREMENTS, MMSE AND GROUND TEST PROGRAMS
08	PRODUCT ASSURANCE	0.20885	0.02906	
09	SYSTEM TEST	0.15615	0.09382	
10	GROUND OPERATIONS SUPPORT	0.13988	0.05805	DEMONSTRATION/ACCEPTANCE TEST; STANDBY SUPPORT
		4.56867	+ 1.27370 =	TOTAL COST = $5.84237
		0.38834	+ 0.10827 =	FEE = 0.49661
		$4.95701	+ 1.38197 =	PROGRAM PRICE = $6.33898

Figure 7 PSS Program Cost Breakdown

FY	77	78	79	80	81	Total
Phase I	654.77	2037.43	1484.84	372.32	19.31	4568.67
Phase II	0	0	0	923.84	349.92	1273.76
Total Cost	654.77	2,037.43	1,484.84	1,296.16	369.23	5,842.43
Total Funding Includes (fee) (Thousands)	710.43	2,210.61	1,611.05	1,406.33	400.62	6,339.04

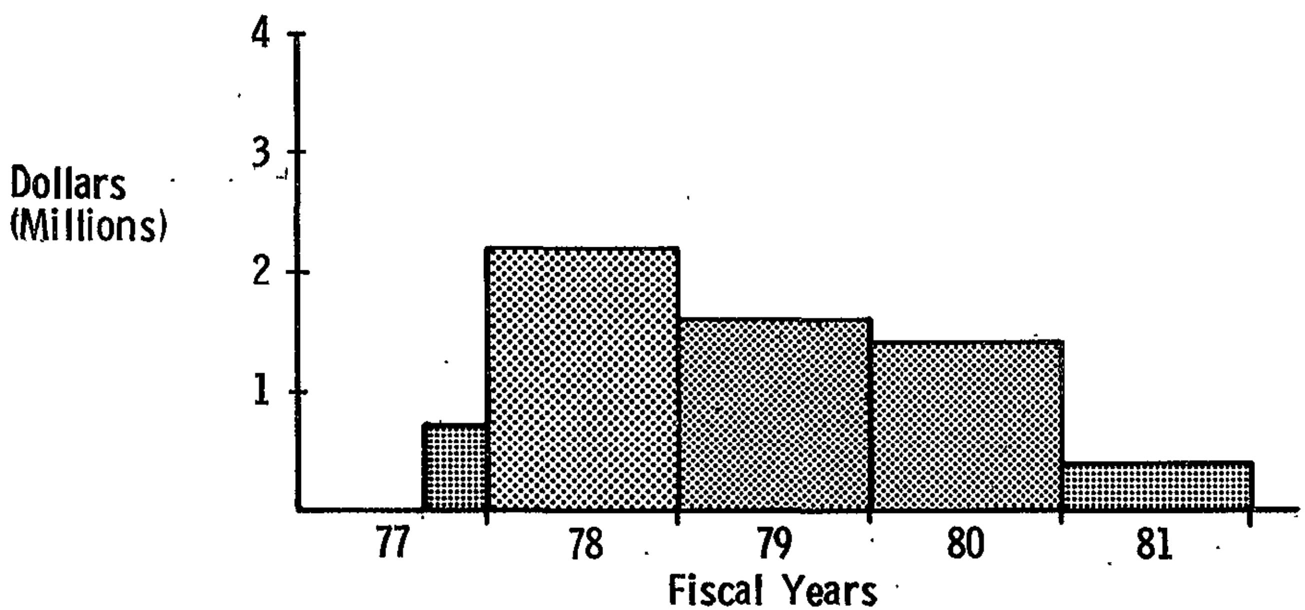


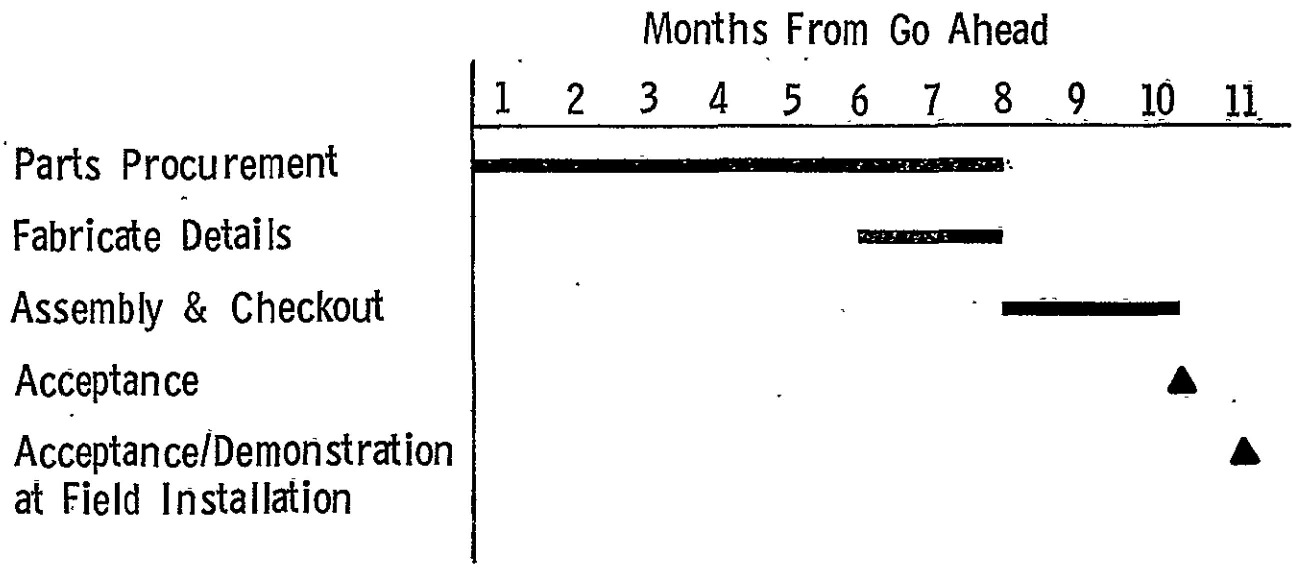
Figure 8 PSS Funding

MMSE IDENTIFICATION	QUANTITY	UNIT COST*	COST PER C&D SET*
PHASE I			
Locked Switch, 2-Position	12	$ 700	$ 8,400
Momentary Switch	20	950	19,000
3-Position Switch	4	900	3,600
2-Position Switch	1	900	900
Status Indicator	10	900	9,000
Event Timer	2	10,000	20,000
Rotary Switch	1	1,000	1,000
Manual Position Controller	1	25,000	25,000
			$ 86,900
			x 3.1**
			$269,390 Program Requirement
PHASE II			
Locked Switch, 2-Position	18	$ 700	$ 12,600
Momentary Switch	11	950	10,450
Status Indicator	15	900	13,500
5-Digit Display	2	20,000	40,000
Rotary Switch	6	1,000	6,000
LED Display, Nomenclature	6	200	1,200
Potentiometers	5	200	1,000
Analog Meter	3	2,500	7,500
			$ 92,250
			x 3.1**
			$285,975 Program Requirement

* Costs reflect vendor quotes and estimates. No PSS contractor G&A or fee is included.

** Three units plus 10% spares

Figure 9 MMSE Hardware Cost



WBS NO.	WBS IDENTIFICATION	COST
01	Project Management	.058
02	Systems Engineering & Integration	.029
03	Control & Display Equipment D/D	.053
04	Control & Display Equipment Manufact.	.528
05	GSE & STE D/D	0
06	GSE & STE Manufact.	0
07	Software Devel.	0
08	Product Assurance	.034
09	System Test	.034
10	Ground Operations Support	.005
	Total Price	.741*

* Includes G&A & Fee, Dollars in Millions

Figure 10 Subsequent Unit Schedule and Cost

STUDY OVERVIEW

The following sections of this report contain summaries of the principal tasks of the PSS study. Figure 11 shows the relationship of the six major study tasks and Table 3 lists the reviews and presentations which were accomplished within the study schedule.

3.0 PAYLOADS CONTROLS AND DISPLAYS REQUIREMENTS (TASK I)

3.1 Payload Selections - The Space Transportation System (STS) Program payloads as described in the two NASA documents *Summarized NASA Payload Descriptions Level A Data*, and *Payload Descriptions, Volume II--Books 1 and 2, Level B Data* number approximately 250 payloads. To effectively analyze each payload for its control and display requirements and to contact the payload personnel for detail information was beyond the scope of this study. The approach undertaken was to review these 250 payloads and from their objectives and experiment hardware equipment identified and described in the above documents and additional payload documentation, reduce the number of payloads to a quantity that could be effectively analyzed for their control and display requirements and, at the same time, be representative candidates which will bound all 250 payloads. A typical example would be the Solar Physics payload, Dedicated Solar Sortie Mission (SO-01-S) which in itself is a complete mission including twelve solar experiments, would be representative of any pallet-mounted solar payloads, and the Solar Maximum Mission would be representative of any free-flyer solar payload that has presently been identified as planning payloads for the Solar Physics discipline.

Utilizing this type of an approach enabled the candidate list for the study payloads to be reduced to the twenty-eight listed on Tables 4 and 5. This list was presented at the first Design Review held on January 22, 1976 at NASA/MSFC, Huntsville, Alabama. The Steering Group concurred with the recommended group with minor changes which are included in the tables.

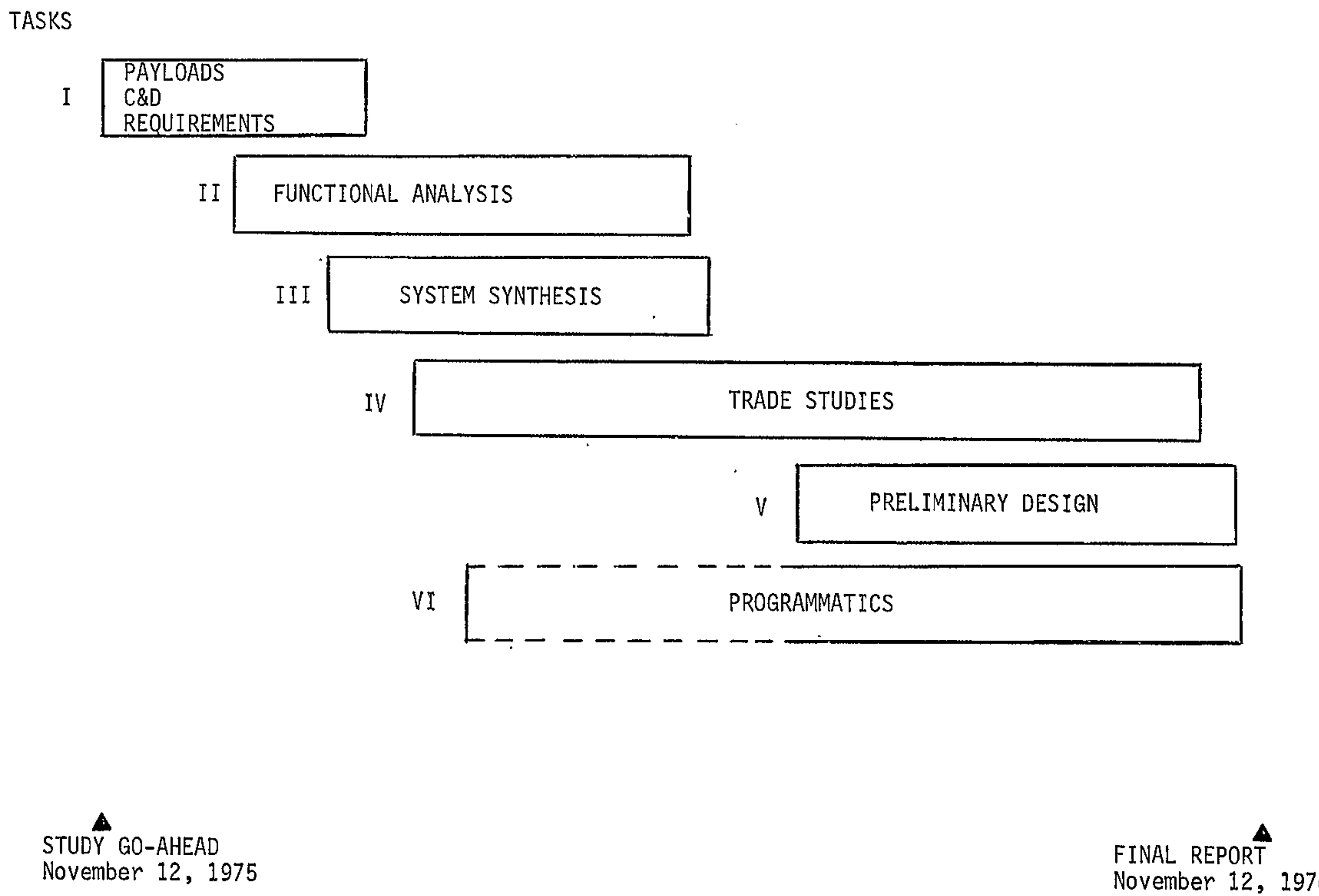


Figure 11 Overview of PSS Study Tasks

Table 3 PSS Study Reviews and Presentations History

REVIEWS	DATES	SITE	OBJECTIVES
Design Review #1	January 22, 1976	NASA/MSFC	• Review Task I, "Payloads C&D Requirements" • Agreement on Representative Payloads and Missions for Follow-On Study Tasks
Design Review #2	March 16, 1976	MMC	• Reviewed and Revised Study Schedule • Discussion on Programmatic/Costing Options to Scope Phase C/D Effort • Review Preliminary Outputs -- Task II, Functional Analysis Task III, System Synthesis Task IV, Trade Studies • Presented Revised Ground Rules and Assumptions for Task VI, Programmatics
Concept Review	June 24, 1976	NASA/MSFC	• Presentation of Proposed AFD C&D Concepts • Selected AFD C&D Concept • Presentation of Final Outputs -- Task II, Functional Analysis Task III, System Synthesis • Review Status of Task IV and Task V • Presentation of Software System Interfaces - Spacelab and Orbiter
Configuration Review	July 20, 1976	NASA/MSFC	• Review of Revised AFD C&D Concept
JSC (Glynn Lunney)	July 22, 1976	NASA/JSC	• Present Selected Configuration of AFD Dedicated Payload C&D
NASA Headquarters	July 26, 1976	NASA/HDQ	• Review AFD C&D Concept and Present Selected Configuration of AFD Dedicated Payload C&D

Table 3 Continued

REVIEWS	DATES	SITE	OBJECTIVES
Final Steering Group Meeting	September 14, 1976	MMC	• Present AFD C&D Concept and C&D Utilization • Define System and Hardware Interfaces • Review CEI Specifications • Present Phase C/D Programmatics • Observe AFD C&D Simulator Demonstration
Final Review	September 21, 1976	NASA/MSFC	• Present AFD C&D Concept and C&D Utilization • Definition of System and Hardware Interfaces • Present Phase C/D Programmatics • Executive Presentation
Final NASA Headquarters		NASA/HDQ	• Final Presentation AFD C&D Concept and Study Task Outputs

Table 4 Recommended Payloads--Pallet and Spacelab Module Mounted

PALLET	SPACELAB MODULE
1. Astronomy • (AS-01-S) Spacelab IR Telescope Facility (SIRTF) • (AS-03-S) Deep Sky UV Telescope • (AS-04-S) Spacelab UV Optical Telescope (SUOT) 2. Solar Physics • (SO-01-S) Dedicated Solar Sortie Mission (DSSM) 3. High Energy • (HE-15-S) Magnetic Spectrometer 4. Earth Observations • (EO-21-S) Shuttle Imaging Microwave System (SIMS) 5. Space Processing • (SP-13-S) Automated Levitation • (SP-15-S) Automated Furnace/Levitation 6. Life Sciences • (LS-04-S) Teleoperator Orbiter Bay Experiment (TOBE) Spacelab • Spacelab 2	• Spacelab 1 • Spacelab 3 7. Atmospheric and Space Physics • (AP-06-S) AMPS 6. Life Sciences • (LS-09-S) Life Sciences Mini-lab

Note: Digits 1 through 8 are payload disciplines.

Table 5 Recommended Payloads--Automated With or Without IUS

WITH IUS	WITHOUT IUS
• Interim Upper Stage (IUS)	2. Solar Physics
8. Communications and Navigation	• Solar Maximum Mission (SMM) (SO-03-A)
• Disaster Warning Satellite (DWS) (CN-54-A)	4. Earth Observations
• Foreign Synchronous Meteorological Satellite (FSMS) (EO-57-A)	• Earth Observatory Satellite (EOS) (EO-08-A)
• DOD - Classified Payload	6. Life Sciences
• Storm Satellite (STORMSAT) (EO-15-A)	• Biomedical Experiment Scientific Satellite (BESS) (LS-02-A)
9. Space Technology	7. Atmospheric and Space Physics
• Space Plasma High Voltage Interaction Experiment Satellite (SPHINX) (ST-02/03-A)	• Gravity and Relativity Satellite (GRS)(AP-04-A)
10. Planetary	9. Space Technology
• Jupiter Orbiter Probe (PL-13-A)	• Space Telescope (ST) (AS-01-A)
• Space Test Project (STP)	• Long Duration Exposure Facility (LDEF) (ST-01-A)

Note: Digits 2 through 10 are payload disciplines.

Matrices detailing the control and display requirements for the twenty-eight payloads were prepared and a typical example is presented in Figure 12. To obtain detailed payload data which may have been lacking from the documents identified above required contacts to be made with the Principal Investigators and project personnel on specific payloads. The payload personnel contacted were very cordial and informative, providing details as presently available on payloads such as Storm Satellite (STORMSAT), Space Plasma High Voltage Interaction Experiment Satellite (SPHINX), Space Test Project (STP), Long Duration Exposure Facility (LDEF), etc.

3.2 Payload Missions - The study ground rule agreed on with NASA/MSFC was to analyze in this study the missions starting with the early Spacelab 2 (1980) and those subsequent missions through 1990.

The various NASA Mission Models (572 Yardley Model, October 1973 Traffic Model, etc) were utilized in evaluating the missions presently planned as scheduled missions during this time period (1980 through 1990). The number of missions presently scheduled during this time period is approximately 360. As in the case of the final payload selections, a similar technique was utilized to reduce the total number of missions to an amount which could be effectively evaluated during this study.

The 360 missions were reviewed and evaluated in combination with the twenty-eight payload candidates selected. This systematic approach enabled the quantity of missions selected as candidates for this study to number eighteen and these are listed on Table 6. These missions bound and are representative of the control and display requirements of the remaining 342 missions and are classified into the following group types specified in Table 6--1) eight free-flyers, 2) four pallet mounted, 3) two hybrid, and 4) four Spacelab missions. The free-flyer missions as noted on Table 6 consist both of payloads utilizing the Interim Upper Stage (IUS) for inserting payloads from the low earth orbit to a higher or synchronous orbit, and those multiple payload missions [Biomedical Experiment Scientific Satellite (BESS), Gravity and Relativity Satellite (GRS), Solar Maximum Mission (SMM)] which utilize the multi-mission spacecraft

Payload	Potential C&D Requirements	Type Requirement			Discipline Impacted										Mission
		Physical	Functional	Operational	Struc. Mech.	Thermal	Elec	Data Mgmt.	Comm.	Nav/Ptg.	C&W	Software	Visual	Control Electronics	
Gravity and Relativity Satellite	1. Orbiter Ptg-Deploy Accuracy: 1800 sec for 0.5 hr Stability: 1800 sec for 0.5 hr Stability Rate: 18 sec/sec	Orbiter Systems	Request Orbiter Ptg	Orbiter Maintain Position						X					1982 BESS/GRS Deploy, SMM Retrieve
	4. 1100 Watts Avg (13.5 hrs)/Orbiter	Switching Control	Monitor Status	Orbiter Power			X								
	6. CRT for Checkout and Monitoring	CRT Display	Select Parameter for Display									X	X		

Figure 12 Payload C&D Requirements by Type and Engineering Discipline by Mission

Table 6 Payload Missions

FREE FLYERS

- Jupiter Orbiter Probe - IUS
- BESS/GRS/SMM
- STORMSAT/SPHINX - IUS
- LANDSAT (EOS)
- Space Telescope/BESS
- DWS/FSMS - IUS
- DOD/STP - IUS
- DOD/IUS - Classified Payload

SPACELAB (PRESSURE MODULE + PALLET)

- Spacelab 1
- Spacelab 3
- AMPS
- Life Sciences Laboratory

PALLET MOUNTED

- Astronomy Facility
- Dedicated Solar Sortie Mission
- SIRTF and Deep Sky UV Survey Telescope
- Spacelab 2

HYBRID (PALLET + AUTOMATED)

- LDEF/Auto Levitation
- BESS/Auto Levitation/Furnace/DWS

configuration and provide their own propulsion module and therefore do not require the utilization of IUS.

4.0 FUNCTIONAL ANALYSIS (TASK II)

4.1 Payloads Functional Controls and Displays Requirements - The controls and displays (C&D) requirements matrices for each of the study payloads (listed in Section 3.0) were utilized to develop the functional controls and displays requirements for each of the twenty-eight payloads. Supplemental payload data were also obtained through telecon contacts with the Principal Investigators and payload project personnel (LDEF, SPHINX, STORMSAT, SIRTF, SIMS, etc) for updated payload inputs.

The functional C&D requirements developed were presented as a separate handout at the Second Design Review held on March 16, 1976 at Martin Marietta Corporation in Denver, Colorado. An example of the matrix format utilized is illustrated in Figure 13 for the Earth Observation Satellite payload.

4.2 Functional Analysis Diagrams - Functional analysis diagrams were developed for the study payloads. These diagrams presented the payload's functional activities flow based on the six mission phases established. These phases are:

- 1 - launch, ascent, orbit insertion;
- 2 - on-orbit checkout and activation;
- 3 - on-orbit operation;
- 4 - deployment/retrieval;
- 5 - on-orbit deactivation;
- 6 - descent, landing, post-landing.

The diagrams were useful in illustrating the activities performed during each of the mission phases specified.

4.3 Mission Functional C&D Requirements - Functional C&D requirements were developed for each of the eighteen missions listed on Table 6 (Section 3.0). These requirements were generated by incorporating the functional C&D requirements for each individual payload identified in paragraph 4.1, and then combining the payloads to fulfill the mission needs.

Payload Subsystems and Element Categories (1)	Functional C&D Requirements	Mission Phase (2)	Station Location (3)	Time Duration (min.) (4)	Remarks
1. Orbiter primary supply Spacelab igloo. Unregulated 25-32V DC	• Controls 1.a) Control to enable orbiter power to Spacelab bus	2, 5	PS	2	1.a) Hardwire to switch on PSS to permit fast shutdown in event of short duration.
2. Spacelab power to SIRTF major elements-- a) IPS b) Telescope and associated equipment	2.a) Control to enable Spacelab bus power to activate IPS	2, 5			
	2.b) Control to enable Spacelab bus power to activate telescope and equipment	2, 5			
0.1 kw nonoperating 5 kw operating	3.a) & b) Control to place individual LH_2 and LO_2 containers on line and to isolate depleted containers. 3.c) Control to allow H_2O collection in onboard tanks and to dump H_2O at appropriate times	2, 3	PS	2	3.a) & b) Additional LH_2 and LO_2 will be required for SIRTF missions longer than 7 days
	• Displays 1.a) Display power supply to igloo - ON/OFF	2, 5	PS	--	
	.a) Display power supply voltage - 25-32V DC	2, 5			
	.a) Display power supply current - 200 Amp (max)	2			

NOTES: (1) Categories: Propulsion, Environmental Control, Electrical Power, Structures, Guidance Navigation and Control, Attitude Control, Communications and Data Management, and Specialized Sensors/Scientific Instruments

(2) 1 - Launch, Ascent, Orbit Insertion
2 - On-Orbit Checkout/Activation
3 - On-Orbit Operation
4 - Deployment/Retrieval
5 - On-Orbit Deactivation
6 - Descent, Landing, Post-Landing

(3) Station C&D function is performed --
• Payload Station (PS)
• Mission Station (MS)
• On-Orbit Station (OOS)

(4) Time required to perform activity.

Figure 13 Functional C&D Requirements for Related Payload Flight Phases (Earth Observation Satellite)

The following paragraphs present a brief description identifying primarily the highlight features of the two most demanding (related to AFD C&D requirements) missions. These are the Astronomy Facility and the Dedicated Solar Sortie Missions.

4.3.1 Astronomy Facility Mission - The experiments and instruments that make up the Astronomy Facility are listed on Table 7.

Table 7 Astronomy Facility Mission

SUOT FACILITY	
• Spacelab UV Optical Telescope (SUOT)	
• Finder Telescope	
• Acquisition Camera	
FOCAL PLANE INSTRUMENTS	
• Direct Imaging Camera (on all missions)	
• Far UV Spectrograph	Two selected for any mission
• Precisely Calibrated Spectrophotometer	Two selected for any mission
• Planetary Imaging Camera	Two selected for any mission
ADDITIONAL SMALL PAYLOADS	
• UV Photometer (2)	
• Imaging Telescope	
• IUE Spectrograph	
• UV Polarimeter	
• Microchannel Spectrometer	
• IR Telescope	
• Schwarzchild Camera	
• Schmidt Cameras (2)	
• EUV Spectrometer	

The mission as analyzed is the one proposed by the Astronomy definition team under Karl Henize, Team Leader, NASA/JSC-TE.

To understand the complexity of this mission can be effectively accomplished by referring to Figure 14 which illustrates the arrangement of the instruments on the Spacelab pallets. As noted, the SUOT baseline telescope utilizes two pallets and the remaining instruments are arranged as shown on the remaining three pallets. The basic SUOT telescope and its focal plane

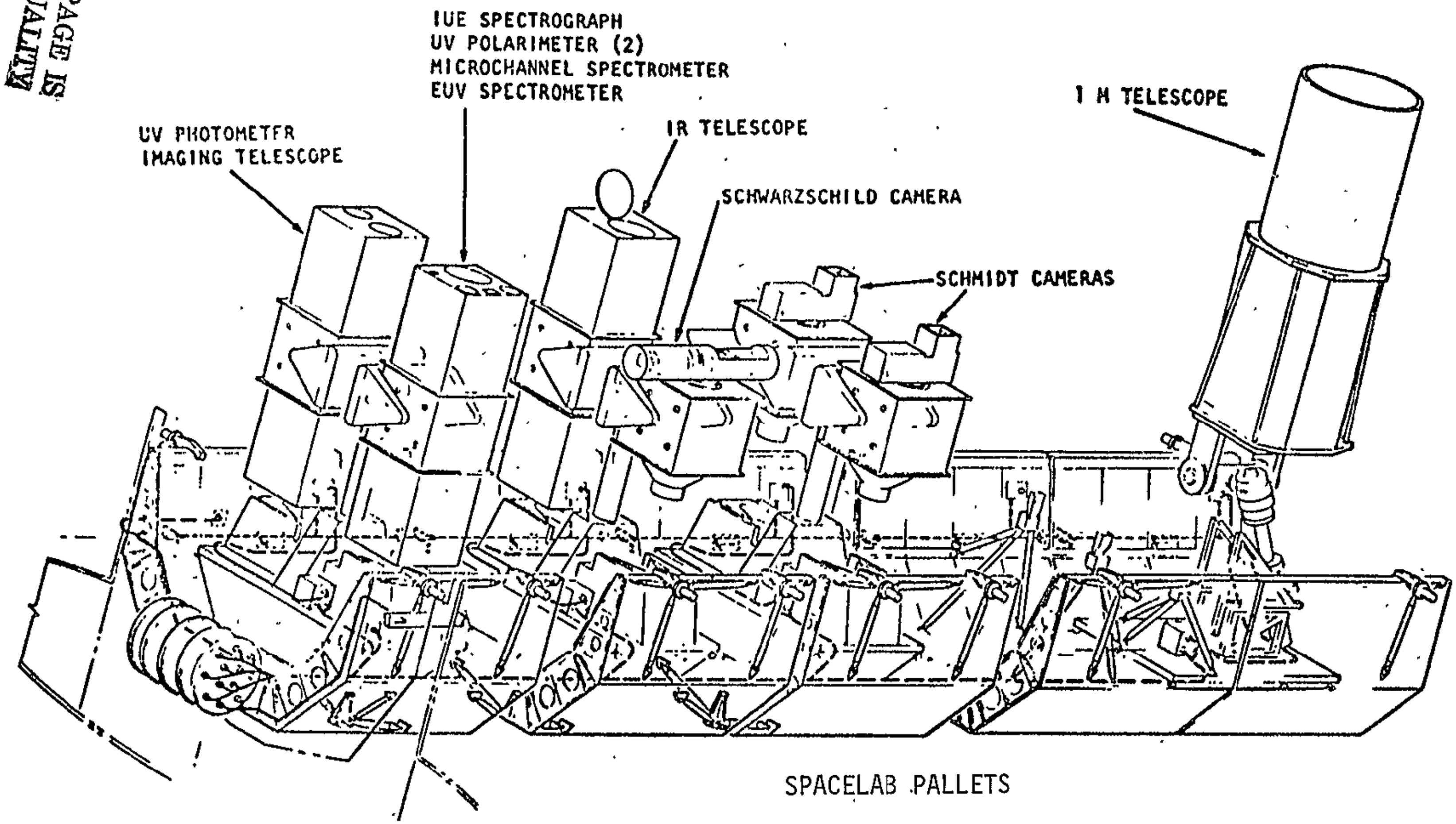


Figure 14 . Astronomy Facility Mission Configured on Pallets

instruments utilize the Spacelab Instrument Pointing System (IPS) for target acquisition. The remaining eleven small payloads utilize a Small Instrument Pointing System (SIPS) on each of the three remaining pallets.

4.3.2 Dedicated Solar Sortie Mission - The Dedicated Solar Sortie Mission (DSSM) includes twelve experiments--1) X-Ray Telescope, 2) White Light Coronagraph, 3) UV Spectrometer, 4) X-Ray Spectrograph, 5) XUV Monitor, 6) XUV Spectroheliograph, 7) EUV Spectroheliograph, 8) Hard X-Ray Collimator, 9) 65 cm Photoheliograph, 10) Gamma-Ray Spectrometer, 11) X-Ray Burst Detector, and 12) HEαI Line Profile. The initial six experiments listed above are anticipated to be modified Skylab ATM experiments.

4.4 Detailed Functional Analysis - The detailed functional analysis results were presented in a separate handout, "Functional Aanlysis," at the Concept Review held on June 24, 1976 at NASA/MSFC. These results enabled the C&D requirements to be grouped either as "common" or "unique."

4.4.1 "Common" Functional C&D Requirements - The definition of "common" functional controls are those commands requiring typically two or three position discretes, adjustments, multi-selections, or keyboard functions. "Common" displays are typically status indicators, lights and/or flags, digital and cathode ray tube monitors. These are typical requirements for the majority of the STS program payloads.

The manual pointing controller for this study is considered as a "common" control function requirement due primarily to the many instruments that require fine pointing to acquire targets.

Examples of "common" control and display functional requirements are presented in Figure 15.

4.4.2 "Unique" Control and Display Functional Requirements - "Unique" C&D functional requirements as interpreted in this study are considered as specific requirements applicable to a single payload instrument or possibly to only a few of the instruments.

FUNCTIONAL REQUIREMENTS		PAYLOAD SUBSYSTEM	MISSION PHASE	REMARKS
CONTROL	DISPLAY			
				EXPERIMENT: X-Ray Telescope
● Activate High Voltage - (ON/OFF)	● High Voltage - (ON/OFF)	● Experiment Power	2, 3, 5	●
● Activate Power - (ON/OFF)	● Power - (ON/OFF)	● Camera	2, 3, 5	●
● Activate Thermal Power (PRI/OFF/SEC)	● Power - (PRI/OFF/SEC)	● Thermal	2, 3, 5	●
	● Thermal Sensor Data	● Thermal	2, 3	● "Common"
● Activate Cover - (OPEN/CLOSE)	● Cover - (OPEN/CLOSE)	● X-Ray Telescope Cover	2, 3, 5	●
● Select Filter - (1/2/3)	● Filter Selected - (1/2/3)	● X-Ray Telescope Filter	2, 3	●
● Select Exposure - (SHORT/NORM/LONG)	● Exposure Selected - (SHORT/NORM/LONG)	● Camera	2, 3	●
● Adjust Brightness	● CRT (Unique)	● X-Ray Image	2, 3	▲ "Unique" X-Ray Image
● Adjust Focus	● CRT (Unique)	● X-Ray Image	2, 3	▲ "Unique" X-Ray Image
	● X-Ray Counts	● X-Ray Image Detector	3	● Detected during one sec
● Activate Alarm - (ON/OFF)	● Audio Alarm	● Flare Detector	3	
	● High Voltage Supply Failure	● Exp. Power	2, 3	▲ Alert (SM)
	● Aperture Control Failure	● Aperture Control	2, 3	▲ Alert (SM)
	● Be Detector Failure	● Exp. Detector	2, 3	▲ Alert (SM)
	● Al Detector Failure	● Exp. Detector	2, 3	▲ Alert (SM)

Figure 15 Functional C&D Requirements - Dedicated Solar Sortie Mission (DSSM)

Our investigation of the payloads presently planned for the STS program revealed a number of payloads had many desires requested but, for successful mission objectives, these could be relinquished. The only "unique" requirements encountered were the one presented in Figure 15 for the X-Ray Telescope, which requires a CRT with a special phosphorous coating to display the x-ray image (this is similar to the x-ray three-inch monitor used on the Skylab ATM). The other unique requirement was for the electron accelerator instrument on AMPS, which required an oscilloscope. However, AMPS presently utilizes the Spacelab pressurized module and no AFD C&D requirement exists.

The results of the mission functional C&D requirements as presented at the Concept Review are summarized on Table 8. These functional requirements

Table 8 Summary of Mission Functional C&D Requirement Results

MISSION	FUNCTIONAL REQUIREMENTS	
	CONTROLS	DISPLAYS
A. FREE-FLYER		
• Jupiter Orbiter Probe - IUS	30	35
• DOD/STP - IUS	70	121
• DOD/Classified Payload - IUS	87	88
• STORMSAT/SPHINX - IUS	119	174
• DWS/FSMS - IUS	148	165
• LANDSAT (EOS)	124	181
• Space Telescope/BESS	144	189
• BESS/GRS/SMM	255	363
B. HYBRID		
• LDEF/Auto Lev./Furnace	78	101
• BESS/Auto Lev./Furnace/DWS	203	246
C. PALLET MOUNTED		
• SIRTF and Deep Sky UV Survey Telescope	107	179
• Spacelab 2	121	204
• Dedicated Solar Sortie	206	244
• Astronomy Facility	468	633

include the total number required for the missions and as such include not only those performed at the Aft Flight Deck, but also those commanded from the ground.

4.5 Driver Missions - The terminology used for "driver" missions was those missions that required the maximum number of functional controls and displays requirements and would also bound any mission combinations presently planned or that could be proposed in the future. The "driver" missions selected were:

- Dedicated Solar Sortie Mission (DSSM);
- Astronomy Facility;
- BESS/GRS/SMM;
- BESS/Auto Levitation/Furnace/DWS.

Also included, primarily because of its early mission status, was the Spacelab 2 mission.

5.0 SYSTEM SYNTHESIS (TASK III)

In Task III of the study, the equipment options which could satisfy the C&D requirements identified in Task II were defined. The widest possible variety of available hardware and software, as individual pieces of equipment and as systems, was investigated. The intent was to synthesize a complete AFD system or systems which could accommodate the range of requirements identified for the study missions. The candidate equipment was defined in terms of technical characteristics, cost, and scheduling (DDT&E flows) requirements. Actual trade studies against selection criteria were performed as part of Task IV.

Table 9 shows the types of components which were surveyed, based on the C&D required by the payloads studied. It is important to note that Space Transportation System (STS) qualified hardware already exists in many of the categories listed, and are directly applicable to use in the AFD. Table 10 lists the major components utilized by the Orbiter which are also required by the AFD C&D. Such components provide advantages in procurement, spares requirements, maintenance/servicing, and qualification costs.

Table 11 shows an example of the format utilized to define equipment candidates. Technical and economic factors are summarized for each candidate in the specified application. A similar matrix was generated for each component type.

Schedule risk was determined by preparing DDT&E flows which identify component procurement lead times (including design, development, and test, if required) in relation to STS program schedules. Table 12 shows the component DDT&E requirements in terms of lead times prior to anticipated launch of Spacelab 2 (first mission wherein payload AFD C&D equipment is required).

The basic system synthesized as the output of Task III involved the general types of equipment listed in Table 13. Specific trade studies, conducted in Task IV, were utilized to determine optimum component configurations (see Section 6.0).

Table 9 Candidate Components Surveyed in Task III

• Switches	• Cathode Ray Tubes	• Software Languages
• Gages	• Panel Indicators	• Man/Machine Interface Language
• Keyboards	• Control Handles (joysticks)	• Tape Recorders and Disks
• LED Readouts	• Plasma Displays	• Analog Panel Meters
• Hard Copiers	• Memories	• Potentiometers
• Computers	• Alphanumeric Generators	• Circuit Breakers

Table 10 Orbiter Candidate Components and Vendors

COMPONENT	CONTRACTOR
Annunciators	Aerospace Avionics
Rotary Switches	Applied Resources
Variable Transformer, Displays and Controls	BOMAR/TIC
Mission and Event Timers	Conrac
Digital Select Thumbwheel Switch, Toggle Switches	Edison Electronics
Tape Meter	Eldec
Mass Memory/Multifunction CRT Displays	IBM
Pushbutton Switches	J. L. Products
Caution and Warning Electronics	Martin Marietta Corp.
Transformer (Power Displays and Controls)	Sterling Transformer Corp.
Event Indicator, Electrical Indicator Meter	Weston Instruments

Table 11 Example of Component Comparison - Payload Central Processors

	IBM AP101	IBM ML1	CII MITRA 125MS/S	SPERRY 1819B	SINGER SKC 3100	TELEDYNE TDY 43S	DELCO 362F
Physical Parameters							
Size	2 ATR 64K	½ ATR - 32K	1 ATR	1 ATR	1 ATR, 7.5x7.6x11.5	1 ATR	1 ATR
Weight	110 lb	20-30 lb	60 lb	30 lb	25 lb	40 50 lb	35 lb
Power	600 Watts	~300 Watts	~300 Watts	~150-175 watts	200 watts (64K)	~400 watts	~200 watts
Cooling	Air	Air or Cold Plate	Water	Air	Cold Plate	Air	Air/Cold Plate
Performance Parameters							
KOPS	480	400-480	300-330	750-900	255	400	350 400
WD Size	32	32	16	18	16/19	16	16/32
Arithmetic	2's Comp.	2's Comp.	2's Comp.	2's Comp	2's Comp.	2's Comp	2's Comp
Addressing	Dir-64K	Dir-64K 16 Bit Half Word	256 w/ relation to base	4K page	1K page	65K	Dir 512
No. Interrupts	33, 11PRI, 5 classes	36, 20PRI, 13 classes	100, 32 levels	28	2 levels	16 vectored levels	
No. Regs	3 sets of 8x32 bit	3 sets of 8x32 bit	256 + 64 base & size	A, B + 8 Gen*	A, B, Base	16x16 bit gen.	16 dedicated
Flt. Pt.	Yes	Yes	Yes	No	No	Yes	Yes
Dbl. Prec.	No	No	Yes	No	Yes	Yes	Yes
Microprogrammed	Yes	Yes	Yes (4K)	Yes	Yes	Yes	Yes
Development Status							
Applications	Shuttle, F8, ALCS, GPS User Lab	Possible Air Force	Spacelab, Tank, Fire control, EW Aircraft	Shuttle Tug Aircraft VSTOL	F16, JTIDS	Nav, Flight Control, Engine Monitor	3000 Built, Fire Control, Nav, Guid
ROM Cost	$150K	$100K	$170K	$60K	$130K	$80 100K	$50 75K
Lead Time	1 year – 14 months	1 year – 14 months	10/78 (1/77 for ground unit ($65K))	90 days	9 months	6 months, first out 1/77	9 months – 1 year
Support Software							
Compiler(s)	HAL/S	Supported on	HAL/S	HAL/S	No	No	
Assembler	on 370 or Self	S/370	on 370 or Self	1819B	360/370, CDC 6000	Yes	IBM 360/370
Comments	Used for Shuttle Avionics; BITE; Has IOP.	BITE	Can be set up as multi-processor, 1 CPU can support 3 IOPs	Uprated 1819A. *Not really general, but has some flexibility.		Univac 1816, AN/UYK 20	J38

Table 12 Component DDT&E Requirements

SUGGESTED COMPONENT START	TIME PRIOR TO LAUNCH (months)	COMPONENTS AVAILABLE FOR INTEGRATION	TIME PRIOR TO LAUNCH (months)
CORE C&D		CORE C&D	
• New Development	32 - 36	• Design Verification	20 - 21
• New Buy	29 - 33	• Qualification	17 - 18
• Off-the-Shelf	26 - 30	• Flight	9 - 10
MISSION-UNIQUE C&D		MISSION-UNIQUE C&D	
• New Development	25 - 29	• Proto-Flight	13 - 14
• New Buy	22 - 26		
• Off-the-Shelf	19 - 23		

Table 13 AFD C&D System as Synthesized by Task III

COMPONENT DESCRIPTION	AFD UTILITY	POSSIBLE LOCATION
• CRT w/ Alphanumeric Keyboard	• Experiment Activation, Experiment Operation, Data Display	• Payload Station-L10/L11 or Mission Station-R12
• CRT w/ Video	• Experiment Pointing	• PS - L10/L11/A3 (CCTV)
• Manual Pointing Controller	• Experiment Pointing	• PS - L10/L11/Portable
• Multi-Use Mission Support Equipment (MMSE) - Event Timers - Switches, Indicators Meters, etc.	• Payload Status, Operation	• PS or OOS - L10/L11/L12/A6/A7
• Spacelab Tape Recorder	• Data Recording	• PS - L12

6.0 TRADE STUDIES (TASK IV)

In Task IV various trade studies were performed on the AFD C&D system configurations developed in Task III. The intent was to establish C&D interface compatibility with Orbiter AFD constraints, develop viable equipment and systems options to satisfy mission requirements, and define a complete AFD C&D concept for preliminary design and programmatic analysis in Tasks V and VI.

6.1 Orbiter Constraints - Orbiter interface constraints and resources which affect the design of the AFD C&D are--payload C&D panel areas, dedicated equipment volumes, equipment weight limitations, thermal dissipation, electrical power, available wiring in the AFD, and the video interface.

Panel areas dedicated for C&D in the AFD consist of those shaded areas indicated in Figure 1. The R12, L10, L11, and L12 panel surfaces are 19-in. wide and 21-in. high.

Equipment volumes extend 20 inches below the panel surface at the PS and MS; there is a limited volume dedicated for payload use below the PS consoles. The weight of each console at the MS or PS is limited to 150 lbs (15 lbs of which is structure).

Thermal dissipation and power dissipation are interrelated in that power utilization in the AFD is limited by the thermal cooling capacity of the Orbiter. The cooling capability provided in the AFD will be 475 lb/hr nominal flow of unfiltered cabin air in a temperature range of 65 to 90°F and a dewpoint range of 45 to 62°F. The total on-orbit cooling capability for the AFD (MS and PS) will be an average of 2,560 BTU/hr (750 watts) in any three-hour period. The maximum allowable power dissipation in the same period is 1,000 watts for 15 minutes.

Electrical power at the PS consists of 28V DC and 115V, 400 Hz AC. Power at the MS consists of 28V DC. A firm requirement also exists for 115V 400 Hz AC power at the MS (for the Spacelab CRT and Keyboard at R12). No power is available at the OOS.

The wiring available in the AFD is that provided for in the Orbiter system design; Table 14 shows the available payload wiring.

Payload TV is available at the Orbiter video switch box. Up to three payload TV signals can be displayed in the AFD; four Orbiter TV signals can be displayed on the closed circuit television monitors (CCTV) located above and to the port side of the OOS. A modification is required to the video switching box to accommodate the video interfaces, select and display, at the PS.

6.2 Selection Criteria - The candidate C&D components (identified in Task III), which must operate within the identified constraints, were evaluated on a comparative basis using the criteria summarized in Table 15. Cost and schedule risks were, in most cases, the determining factors in eliminating individual components and system designs from consideration. The advantages of using equipment already qualified for the STS program--or equipment used in identical or similar form on other NASA programs--together with proper utilization of baselined Orbiter or Spacelab equipment and systems in the AFD, allowed formulation of AFD C&D configuration options shown in Figure 16.

As a result of the Concept Review, Options 3 and 4 were selected for preliminary design. The following paragraphs describe the system characteristics as derived from the trade studies in Task IV.

The principal trade study analysis involved the use of the various CRT/keyboard configurations available as multi-function display systems. Table 16 summarizes the characteristics of the components retained for inclusion in the AFD design.

Both options selected for preliminary design utilize MMSE at panel L12, and in portions of panels L11 and A7. The MMSE provides several advantages in the performance of payload operations. Power limitations in the AFD preclude the use of a third CRT at the payload station; therefore, the MMSE (which uses $<$ 50 watts) is required to allow control and monitoring of payload functions in addition to those displayed on the CRTs at panels L11 and L10. Hardwired switches, which form a part of the MMSE set, provide direct control of critical payload parameters, such as the application of high voltage power to a payload instrument. Other MMSE, such as slewable digital displays and event timers, allow direct monitoring of payload operations while other experiments are activated or monitored on the CRTs. The use of a manual pointing controller as part of the MMSE is dictated by the many identified requirements for instrument pointing.

The specific components of MMSE required within the core concept were identified by analyzing study payload C&D utilization requirements for complete missions. An optimum MMSE complement consistent with the power and wiring limitations in the AFD was identified by analyzing the requirements of the driver missions (see section 4.5), the Spacelab 2 mission and a DOD/IUS mission.

6.3 Analysis of Orbiter and Spacelab Equipment - This section of the report is limited to a discussion of the Orbiter and Spacelab equipment which is utilized at the AFD in support of payload mission operations. Emphasis will primarily be on the equipment which interfaces with the C&D; however other related Orbiter and Spacelab equipment will be briefly mentioned. Figure 17, the AFD Systems Interfaces, will be utilized as a reference for the equipment discussions in the remainder of this section.

Table 14 AFD Available Payload Wiring

Wire Type	MSS - Bulkhead	MSS - OOS	PSS - OOS	PSS - Bulkhead	PSS - MSS
TSP	13	41	41	94	4
TP	5	13	13	88	0
Coax	0	0	4	3	3

Table 15 Selection Criteria and Rationale

CRITERION	RATIONALE
PRIMARY	
Performance	Ability to meet payload requirements
Cost	Desire for low cost system--initially and operationally
Schedule Risk	Ability to meet need dates
SECONDARY	
Physical (performance)	Compatibility with Orbiter constraints/resources
Commonality (cost/schedule)	Provides flexibility, cost, schedule, spares, maintenance, servicing, procurement advantages
User Integration (cost/schedule)	Impacts user acceptance, operational era costs
Foreign vs Domestic (cost/schedule)	Impacts maintenance, servicing, initial procurement
Turnaround Time (cost/schedule)	Impacts quantity of units needed, operational era costs

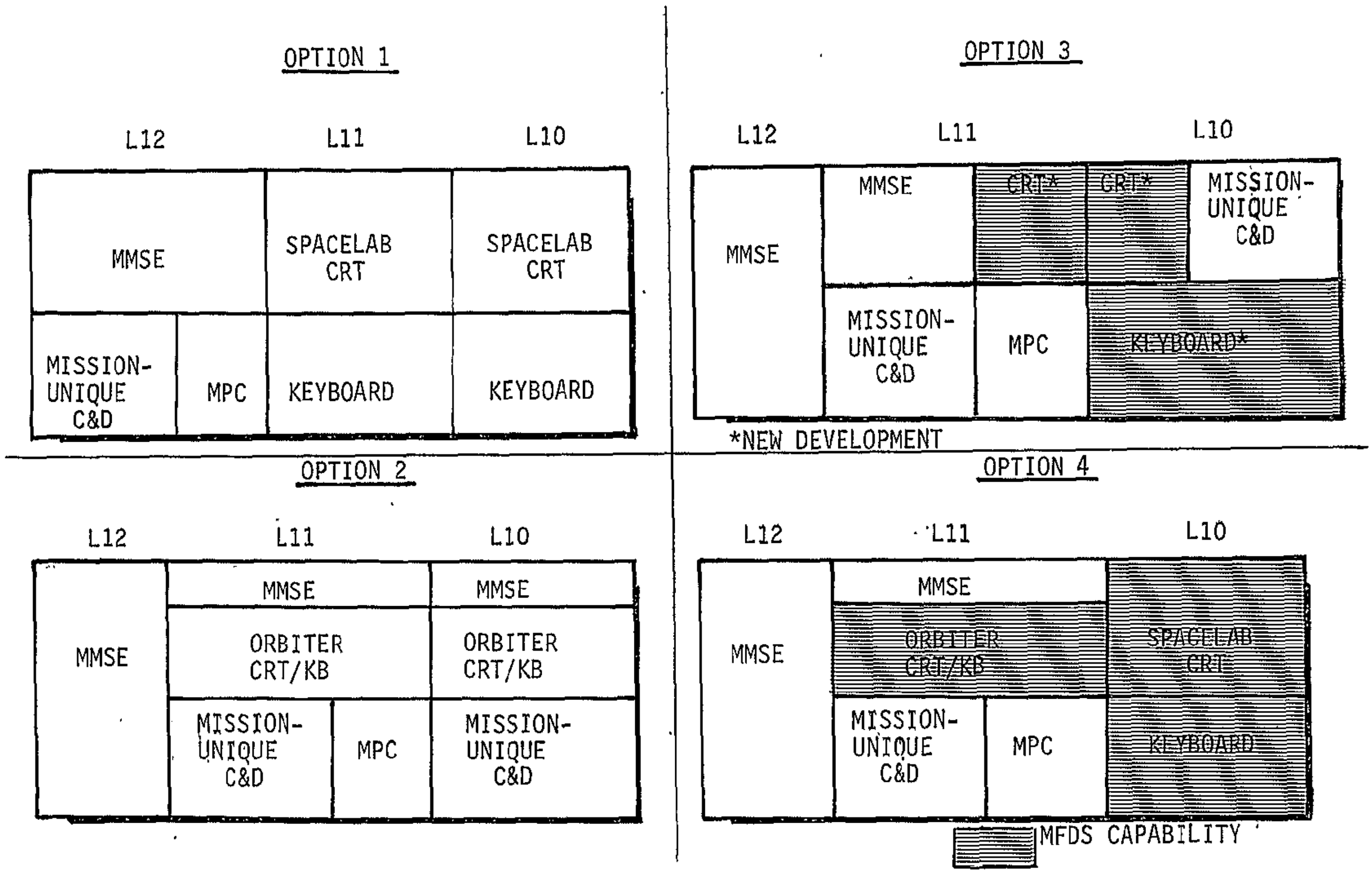


Figure 16 PSS Options and Configuration Layouts

Table 16 Multifunction Display Systems Summary

COMPARATIVE FACTORS	MFDS (IBM/Norden)	MFDS (Bendix)	Spacelab
Size of Screen	5-in. x 7-in.	8.5-in. x 11-in.	7.5-in. x 10-in.
Color	No	No	Yes: Red-Green-Yellow
Resolution	83 lines/in.(416 lines)	60 lines/in.(525 lines)	
Power - On (watts)	313	170	290
Power - Standby (watts)	20	20	50
Voltage	28 volt DC, 5 volt DC	115 volt, 400 Hz	115 volt, 400 Hz
Weight (lbs)	66	105	65
Number of Keys	32 Keys ACS II keyboard + special symbols	60 Keys ACS II keyboard + special symbols	78 Keys ACS II keyboard
Resolution - Alphanumeric	• Large characters--22 lines, 43 characters • Small characters--26 lines, 51 characters	25 lines, 50 characters Status line - top line Address-bottom 2 lines	21 lines, 47 characters
Graphics - geometric patterns, circles, and vectors	• Vectors (variable length) • Circles (variable diameters)	• Vectors (variable length) • Circles (variable diameters)	• Vectors • Circles
Video	Hardware modification required	Yes--EIA RS 330 standard format	No
Video with Alphanumeric Overlay	Hardware modification required	Yes	No
Video with Graphic Overlay	Hardware modification required	Yes	No
Size of Display and Key-board	Width, 14.9"; Height, 7.4"	Width, 18.0"; Height, 21.8"	Width, 19.0"; Height 24.0"

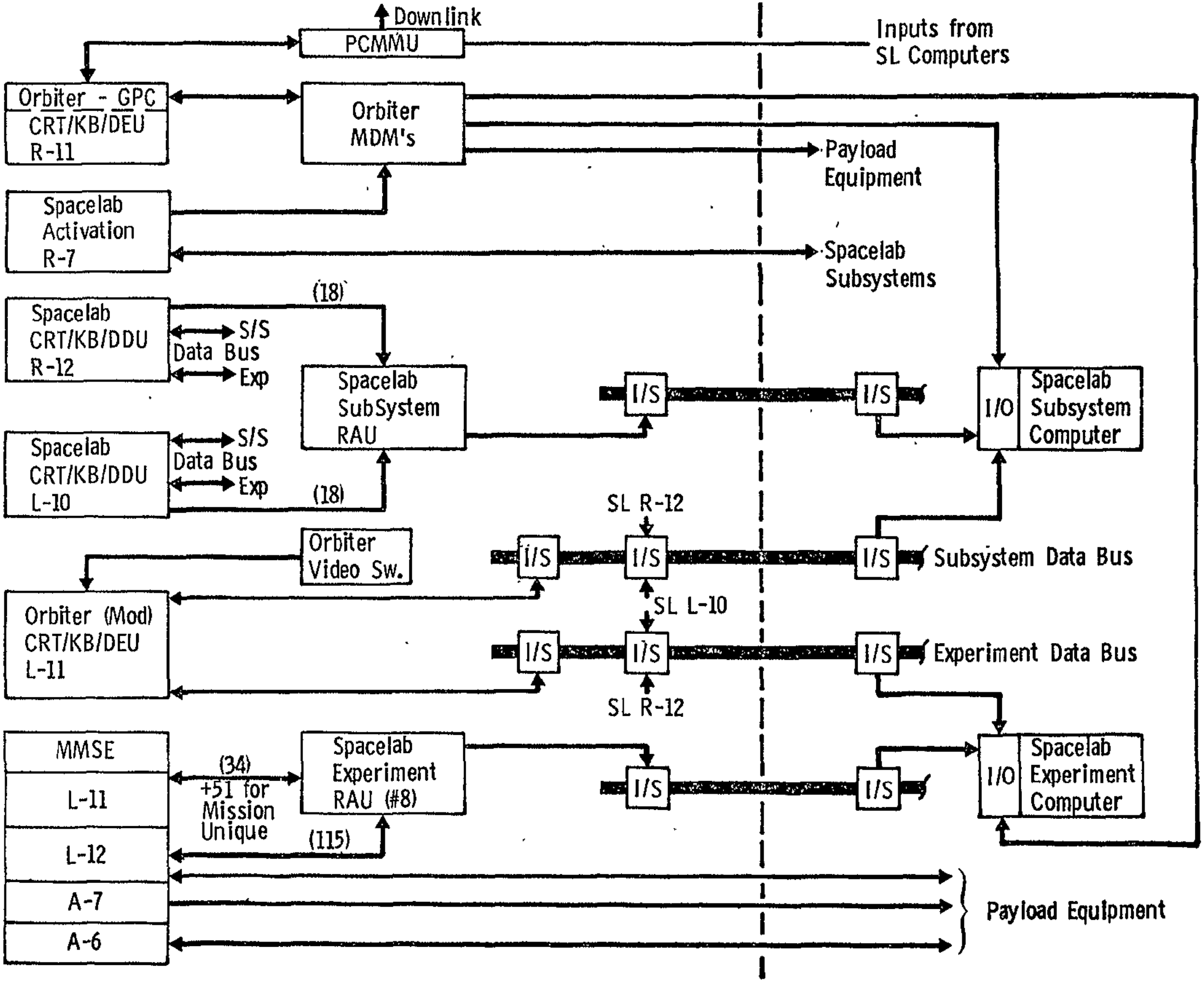


Figure 17 AFD C&D Systems Interfaces

6.3.1 Orbiter Equipment - AFD Utilized - The orbiter general purpose computer and input output processor (GPC/IOP) is the key to utilization of orbiter equipment and services at the AFD. One of five orbiter GPCs will be available for payload use during the on-orbit phase of flight. During other phases of flight the orbiter GPC is not available for payload use. In addition, it should be noted that during the on-orbit phase only a portion of the assigned payload computer is available for use in that it will be shared with orbiter system management tasks. During this operation if the orbiter requires use of the computer as a result of other computer equipment failures, it has priority and can terminate the payload task. Within the above system constraints one orbiter GPC/IOP is available for payload utilization provided it conforms to the standard orbiter services provided in the systems software. These services are:

- Data acquisition and output handling;
- Fault detection and annunciation;
- Payload control supervisor;
- Uplink throughput;
- GN&C data transfer;
- PL table maintenance, commanding and process control.

The orbiter GPC/IOP communicates with payload multiplexer/demultiplexers (MDMs) via data buses. These MDMs are the primary command and monitor interface with the payloads. Two payload MDMs are provided in the basic orbiter system. Provisions have also been made to add additional MDMs in the form of a kit at the midbody of the orbiter. These MDMs, conbined with standard software services and driven by mission-unique systems software, will provide ample control of payload experiments.

The status of payloads may also be acquired by monitoring the telemetry data. Through pre-mission selection, specific telemetry quantities will be routed to the Orbiter GPC/IOP. This will allow the Orbiter computer access to the same information as contained in the ground transmission.

6.3.2 Orbiter Support Equipment - Beside the primary orbiter equipment discussed above, which are used to control the payloads from the AFD, several other types of orbiter equipment may be utilized during mission operations. A payload recorder, the controls for which are mounted in the AFD, is assigned to payload use. It can record up to 14 channels of 1 Mb data, resulting in up to 58 min. of data. Also, the orbiter CCTV system may be utilized to simultaneously display up to four independent pictures on two 4.75 x 6.3-in. display screens. A total of seven video signals (four assigned to orbiter and three assigned to payloads) may be selected from to obtain up to four video pictures. In addition, the switching network of the CCTV has a remote control and one external port which will be routed to the payload station in the AFD. It should be noted that a few payloads require five or more video signals. These payloads would require an additional switching box to select the desired signal from more than five outputs.

The Payload Signal Processor (PSP) and the Payload Interrogator (PI) for RF communications will provide a command and telemetry data link for attached and free-flying payloads. The command link is limited to 2 Kbs of information rate, while the telemetry is 16 Kbs. The telemetry signal is routed through the payload data interleaver (PDI) and PCMMU for either down link or GPC/IOP operations. The command uplink routes through the NSP, MDM, and PSP to reach the attached or RF payload interfaces.

The network signal processor (NSP) is the central point for all uplink and downlink transmissions to the ground. All payload telemetry for downlink is routed through the NSP to the orbiter GPC/IOP for decoding and subsequent transmission to the payloads via the MDM and PSP.

6.3.3 Spacelab Equipment - AFD Utilized - As in the orbiter system, the two Spacelab computers (SLC) and input/output processors (IOP) are the key to utilization of Spacelab equipment. The computers will contain systems software which will allow communications with all peripheral devices such as the CRT display, alphanumeric keyboard, remote acquisition unit (RAU), and mass memory unit. The integration of CCD will require an extension to the systems software in the experiment computer, allowing communication with the AFD control and display equipment.

A subsystem RAU is currently baselined for the AFD. Trade studies investigating the need for this RAU plus the utilization of an experiment RAU in the AFD resulted in the following data: 36 functions are required for the subsystem RAU, whereas 149 functions, are required for an experiment RAU. The experiment RAU will be utilized to multiplex the 149 serial, discrete, and analog functions into one serial data bus communicating with the experiment computer, leaving 51 functions to support mission unique requirements.

A small emergency panel is provided for backup control of the instrument pointing system (IPS). This panel is located at the on-orbit station and provides a hardwired manual operation of the IPS.

6.3.4 Spacelab Equipment - Support - The mass memory unit is available to payloads for storage of mission-unique applications software which is not currently being utilized. This can include processing programs, display formats, and mission timeline procedures. In addition, large data bases (i.e., star catalogs) can be stored for reference by mission applications programs.

The power distribution box located at the payload station supplies power for all Spacelab equipment in the AFD (two displays, two electronics units, one experiment RAU, and the backup IPS panel).

6.3.5 Interfaces - The Spacelab type data bus and patchable hardwired connections are the only interfaces between the payload and the CCD. An additional bus interface, via the Orbiter GPC, exists between the MFDS and payload for control by orbiter computing systems. This system interface utilizing software-driven data buses allows the CCD to satisfy a wide range of mission unique requirements.

The standard orbiter services are hardwired through the interface to telemetry and multiplexer systems which are in turn data bused to the orbiter main computer. A combination of these two major systems interfaces will be utilized by Spacelab to satisfy total mission requirements. The orbiter equipment and interface will be utilized to activate the Spacelab systems while the total CCD interface will be used during on-orbit operations of pallet-mounted experiments.

The free-flyer missions require the minimum utilization of the AFD to payload bay interfaces. It consists of two basic parts. One provides the standard orbiter services via a data bus link. This primarily would consist of guidance and navigation updates and telemetry display status on the orbiter displays. The second part is a series of hardwired switches and status flags for deployment sequences, located on panel L12.

For hybrid missions (pallet and free-flyers) one interface concern exists. The Spacelab system has utilized all the baseline capability to communicate with the Orbiter computing system in the MDM and telemetry interfaces, having the free-flyer only limited via hardwire control at the AFD.

7.0 PRELIMINARY DESIGN (TASK V)

The aft flight deck C&D configuration proposed as a result of this study includes the design of five separate panels which comprise a core C&D system. In addition, the interfaces between this core system and the Orbiter/ Spacelab equipment provided as part of the basic STS system have been defined.

7.1 Panel Layouts - Figures 18 through 22 show the panel layouts of the core C&D. Panels L10, L11, and L12 are located at the payload station (PS) in the AFD, panel R12 is at the mission station (MS), and panel A7 is at the on-orbit station. An alternate configuration of panel L12 includes incorporation of the Spacelab high rate digital tape recorder (see Figure 19). Use of either of the proposed L12 configurations depends on specific mission requirements.

The core C&D panels are integrated within the total AFD capabilities for payloads. Additional panel areas dedicated to payload use and not required by the core C&D are located at R7 (MS), and at A6 and A7 (OOS). The remaining AFD panels are dedicated to Orbiter C&D, some of which (R11, R13, A3) may be utilized by payloads for specific applications.

7.2 Systems Interfaces - The proposed core C&D interface with standard Orbiter systems, Spacelab systems, and payload-unique systems--all of which is located in either the AFD or the Orbiter payload bay. Systems interface diagrams for pallet and free-flyer payloads are shown in Figure 17. The interfaces depicted are consistent with the defined interfaces of both the Orbiter and Spacelab systems.

For Spacelab missions, the primary interface to the core C&D is through the Spacelab experiment and subsystem computers located in the igloo in the payload bay. Additional capability also exists to hardwire some functions directly to a payload or instrument in the payload bay. For free-flyer missions, the Spacelab computational systems would not be available, and the core C&D interfaces either to the Orbiter GPC, to a payload-provided computer, or

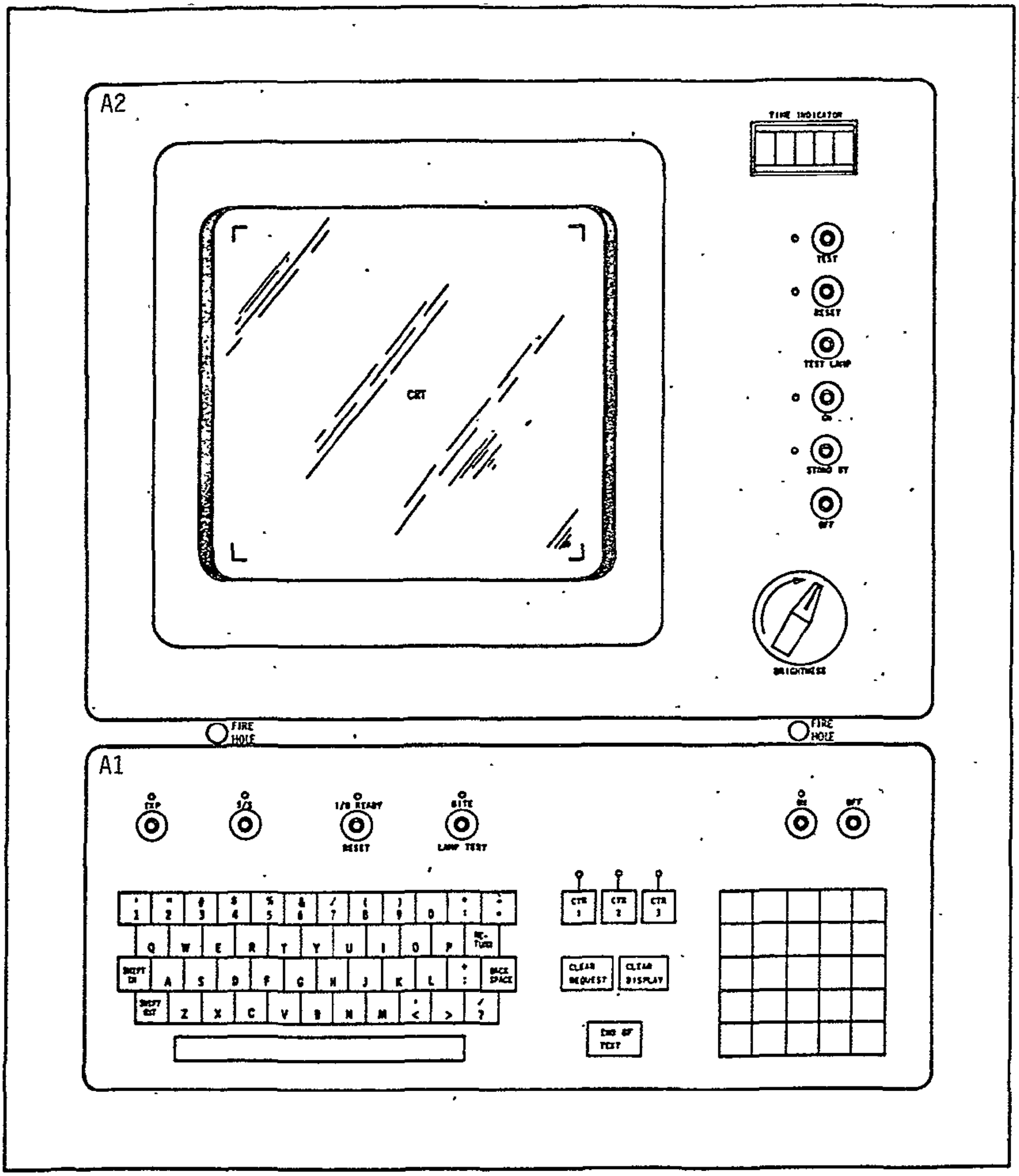


Figure 18 AFD C&D Concept - Panels L10 and R12

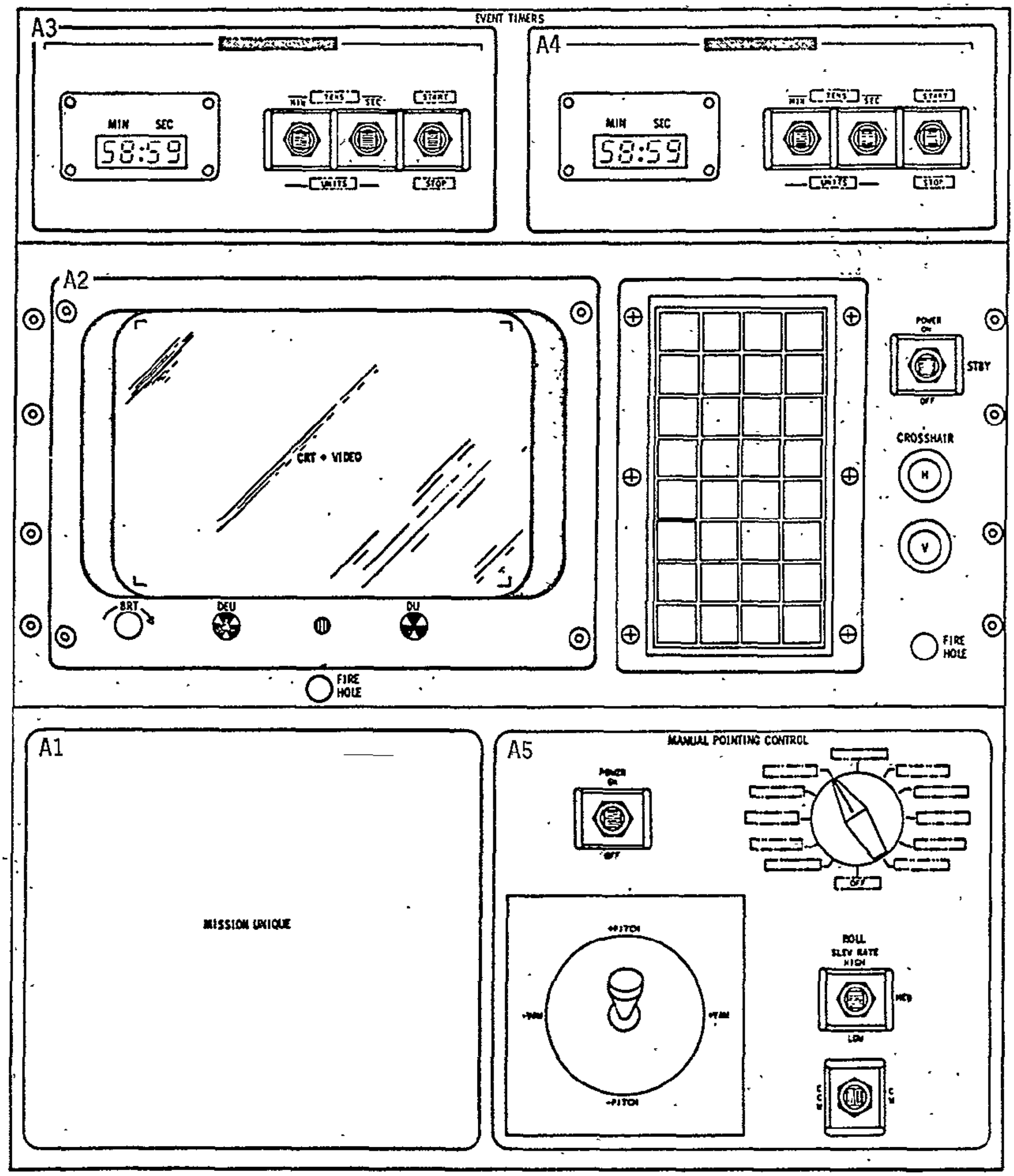


Figure 19 AFD C&D Concept - Panel L11

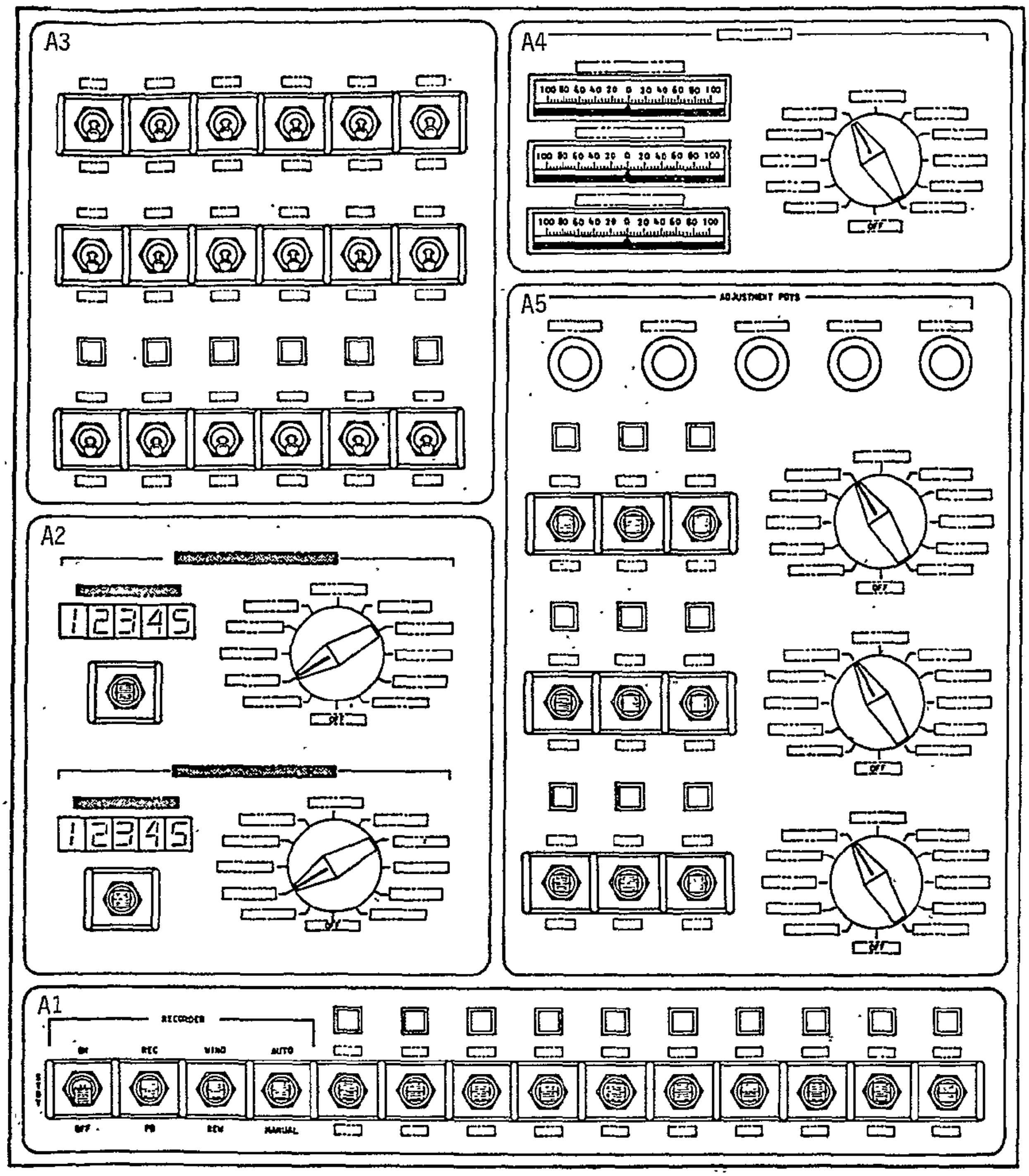


Figure 20 AFD C&D Concept - Panel L12

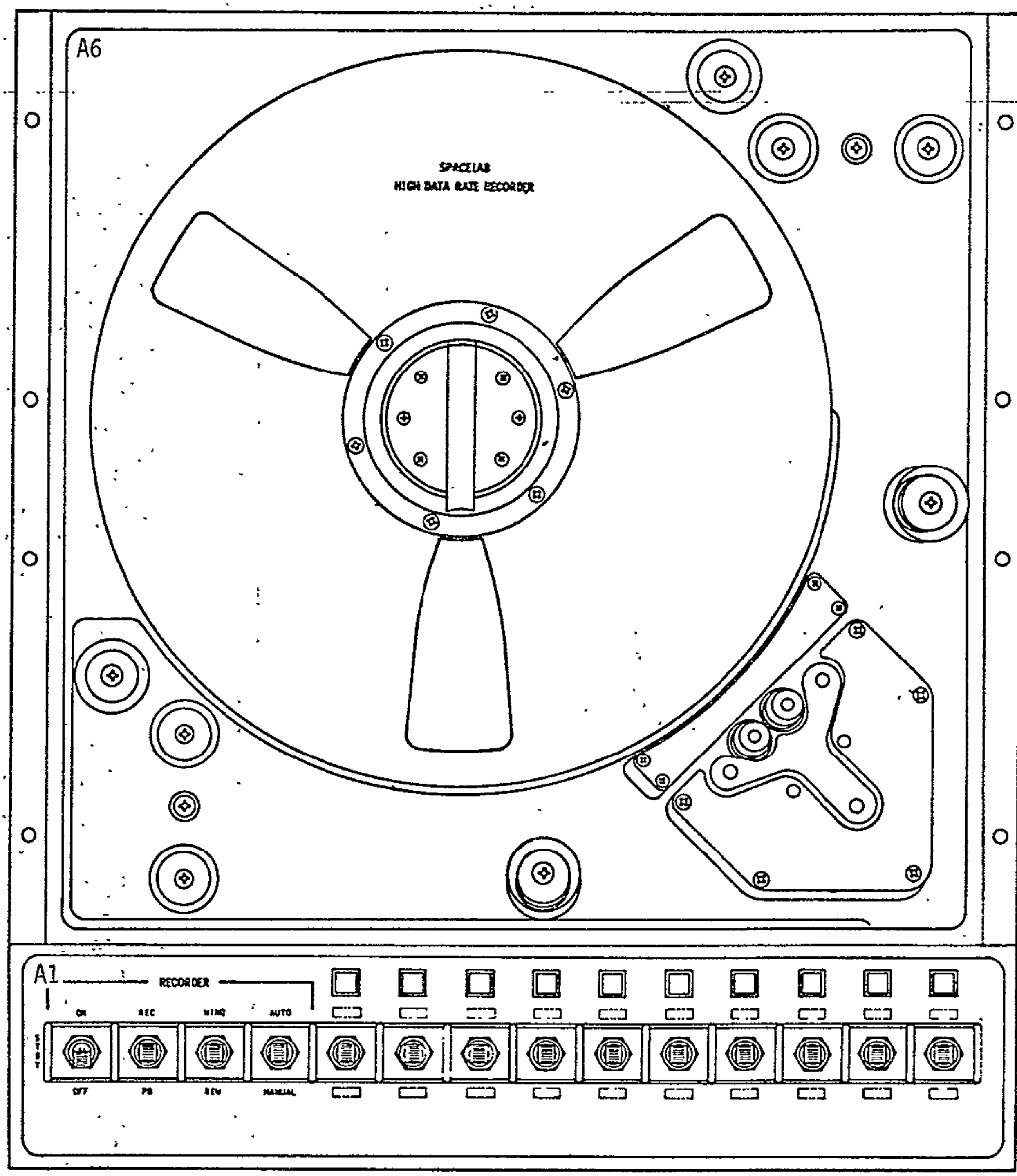


Figure 21 AFD C&D Concept - Panel L12 Alternate

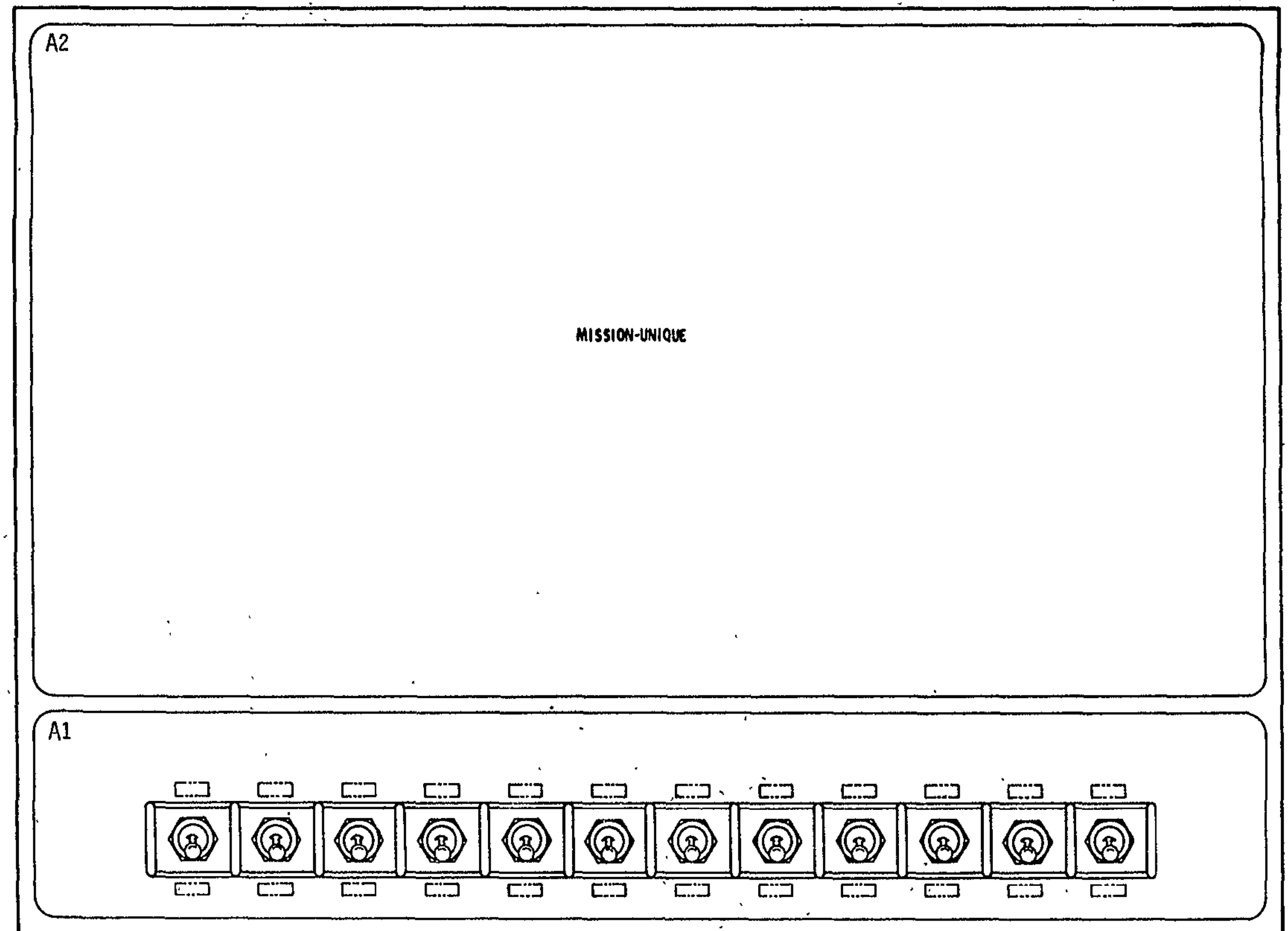


Figure 22 AFD C&D Concept, Panel A7

directly with the payload via hardwires. Specific configurations are dependent on overall mission requirements.

7.3 Hardware Interfaces - The core C&D panels all mount within the standard 19-inch racks provided by the Orbiter. Four of the panels (L10, L11, L12, and R12) occupy a full rack module (19 inches wide x 21 inches high x 20 inches deep), and the on-orbit station rack (A7) occupies a smaller volume (19 inches wide x 14 inches high x 8.0 to 9.5 inches deep). The volume behind the panel surfaces houses electronics associated with the C&D (e.g., display electronics, recorder electronics, experiment RAU, etc).

7.3.1 Power Summary - Power utilization by core C&D is summarized in Table 17. Since on-orbit power consumption by payload C&D in the AFD is limited to 750 watts average during any three-hour period, it is imperative that functional timelines be generated for each specific mission configuration to determine the most efficient use of AFD C&D. Table 18 presents a listing of the possible component utilization combinations, and the corresponding power totals. It should be noted that the figures quoted are a worst case analysis. Figure 23 shows an example of a power timeline for the Astronomy Facility mission, and indicates how such an analysis can be used to insure power constraints are not exceeded.

7.3.2 Wiring Interface Summary - The preliminary wiring design consists of specifying the wiring between the various items of core and mission-unique C&D hardware on panels L10, L11, and L12 and the PSS distribution panel. The preliminary design also made the most efficient utilization of payload-dedicated wiring (provided by Orbiter). Payload-dedicated wiring is that wiring available for payload use between the various distribution panels and between a particular distribution panel and the bulkhead.

The wiring between the controls and displays located on Panels L10, L11, and L12 and the PSS distribution panel was designed to provide the following capabilities--to remove Spacelab equipment and associated cabling on non-Spacelab flights without impacting Orbiter wiring; to add mission-unique wiring in support of mission-unique C&D without impacting Orbiter or core wiring.

Table 17 AFD C/D Power Requirements

PANEL	EQUIPMENT		POWER (watts)	
			OPERATIONAL	STANDBY
R12	Spacelab CRT/KB/DEU		290	50
L10	CRT/KB/EU		-290	50
L11	CRT/KB/EU		-313 (max)	20
	Event Timers		14	--
	LEDs (Legends)		10	--
L12	Spacelab Recorder: (Exp. RAU Required, 25W)	Record	101	46
		Playback	186	
		Wind/Rewind	101	
	Status Indicator Flags (25)		8	--
	LEDs (Legends)		20	--
	Digital Displays		13	--

Figure 24 depicts the PSS to distribution panel cabling. The distribution panel is made up of 20 connectors which contain either payload dedicated and/or Orbiter wiring, as defined by the Orbiter system design. The Orbiter design has provided wiring from the PSS distribution panel to either the on-orbit station, the bulkhead, or Orbiter systems. Nine of the 20 connectors contain payload dedicated wiring--four of which contain both payload-dedicated and Orbiter wiring. The remaining five connectors contain payload-dedicated wires only.

Core C&D wiring which will not change from mission to mission is wired to connectors in the PSS distribution panel which also contain Orbiter wiring. The core C&D wiring which may be removed on non-Spacelab flights is wired to connectors which contain payload-dedicated wires only. Seventy-nine wires from the distribution panel through the bulkhead are available to support mission-unique C&D at panels L11 and L10. This wiring may be utilized at any time without impacting either Orbiter or core wiring.

Table 18 AFD C/D Power Combinations - Watts

R12	L10	L11		L12		AFD C/D	CAPABILITY
		CRT	TIMERS	RECORDER	STATUS		
ON 290	ON 290	ON 313	ON 14	PLAYBACK 186	ON 5	1,098	Maximum Power Combination
ON 290	ON 290	ON 313	ON 14	RECORD 101	ON 5	1,013	Full Up, Record
ON 290	STBY 50	ON 313	OFF	OFF	OFF	653	Exp. Setup + Pointing
ON 290	STBY 50	ON 313	ON 14	RECORD 101	ON 5	773	1 Data Plot + Video + Record
ON 290	ON 290	STBY 20	ON 14	RECORD 101	ON 5	720	2 Data Plots + Record
STBY 50	ON 290	STBY 20	OFF	PLAYBACK 186	OFF	546	Exp. Setup + Data Dump
ON 290	STBY 50	ON 313	ON 14	PLAYBACK 186	ON 5	858	1 Data Plot + Video + Data Dump
ON 290	ON 290	ON 313	ON 14	STBY 46	ON 5	958	Full Up, Recorder Not Required

NOTES: 1) 750 W average power allocation
2) 1000 W peak, 15 min during 3 hour period
3) Mission-unique C/D must be added, if required

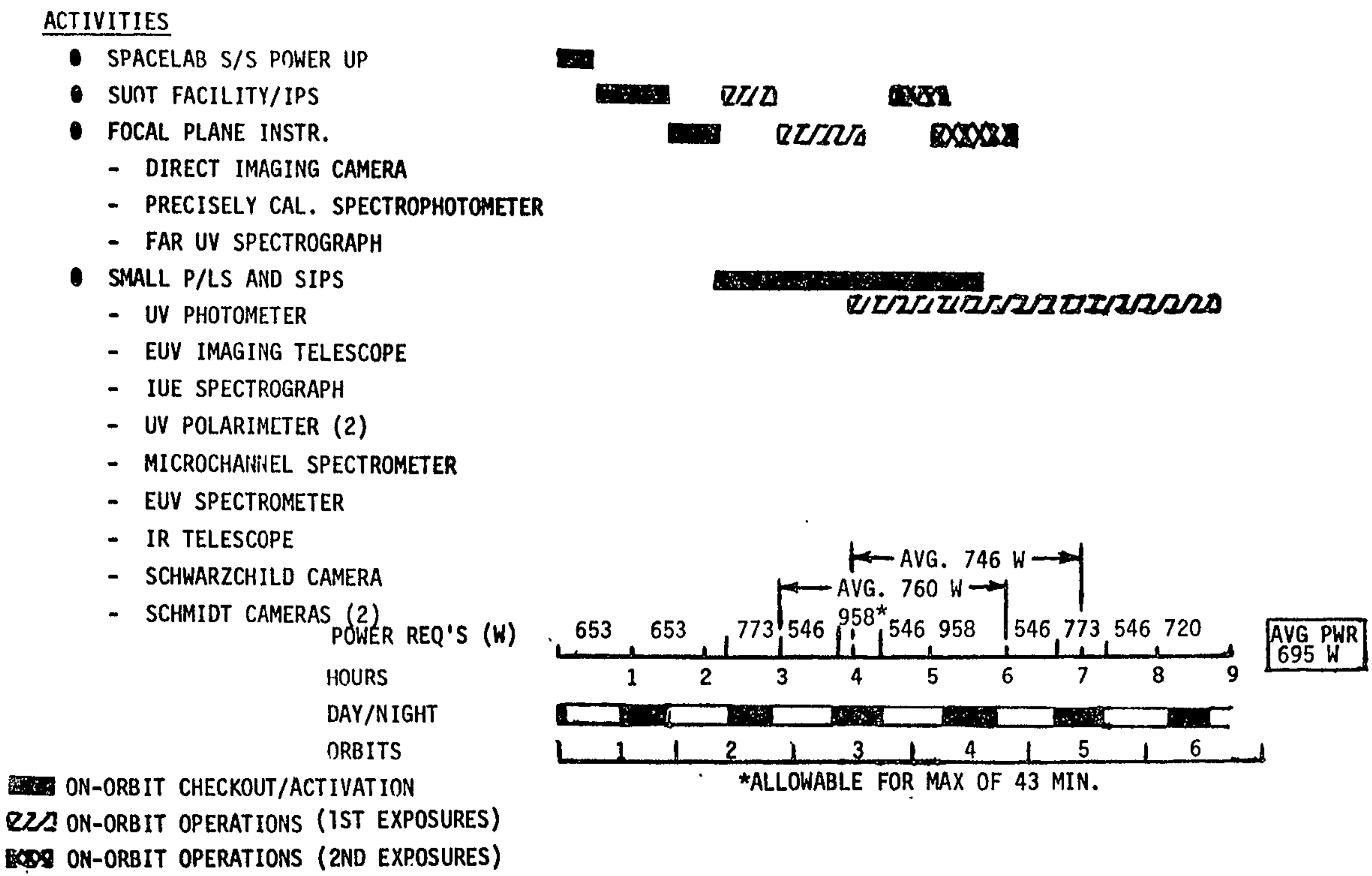


Figure 23 Astronomy Mission - Timeline

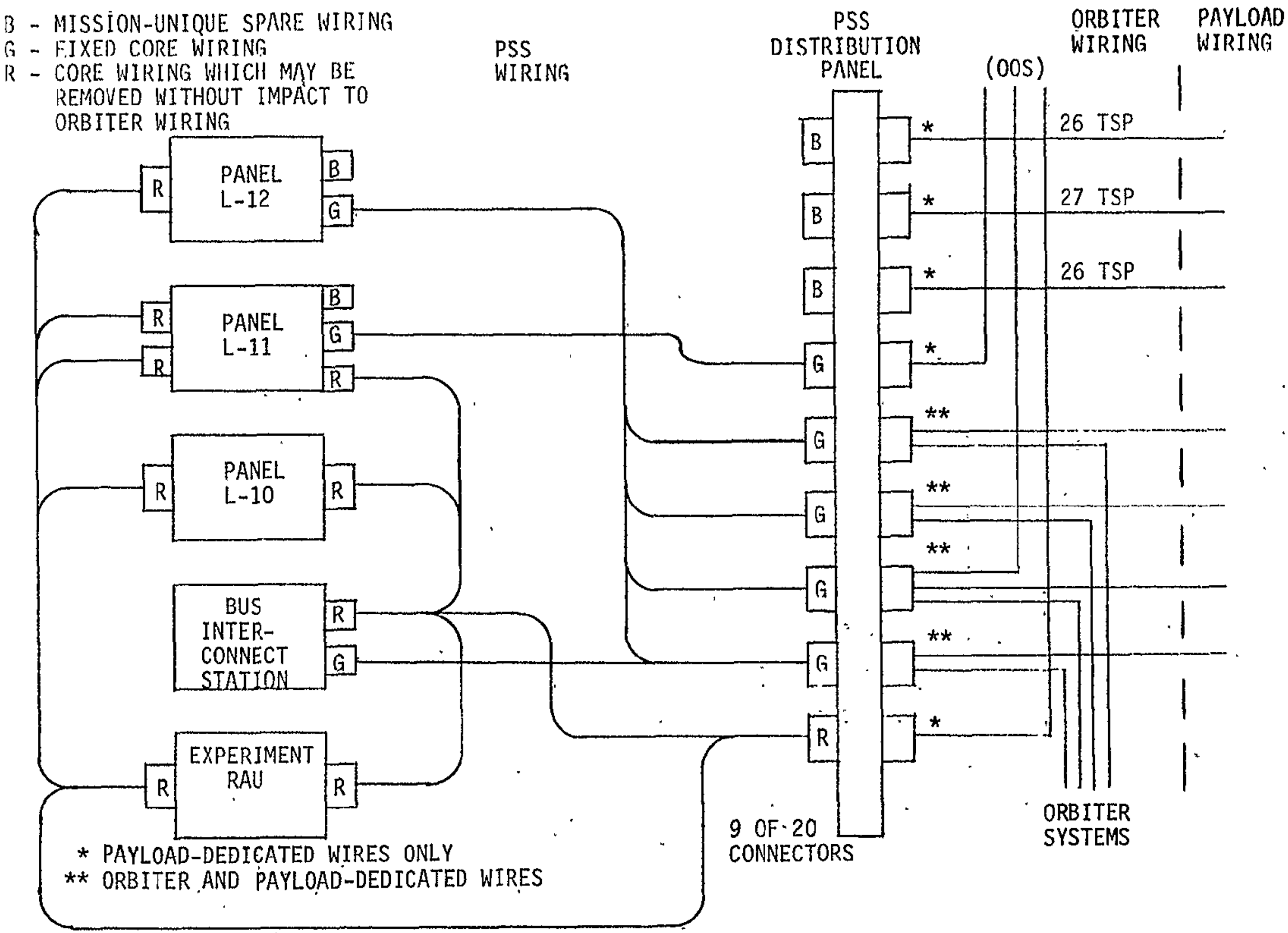


Figure 24 PSS Cabling and Connector Schematic

Table 19 depicts the AFD C&D wiring utilization. It shows the wires used between the three stations (MSS, OOS, PSS) and between a particular station and the bulkhead. Table 19 also indicates spare wiring available for mission-unique C&D.

Table 19 AFD C&D Wiring Utilization

Route \ Type	TSP	TP	COAX
Wiring Utilized by Core C&D plus A6/R7 C&D			
MSS Patch Panel			
To Bulkhead from R7	31	25	-
To Bulkhead from A6	9	5	-
To OOS Patch Panel from R7	2	2	-
To OOS Patch Panel from Core at R12	18	-	-
To Bulkhead from PSS	4		
PSS Patch Panel			
From OOS Patch Panel:			
R7	2	2	-
Core at R12	18	-	-
A7	-	12	-
To Bulkhead from Core at L12, L11, L10	15	72	-
To Bulkhead from Core at A7	-	12	-
PSS Core to RAU*	149	-	-
Wiring Available to Mission-Unique C&D			
PSS Patch Panel			
To Bulkhead	79	-	-
From OOS	11	-	-
To MSS Patch Panel	-	-	3
Mission-Unique at L11 to RAU	51	-	-

TSP = Twisted Shielded Pair
TP = Twisted Pair

*RAU's are considered part of core

7.3.3 Weight Summary - The weight allocated for each panel at the PS and MS is a maximum of 150 lbs. Fifteen (15) lbs are used by the panel structures. All panels associated with the AFD core C&D weigh substantially less than 135 lbs. L12 is the heaviest panel, weighing 92.8 lbs when the recorder is in place. Table 20 summarizes component weights for the AFC core C&D.

Table 20 PSS Core Equipment Weight Breakdown

PANEL L12	
1 Spacelab Recorder/MMSE	83.0/31.0
14 Toggle Switches	2.8
10 Status Indicators	2.0
Cabling and Structure	5.0
Total	92.8

PANEL L11	
1 Display Unit, DEU, Keyboard	66.0
2 Event Timers	2.0
1 Manual Pointing Controller	3.0
10 Toggle Switches	2.0
2 Potentiometers	0.5
1 Rotary Switch	0.2
Cabling and Structure	5.0
Mission-Peculiar Equipment	~5.0
Total	83.7

PANEL L10	
1 Display Unit, DEU, Keyboard	65.0
Cabling and Structure	5.0
Total	70.0

PANEL A7	
12 Locked Switches	1.0
Cabling and Structure	2.5
Total	3.5
Total All Panels (L12, L11, L10, A7)	250.0 lbs

SPACELAB EQUIPMENT (118 lbs)

- Spacelab DU, DEU, Keyboard at R12
- Spacelab Emergency IPS Panel at A6
- RAU and PDB at PSS
- Spacelab Activation at R7
- Cabling and Structure
- NOTE: Addition of Experiment RAU adds 19.5 lbs

NOTE: Each panel less than 135 lbs allocated

7.4 Part I CEI Specifications - Contract End Item (CEI) specifications have been completed for the core C&D, applicable software, and for the ground support equipment (GSE) required by the core equipment. Five separate CEIs have been generated--one each for the multifunction display system portion of the core, the multi-use mission support equipment, two software requirements specifications, and the GSE. The following paragraphs briefly describe the contents of the CEIs, which are contained in full in Volume II, Part II of this final report.

7.4.1 Multifunction Display System (MFDS) Specification - The MFDS Part I CEI Specification is written so as not to preclude use of either STS qualified hardware with modifications or a new development. This specification will be used by a contractor to purchase MFDS equipment in a phase C/D contract.

The multifunction display system (MFDS) is located at the Payload Specialist Station (L10 and L11) and consists of two CRTs and one or two keyboards with associated electronics units. The MFDS is the primary method the payload specialist will use to perform experiment setup and display experiment data. He will use the MFDS to assist in such tasks as experiment activation, setup, and calibration. The payload specialist will also perform the experiment and monitor data taken using the MFDS. He will be able to point telescopes, display data plots, monitor experiment status, etc.

The MFDS Part I CEI Specification includes the following as items of special interest. A full alphanumeric KB plus special function keys shall be provided. One of the two CRTs will have the capability to display video, alphanumeric data, and graphics. The graphics and alphanumerics will be able to overlay a video picture. This CRT has the capability to display either a 512-line video picture or a 1,000-line video picture. The second CRT shall be capable of a tri-color (green, yellow, red) display of alphanumerics, graphics, and graphics overlays.

To assist with experiment pointing the MFDS shall provide the means to electronically generate cross hairs on the CRT. The payload specialist will position the cross hairs over the event of particular interest and then command the instrument to slew to this point of interest.

The specification also specifies that the built-in test equipment shall be capable of detecting at least 96% of single-solid failures. This can be achieved by utilizing MFDS self-checks, test programs, and operator interpreted test patterns.

The MFDS is required to interface with both the Orbiter data bus and with the Spacelab subsystem and experiment data buses. These interfaces are with the Orbiter and Spacelab computers. The MFDS will also be required to contain sufficient memory to support the core C&D software. This will reduce the amount of software stored in the Spacelab or payload computers.

7.4.2 Multi-use Mission Support Equipment (MMSE) Specification - The MMSE specification covers the controls and displays (with associated electronics), apart from the MFDS equipment, located at panels L11, L12, and A7. Table 21 lists the specific items for which requirements are detailed in the specification. The MMSE located on subpanels L12-A1, L12-A3, and the potentiometers on L12-A5 are all hardwired through the $X_0$576 bulkhead. The remaining MMSE is ordinarily wired to the experiment RAU at the PS for data bus control.

The specification defines MMSE performance requirements, interfaces, environments, operability, and human engineering requirements. Most MMSE components are standard, STS-qualified types of hardware, not requiring new development.

7.4.3 Software Requirements Specifications

7.4.3.1 Flight Software CEI - The CCD software CEI will contain top level software requirements for communication with MMSE as well as display units and keyboards in the AFD. For the display and keyboards, alphanumeric, graphic, and video overlay requirements will be presented. For the MMSE software driven control and displays each function by subpanel, including the number of interface variables, will be defined. The detailed requirements spanning from the C&D hardware panels to the main computer command and status registers will be provided during the phase C/D contract. The main computer may consist of either an orbiter AP101, Spacelab M125S, or be payload provided. When fully implemented, the command and status registers in the main computer will become a simple interface with the mission-unique application software. The status registers will reflect the current status of all CCD switch command functions, and the command registers will allow the application software to set functions for subsequent display on the MMSE and display units (CRT).

Table 21 Part I MMSE CEI Equipment List

EQUIPMENT LOCATION	DESCRIPTION
L12-A1	• Two-Position Momentary Toggle Switches (13) • Three-Position Indicators (10) • Three-Position Toggle Switch (1)
L12-A2	• 12-Position Rotary Switch (2) • Two-Position Momentary Toggle Switch (2) • Legends (LEDs) (4) • Digital Displays (5-digit) (2)
L12-A3	• Two-Position Locked Toggle Switch (18) • Three-Position Indicators (6)
L12-A4	• Analog Meters (3) • 12-Position Rotary Switch (1)
L12-A5	• Potentiometers, Rotary (5) • 12-Position Rotary Switch (3) • Two-Position Momentary Toggle Switch (9) • Three-Position Indicators (9)
L11-A3	• Event Time Display, 4-digit (1) • Two-Position Momentary Toggle Switch (3) • Legend (LED) (1)
L11-A4	• Same as L11-A3
L11-A5	• 12-Position Rotary Switch (1) • Three-Position Toggle Switch (1) • Two-Position Momentary Toggle Switch (2) • Manual Pointing Controller (Pitch/Yaw) (Joystick) (1)
A7-A2	• Two-Position Locked Toggle Switch (12)

7.4.3.2 Ground Test Software CEI - This Part I CEI specification will define top level test sequence requirements which will allow fault isolation to the subpanel level for all AFD core C&D. The test sequence software will interface with a simple test sequence executive module which will respond to test sequence commands to issue signals, monitor status, write procedural text pages, and print summary results.

7.4.4 Ground Support Equipment (GSE) Specification - Ground support equipment (GSE) is required to perform acceptance testing of the MFDS verification tests of the Spacelab display equipment. Prior to installation of this equipment into the Aft Flight Deck, GSE is required to verify the core C&D equipment during system integration both at KSC and MSFC.

The Part I CEI specification for GSE, which will be used by a contractor to purchase GSE equipment in Phase C/D, includes requirements for a minicomputer-based system (off-the-shelf, common commercial equipment) which can be made to interface with the core C&D in a manner similar to that of the flight computers.

The following major components comprise the GSE. A CRT/keyboard is required to select various test sequences, and display test results and parameters. A line printer is required to make a permanent record of the test sequence and test results. Mass memory is required to store the procedural text and CRT test patterns, etc. The input/output equipment will interface the minicomputer to the core C&D and will simulate the hardware interface of the Spacelab computers.

The Spacelab data bus interfaces with the core C&D shall be verified using GSE. The Spacelab CRT and keyboard shall be verified with GSE utilizing the BITE capability of the Spacelab equipment. All MMSE shall be verified through the GSE. The GSE will interface directly with the MMSE by simulating the Spacelab remote acquisition unit (RAU), thus making the checkout of the AFD core C&D independent of Spacelab equipment. The Spacelab CRT and keyboard will interface over the data buses and will be checked-out when installed.

The GSE will be required to identify and isolate failures in the core C&D to a level which will facilitate easy replacement down to the card level for the MFDS and down to the subpanel level for MMSE.