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FINAL REPORT

FOR

SPACELAB COST REDUCTION ALTERNATIVES STUDY

FINAL BRIEFING

VOLUME II

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SPACELAB COST REDUCTION ALTERNATIVES STUDY

AGENDA

• INTRODUCTION	R. MORRIS
• FLIGHT CREW TRAINING	W. DAUGHERTY
• EQUIPMENT, FACILITIES AND MANPOWER FOR MINIMUM PAYLOAD OPERATIONS	R. MORRIS
• WAYS TO REDUCE COST/MANPOWER FOR EXPERIMENT FLIGHT OPERATIONS AND PLANNING	R. MORRIS

FLIGHT CREW TRAINING

MID TERM RESULTS

- SPACELAB SUBSYSTEMS CREW OPERATIONS TASKS ARE NOT DIFFICULT AND ARE NOT TIME OR PERFORMANCE CRITICAL
- CDMS OPERATION WILL DOMINATE SPACELAB TRAINING EQUIPMENT REQUIREMENTS

STUDY ACTIVITY AFTER MID TERM

- UPDATE FLIGHT CREW TASKS CONSIDERING "REMOTE CONTROL" SUBSYSTEM OPERATION
- EVALUATE USE OF ENGINEERING MODEL, HI-FI MOCKUP, CVT AND INTEGRATION TESTING FOR TRAINING

MID TERM RESULTS

- SOME OPERATIONAL DATA SYSTEMS HARDWARE COULD BE DEFERRED TO REDUCE NEAR TERM COSTS
- MANPOWER COSTS DOMINATE EQUIPMENT AND FACILITY COSTS
- USE JSC RESOURCES FOR RTRP AND CONTROL OF EARLY SPACELAB FLIGHTS

STUDY ACTIVITY AFTER MID TERM

- DEVELOP MANPOWER, FACILITY AND EQUIPMENT REQUIREMENTS FOR JSC PAYLOAD OPERATIONS CENTER AS A FUNCTION OF PAYLOAD DISCIPLINE
- DEVELOP OPERATIONS CONCEPTS WHICH REDUCE MANPOWER

OBJECTIVE

DEFINE COMPREHENSIVE APPROACHES TO FLIGHT CREW TRAINING WHICH MEET NEEDS OF USER AT MINIMUM COST PER FLIGHT AND MINIMIZE FACILITIES, HARDWARE AND SOFTWARE SUPPORT

CREW TRAINING-STUDY OBJECTIVE

The general objective of this task is to define and evaluate logical alternative approaches to Spacelab flight crew payload associated training which, when compared to the SBPP, reduce the investment in supporting facilities, hardware and software and training personnel, but do not compromise safety or system performance.

SPECIAL MID-TERM DIRECTION

- EVALUATE IMPACT OF CHANGES TO SPACELAB BASELINE, ESPECIALLY REMOTE CONTROL, ON TASK ANALYSIS
- REEXAMINE NEED FOR $6M SPACELAB SIMULATOR IN LIGHT OF TASK ANALYSIS RESULTS AND PLANNED EQUIPMENT BELOW
- EXAMINE PROS AND CONS OF USING HI-FI MOCKUP, CVT AND ENGINEERING MODEL IN TRAINING
- EXAMINE POSSIBILITY OF INCORPORATING CREW TRAINING INTO LEVELS II and III INTEGRATION ACTIVITIES

SPECIAL DIRECTION

Following the mid-term briefing TRW was directed to perform the following activities in addition to those defined in the NASA Statement of Work for this task.

1) Update the Spacelab design baseline and examine the impact of remote control upon the operations task analysis.

2) Based upon the results of the revised task analysis and the applicability of the following planned for equipments, reexamine the need for the $6.0M Spacelab simulator.

3) Examine the pros and cons of using the Hi-Fi Mockup, the Engineering Model and Concept Verification Test/General Purpose Laboratory Simulator (CVT/GPLS) in the training of the flight crew and payload and mission specialists.

4) Examine the possibility of incorporating flight crew and payload and mission specialist training into levels II and III Shuttl/Spacelab/Payload integration.

The following material describes the processes employed and products generated to accomplish the task objectives and special study requirements.

APPROACH TO CREW TRAINING REQUIREMENTS DEFINITION

- SPACELAB SYSTEMS ANALYSIS
- MANNED OPERATIONS ANALYSIS
- TRAINING PROGRAM REQUIREMENTS ANALYSIS
- TRAINING EQUIPMENT REQUIREMENTS ANALYSIS
- PLANNED EQUIPMENT EVALUATION
- EQUIPMENT RECOMMENDATIONS

APPROACH TO CREW TRAINING REQUIREMENTS DEFINITION

In order to define cost effective approaches to Spacelab flight crew training, it is first necessary to define the training requirements. A systems approach was used in performing the analyses necessary to define these requirements. This systems approach consisted of the following steps.

It first entailed an analysis of the Spacelab design in order to define the function, operation and performance capabilities of the equipment. Next, an analysis was performed to identify the following:

- Manned operations and interactions with the equipment
- Time and performance criticality of manned operations
- Skills and knowledge levels required to perform the tasks
- Types of training equipment required to develop requisite skills and knowledge.

Once the manned operations requirements are defined and documented, the training objectives for each manned position are collated and a training program and training sequence developed which ensures the systematic and timely development of required skills and knowledge in the personnel.

Task level training equipment requirements are assimilated into meaningful composites and referenced to the appropriate training objectives which they would effectively support.

Next, planned or existing equipment which have potential to satisfy the training requirements are analyzed and the efficacy of their use in the training program evaluated.

Recommendations as to the types and numbers of equipment necessary to support the training of the flight crews are developed based upon requirements, available and planned resources, schedule and cost.

BASELINE DESCRIPTION

- ESA PAYLOAD ACCOMMODATIONS HANDBOOK
- REMOTE CONTROL OF SPACELAB SYSTEMS DOC - ER-50107-X-X (SCREENING ECP)
- RCWG RECOMMENDATIONS FOR CHANGES TO SCREENING ECP
- ESA - ECLS REMOTE CONTROL DATA
- COORDINATION WITH R. TANNER - MSFC
- IMPACT OF MINI-COMPUTER CONCEPT

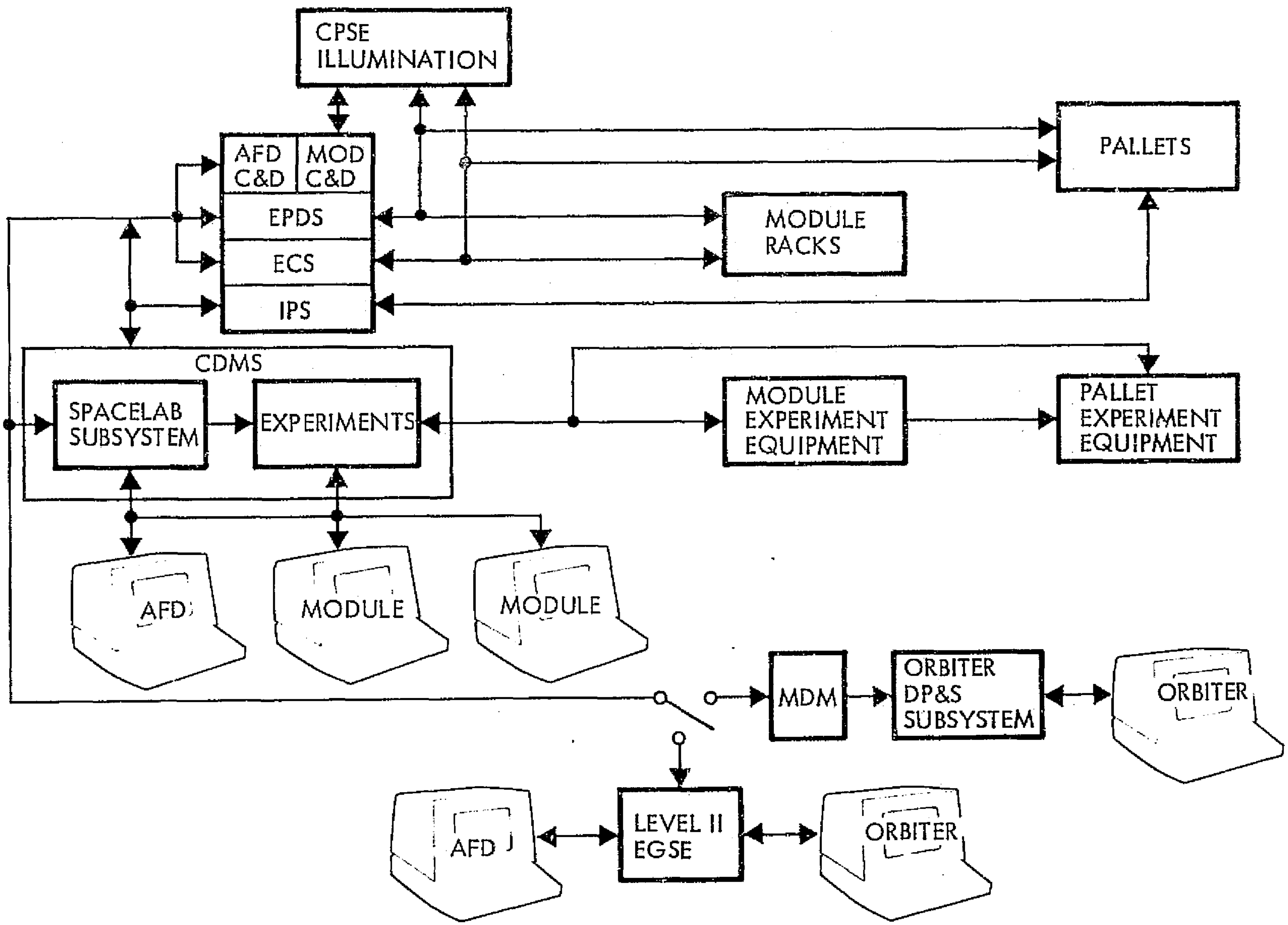
SPACELAB SYSTEMS ANALYSIS

The baseline Spacelab design was derived from the Payload Accommodations Handbook and updated, from the source data described in the chart, to incorporate the latest remote control concept. However, as we had assumed the existence of a remote control capability in our original analysis, the revised baseline basically affected only the method of mechanization and location aspects of the remote control capabilities.

A summary is provided of the discrete commands, the functions commanded and the command sources associated with remote control switching of CDMS, EPDS and ECS.

In addition to the prescribed tasks, an evaluation was made as to the impact, upon operations and training, of the distributed experiment data processing (dedicated mini-computer) concept being investigated by NAR as part of the CRAS program. The results of this analysis are also incorporated within the body of this report.

SPACELAB SUBSYSTEMS CONTROL AND OPERATIONS (VERY SIMPLIFIED)



SPACELAB SUBSYSTEMS CONTROL AND OPERATIONS

In order to simplify the diagram used to depict the Spacelab subsystem remote control capability, the backup computer and mass memory units (both MDM controlled) and the data buses have been deleted.

The major change to the original baseline is that associated with the Orbiter multiplexer/demultiplexer (MDM) interface to the Spacelab subsystems. Activation of these subsystems is accomplished via the MDM interface through Orbiter keyboard entry. This remote control includes the configuring and activation of the SS-CDMS. Generally, after activation, Spacelab subsystem control can be exercised through the SS-CDMS (RAU) which controls the distribution of power to the experiment racks and pallets and also controls the configuring and activation of the EXP-CDMS.

After activation of the CDMS keyboards in the module, Spacelab subsystem CDMS and EXP-CDMS control can only be exercised by addressing the appropriate I/O through the keyboard because the CDMS C&D has been eliminated in the module. A minimum number of backup switches at the AFD and module stations provide some flexibility of control.

The remote control change now requires that Spacelab subsystem operations control be centered in the AFD. This modifies the original concept where, operationally, this control resided in the module. Therefore, both module CRT/keyboards can be dedicated to experiment operations.

One complexity introduced into the Spacelab training requirements by the remote control approach is that subsystem control must be exercised through two different types of data entry keyboards.

ORBITER/SPACELAB COMMAND AND CONTROL INTERACTION

ORBITER (MDM)	SPACELAB CDMS (RAU)	A F D SWITCHES	MODULE SWITCHES
MAIN DC			
SUBSYSTEM INVERTER			
EXPERIMENT INVERTER	EXPERIMENT INVERTER		
	SUBSYSTEM/EXPERIMENT INVERTER SWITCHING		
EXPERIMENT DC POWER	EXPERIMENT DC POWER		
POWER DISTRIBUTION BOX (CB'S)			
	EXPERIMENT PDB (CB'S)		
SUBSYSTEM I/O		SUBSYSTEM I/O	
	EXPERIMENT I/O AND RAU BLOCK TRANSFER		
MMU TO SUBSYSTEM COMPUTER	MMU TO SUBSYSTEM COMPUTER		
	MMU TO EXPERIMENT COMPUTER		
DMA AND POWER TO SUBSYSTEM/BACKUP COMPUTER			
	DMA AND POWER TO EXPERIMENT/BACKUP COMPUTER		
SUBSYSTEM COMPUTER AUTO START/EXECUTIVE LOAD			
	EXPERIMENT COMPUTER AUTO START/EXECUTIVE LOAD		
BACKUP COMPUTER AUTO START/EXECUTIVE LOAD			
SUBSYSTEM RAU'S		SUBSYSTEM RAU'S	
	EXPERIMENT RAU'S	EXPERIMENT RAU'S	
PRESSURE SAFING			
	O_2/N_2 CONTROL		
CABIN FANS CONTROL(?)	CABIN FANS CONTROL	CABIN FANS CONTROL (?)	CABIN FANS (POWER CB)
	TOTAL PRESSURE RELIEF		
	TEMPERATURE CONTROL POWER		TEMPERATURE CONTROL (THERMO)
	H_2O SEPARATOR (CONTROL)		H_2O SEPARATOR (POWER CB'S)
AVIONICS FANS (?)	AVIONICS FANS	AVIONICS FANS (?)	
	CONDENSATE DUMP (CLOSE)		CONDENSATE DUMP (OPEN/CLOSED)
			CONDENSATE HEATERS

ORBITER/SPACELAB COMMAND & CONTROL INTERACTIONS

The accompanying table summarizes the discrete commands, command function and source tables describing the Spacelab Subsystem Remote Control baseline.

As is evident from this table, the MDM commands control the activation of the Spacelab subsystems by providing and controlling the distribution of DC and AC power and controlling the configuring and activation of the subsystem computer, I/O, couplers, subsystem-RAU's, MMU and backup computer. Safing commands for ECS are also provided through the MDM. The question marked (?) items indicate a command capability which has not been resolved at this date.

The Spacelab-CDMS RAU commands are primarily oriented toward control of the experiment side of the Spacelab subsystems and the control of ECS components.

The switches in the AFD and module serve as backup to the MDM/RAU commands. There are more switches at these stations than shown here, but they serve purposes other than remote control backup.

REMOTE CONTROL SWITCHING CONCEPT

CDMS COMMAND SWITCHING

SUBSYSTEM (S/S I/O COUPLERS) — Discrete commands

Combined Commands	Command Sources: MDM	Command Sources: RAU	SW: AFT FLIGHT DECK	SW: MODULE	1 S/S I/O POWER ON	2 S/S I/O POWER OFF	3 STATE VECTOR COMMAND A ON	4 STATE VECTOR COMMAND B ON	5 TELEMETRY A ON	6 TELEMETRY B ON	9 RAU A ON	10 RAU B ON	11 MMU A ON	12 MMU B ON	12A MMU A&B OFF	13 CRT A ON	14 CRT B ON	15 MCU A ON	16 MCU B ON	17 POWER SUPPLY A ON	18 POWER SUPPLY B ON	18A TIME A ON	18B TIME B ON	7 DMA TO SS COMP ON	8 DMA TO BU COMP ON
1	X		X		X		X		X		X				X	X		X		X		X		X	
2	X					X																			
3	X							X		X		X			X		X		X		X		X		
4			X					X																	
5			X							X															
6			X									X													
7	DELETED																								
8			X														X								
9			X																X						
10			X																		X				
11			X																				X		
12		X	X																						
13		X																							
14		X																							
15		X																							
16		X																							
17	DELETED																								
18		X																							
19		X																							
20		X																							
21		X																							
21A		X																							
22	X	X											X												
22A	X	X												X											
23		X													X										
23A		X													X										
24	X	X																							
25	X																							X	
26	X																								X
27		X																							
28		X																							
29	X																								
30	X																								
31		X																							
32	X		X																						
33	X		X																						
34		X	X																						
35		X	X																						
35A	X																								
35B	X																								

EXPERIMENT (EXP I/O COUPLERS) — Discrete commands

Combined Commands	21 EXP I/O POWER ON	22 EXP I/O POWER OFF	23 STATE VECTOR COMMAND A ON	24 STATE VECTOR COMMAND B ON	25 TELEMETRY A ON	26 TELEMETRY B ON	29 RAU A ON	30 RAU B ON	31 MMU A ON	32 MMU B ON	32A MMU A&B OFF	33 CRT A ON	34 CRT B ON	35 MCU A ON	36 MCU B ON	37 POWER SUPPLY A ON	38 POWER SUPPLY B ON	38A TIME A ON	38B TIME B ON	27 DMA TO EXP COMP ON	28 DMA TO BU COMP ON	39 RAU COUPLER BLOCK TRANSFER A ON	40 RAU COUPLER BLOCK TRANSFER B ON
1																							
2																							
3																							
4																							
5																							
6																							
7																							
8																							
9																							
10																							
11																							
12	X		X		X		X				X	X		X		X		X		X		X	
13		X																					
14				X																			
15						X																	
16								X															
17																							
18													X										
19															X								
20																	X						
21																			X				
21A																							X
22											X												
22A											X												
23									X														
23A										X													
24																							
25																							
26																							
27																				X			
28																					X		
29																							
30																							
31																							
32																							
33																							
34																							
35																							
35A																							
35B																							

COMPUTER / MMU — Discrete commands

Combined Commands	41 COMPUTER POWER S/S ON	42 COMPUTER POWER S/S OFF	43 COMPUTER POWER B/U ON	44 COMPUTER POWER B/U OFF	45 COMPUTER POWER EXP ON	46 COMPUTER POWER EXP OFF	46A COMPUTER AUTO START S/S ON	46B COMPUTER AUTO START S/S OFF	46C COMPUTER AUTO START EXP ON	46D COMPUTER AUTO START EXP OFF	46E COMPUTER AUTO START BU ON	46F COMPUTER AUTO START BU OFF	46G COMPUTER EXECUTIVE LOAD S/S	46H COMPUTER EXECUTIVE LOAD EXP	46I COMPUTER EXECUTIVE LOAD B/U	47 MMU POWER ON	48 MMU POWER OFF
1																	
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9																	
10																	
11																	
12																	
13																	
14																	
15																	
16																	
17																	
18																	
19																	
20																	
21																	
21A																	
22																X	
22A																X	
23																X	
23A																X	
24																	X
25	X							X									
26			X									X					
27					X					X							
28			X									X					
29		X															
30				X													
31						X											
32							X										
33													X				
34									X								
35														X			
35A											X						
35B															X		

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REMOTE CONTROL SWITCHING CONCEPT

CDMS COMMAND SWITCHING

Combined Commands	Command Source: MDM	Command Source: RAU	Command Source SW: Aft Flight Deck	Command Source SW: Module	Subsystem 1 ON	Subsystem 1 OFF	Subsystem 2 ON	Subsystem 2 OFF	Subsystem 3 ON	Subsystem 3 OFF	Subsystem 4 ON	Subsystem 4 OFF	Subsystem 5 ON	Subsystem 5 OFF	Subsystem 6 ON	Subsystem 6 OFF	Subsystem 7 ON	Subsystem 7 OFF	Subsystem 8 ON	Subsystem 8 OFF	Subsystem 9 ON	Subsystem 9 OFF	Subsystem 10 ON	Subsystem 10 OFF	Experiment 1 ON	Experiment 1 OFF	Experiment 2 ON	Experiment 2 OFF	Experiment ON	Experiment OFF	Experiment 4 ON	Experiment 4 OFF	Experiment 5 ON	Experiment 5 OFF	Experiment 6 ON	Experiment 6 OFF	Experiment 7 ON	Experiment 7 OFF	Experiment 8 ON	Experiment 8 OFF	Experiment 9 ON	Experiment 9 OFF	Experiment 10 ON	Experiment 10 OFF	Keyboard No. 1 ON	Keyboard No. 1 OFF	CRT No. 1 ON	CRT No. 1 OFF	Keyboard No. 2 ON	Keyboard No. 2 OFF	CRT No. 2 ON	CRT No. 2 OFF	Keyboard No. 3 ON	Keyboard No. 3 OFF	CRT No. 3 ON	CRT No. 3 OFF	TV Camera ON	TV Camera OFF
Remote Acquisition Units (Subsystem, Experiment) / Peripherals — Discrete Commands					49	50 / 51	49	50 / 52	49	50 / 53	49	50 / 54	49	50 / 55	49	50 / 56	49	50 / 57	49	50 / 58	49	50 / 59	49	50 / 60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94
36	X		X		X		X		X		X		X		X		X		X		X		X																																			
37	X					X		X		X		X		X		X		X		X		X		X																																			
38			X			X																																																			
39			X					X																																																	
40			X							X																																															
41			X									X																																													
42			X											X																																											
43			X													X																																									
44			X															X																																							
45			X																	X																																					
46			X																			X																																			
47			X																					X																																	
48		X																							X																																
49		X																								X																															
50		X																									X																														
51		X																										X																													
52		X																											X																												
53		X																												X																											
54		X																													X																										
55		X																														X																									
56		X																															X																								
57		X																																X																							
58		X																																	X																						
59		X																																		X																					
60		X																																			X																				
61		X																																				X																			
62		X																																					X																		
63		X																																						X																	
64		X																																							X																
65		X																																								X															
66		X																																									X														
67		X																																										X														
68																									X		X		X		X		X				X		X		X		X														
69			X																							X		X		X		X		X		X		X		X		X		X														

REMOTE CONTROL SWITCHING CONCEPT

EPDS COMMAND SWITCHING

COMBINED COMMANDS	COMMAND SOURCE: MDM	COMMAND SOURCE: RAU	SWITCHES: AFT FLIGHT DECK	SWITCHES: MODULE	RCCB 101 SS INV		RCCB 102 SL MAIN DC		RCCB 103 EXP INV		RCCB 114 INV TO SS BUS		RCCB 114A INV TO EXP BUS		RCCB 104 ECS DC1		RCCB 105 ECS DC2		RCCB 106 ECS AC2		RCCB 107 ECS AC3		RCCB 108 LIGHTING POWER (DC)				RCCB 109 IPS AIRLOCK, SIG COND				RCCB 110 CDMS DC1		RCCB 111 CDMS DC2		RCCB 112 CDMS DC3		RCCB 113 CDMS AC		RCCB 118 DC1		RCCB 119 DC2		RCCB 120 DC3,4		RCCB 121 AC1		RCCB 122 AC2		RCCB 123 AC3,4		RCCB 136 DC1		RCCB 137 DC2		RCCB 138 DC3,4		RCCB 139 AC1		RCCB 140 AC2		RCCB 141 AC3,4	
					CLOSE	OPEN	CLOSE	OPEN	CLOSE	OPEN	SS	EXP	EXP	SS	CLOSE	OPEN	CLOSE	OPEN	CLOSE		CLOSE	OPEN	CLOSE		OPEN		CLOSE		OPEN		CLOSE	OPEN	CLOSE	OPEN	CLOSE	OPEN	CLOSE	OPEN	CLOSE	OPEN	CLOSE	OPEN	CLOSE	OPEN	CLOSE	OPEN	CLOSE	OPEN	CLOSE	OPEN	CLOSE	OPEN	CLOSE	OPEN	CLOSE	OPEN	CLOSE	OPEN	CLOSE	OPEN	CLOSE	OPEN
																																							EXPERIMENT DISTRIBUTION BOX NO.1 (MODULE)												EXPERIMENT DISTRIBUTION BOX NO.4 (PALLET)											
101	X				X																																																									
102	X					X																																																							
103	X	X					X																																																						
104	X	X						X																																																					
105		X	X						X																																																				
106		X	X							X																																																			
107		X	X								X																																																		
108		X	X									X																																																	
109		X											X																																																
110		X												X																																															
111	X	INDIVIDUAL SWITCHES FOR EACH RCCB		X											X		X		X		X		X		X		X		X		X		X		X		X																									
111A				X												X		X		X		X		X		X		X		X		X		X		X		X																								
112		X																																					X						X																	
113		X																																						X						X																
114		X																																							X						X															
115		X																																								X						X														
116		X																																									X						X													
117		X																																										X						X												
130		X																																																	X											
131		X																																																		X										
132		X																																																			X									
133		X																																																				X								
134		X																																																					X							
135		X																																																						X						
136		X																																																							X					
137		X																																																								X				
138		X																																																									X			
139		X																																																										X		
140		X																																																											X	
141		X																																																												X

EXPERIMENT DISTRIBUTION BOXES NUMBERS 2 AND 3 (MODULE) CONTROLLED BY RAU COMMANDS 118-123 AND 124-129 SIMULAR TO EXP DIST BOX NUMBER 1

EXPERIMENT DISTRIBUTION BOX NUMBER 5 (PALLET) CONTROLLED BY RAU COMMANDS 142-153 SIMILIAR TO EXP DIST BOX NUMBER 4

REMOTE CONTROL SWITCHING CONCEPT

ECS COMMAND SWITCHING

COMMANDS	COMMAND SOURCE: MDM	COMMAND SOURCE: RAU	SWITCHES: AFT FLIGHT DECK	SWITCHES: MODULE	Function controlled (X)
201					ACS INSTRUMENT POWER – ON
202		X			ACS INSTRUMENT POWER – OFF
203		X			O_2 SOLENOID VALVE 1201-1 – OPEN
204	♦	X			O_2 SOLENOID VALVE 1201-1 – CLOSE
205		X			O_2 SOLENOID VALVE 1201-2 – OPEN
206	♦	X			O_2 SOLENOID VALVE 1201-2 – CLOSE
207		X			N_2 SOLENOID VALVE 1301-1 – OPEN
208	♦	X			N_2 SOLENOID VALVE 1301-1 – CLOSE
209		X			N_2 SOLENOID VALVE 1301-2 – OPEN
210	♦	X			N_2 SOLENOID VALVE 1301-2 – CLOSE
211		X			O_2 CONTROLLER POWER 1501-1 – ON
212		X			O_2 CONTROLLER POWER 1501-1 – OFF
213		X			O_2 CONTROLLER POWER 1501-2 – ON
214		X			O_2 CONTROLLER POWER 1501-2 – OFF
215		X			POSITIVE PRESSURE RELIEF VALVE 1601-1 – CLOSE
216		X			POSITIVE PRESSURE RELIEF VALVE 1601-2 – CLOSE
217	♦				CABIN DEPRESS. VALVE 1604 – OPEN
218	♦				CABIN DEPRESS. VALVE 1604 – CLOSE
219		X			CABIN LOOP INSTRUMENT POWER – ON
220		X			CABIN LOOP INSTRUMENT POWER – OFF
221		X			TEMP/HUMIDITY CONTROLLER POWER 2301-1 – ON
222		X			TEMP/HUMIDITY CONTROLLER POWER 2301-1 – OFF
223		X			TEMP/HUMIDITY CONTROLLER POWER 2301-2 – ON
224		X			TEMP/HUMIDITY CONTROLLER POWER 2301-2 – OFF
225	*	X	*		CABIN FAN POWER 2104-1 – ON
226	*	X	*		CABIN FAN POWER 2104-1 – OFF
227	*	X	*		CABIN FAN POWER 2104-2 – ON
228	*	X	*		CABIN FAN POWER 2104-2 – OFF
229		X			ROTARY SEPARATOR POWER 2403-1 – ON
230		X			ROTARY SEPARATOR POWER 2403-1 – OFF
231		X			ROTARY SEPARATOR POWER 2403-2 – ON
232		X			ROTARY SEPARATOR POWER 2403-2 – OFF
233	DIRECT CONNECTED TO EMERGENCY BUS				AVIONICS LOOP SENSOR POWER – ON
234	DIRECT CONNECTED TO EMERGENCY BUS				AVIONICS LOOP SENSOR POWER – OFF
235	*	X	*		AVIONICS FAN POWER 2904-1 – ON
236	*	X	*		AVIONICS FAN POWER 2904-2 – ON
236A	*	X	*		AVIONICS FAN POWER 2904-1 – OFF; 2904-2 – OFF
237		X			WATER LOOP SENSOR POWER – ON
238		X			WATER LOOP SENSOR POWER – OFF
239	X	X			WATER PUMP POWER NO. 1 – ON
240		X			WATER PUMP POWER NO. 1 – OFF
241		X			WATER PUMP POWER NO. 2 – ON
242		X			WATER PUMP POWER NO. 2 – OFF
243		X	X		WATER LOOP HEATER POWER – ON
244		X	X		WATER LOOP HEATER POWER – OFF
245		X			FREON LOOP SENSOR POWER – ON
246		X			FREON LOOP SENSOR POWER – OFF
247	X	X			FREON PUMP POWER NO. 1 – ON
248		X			FREON PUMP POWER NO. 1 – OFF
249		X			FREON PUMP POWER NO. 2 – ON
250		X			FREON PUMP POWER NO. 2 – OFF
–				X	CONDENSATE DUMP VALVE 2601 – OPEN
–		X		X	CONDENSATE DUMP VALVE 2601 – CLOSE
–				X	OVERBOARD DUMP SIGNAL CONDITIONER 2606-1 – ON
–				X	OVERBOARD DUMP SIGNAL CONDITIONER 2606-2 – ON

NOTE: * COMMAND CONTROL UNDECIDED, MAY BE MDM OR SWITCH

♦ SAFING

ORIGINAL PAGE IS OF POOR QUALITY

REMOTE CONTROL SWITCHING CONCEPT

ECS COMMAND SWITCHING

COMMANDS	MDM	RAU	AFT FLIGHT DECK (SWITCHES)	MODULE (SWITCHES)	FUNCTION	STATE
201					ACS INSTRUMENT POWER	ON
202		X			ACS INSTRUMENT POWER	OFF
203		X			O_2 SOLENOID VALVE 1201-1	OPEN
204	♦	X			O_2 SOLENOID VALVE 1201-1	CLOSE
205		X			O_2 SOLENOID VALVE 1201-2	OPEN
206	♦	X			O_2 SOLENOID VALVE 1201-2	CLOSE
207		X			N_2 SOLENOID VALVE 1301-1	OPEN
208	♦	X			N_2 SOLENOID VALVE 1301-1	CLOSE
209		X			N_2 SOLENOID VALVE 1301-2	OPEN
210	♦	X			N_2 SOLENOID VALVE 1301-2	CLOSE
211		X			O_2 CONTROLLER POWER 1501-1	ON
212		X			O_2 CONTROLLER POWER 1501-1	OFF
213		X			O_2 CONTROLLER POWER 1501-2	ON
214		X			O_2 CONTROLLER POWER 1501-2	OFF
215		X			POSITIVE PRESSURE RELIEF VALVE 1601-1	CLOSE
216		X			POSITIVE PRESSURE RELIEF VALVE 1601-2	CLOSE
217	♦				CABIN DEPRESS. VALVE 1604	OPEN
218	♦				CABIN DEPRESS. VALVE 1604	CLOSE
219		X			CABIN LOOP INSTRUMENT POWER	ON
220		X			CABIN LOOP INSTRUMENT POWER	OFF
221		X			TEMP/HUMIDITY CONTROLLER POWER 2301-1	ON
222		X			TEMP/HUMIDITY CONTROLLER POWER 2301-1	OFF
223		X			TEMP/HUMIDITY CONTROLLER POWER 2301-2	ON
224		X			TEMP/HUMIDITY CONTROLLER POWER 2301-2	OFF
225	*	X	*		CABIN FAN POWER 2104-1	ON
226	*	X	*		CABIN FAN POWER 2104-1	OFF
227	*	X	*		CABIN FAN POWER 2104-2	ON
228	*	X	*		CABIN FAN POWER 2104-2	OFF
229		X			ROTARY SEPARATOR POWER 2403-1	ON
230		X			ROTARY SEPARATOR POWER 2403-1	OFF
231		X			ROTARY SEPARATOR POWER 2403-2	ON
232		X			ROTARY SEPARATOR POWER 2403-2	OFF
233	DIRECT CONNECTED TO EMERGENCY BUS				AVIONICS LOOP SENSOR POWER	ON
234	DIRECT CONNECTED TO EMERGENCY BUS				AVIONICS LOOP SENSOR POWER	OFF
235	*	X	*		AVIONICS FAN POWER 2904-1	ON
236	*	X	*		AVIONICS FAN POWER 2904-2	ON
235A	*	X	*		AVIONICS FAN POWER 2904-1; 2904-2	OFF; OFF
237		X			WATER LOOP SENSOR POWER	ON
238		X			WATER LOOP SENSOR POWER	OFF
239	X	X			WATER PUMP POWER NO. 1	ON
240		X			WATER PUMP POWER NO. 1	OFF
241		X			WATER PUMP POWER NO. 2	ON
242		X			WATER PUMP POWER NO. 2	OFF
243		X	X		WATER LOOP HEATER POWER	ON
244		X	X		WATER LOOP HEATER POWER	OFF
245		X			FREON LOOP SENSOR POWER	ON
246		X			FREON LOOP SENSOR POWER	OFF
247	X	X			FREON PUMP POWER NO. 1	ON
248		X			FREON PUMP POWER NO. 1	OFF
249		X			FREON PUMP POWER NO. 2	ON
250		X			FREON PUMP POWER NO. 2	OFF
–				X	CONDENSATE DUMP VALVE 2501	OPEN
–		X			CONDENSATE DUMP VALVE 2501	CLOSE
–				X	OVERBOARD DUMP SIGNAL CONDITIONER 2806-1	ON
–				X	OVERBOARD DUMP SIGNAL CONDITIONER 2806-2	ON

NOTE: *COMMAND CONTROL UNDECIDED, MAY BE MDM OR SWITCH

♦ SAFING

EFFECT OF REMOTE CONTROL ON OPERATIONS AND TRAINING

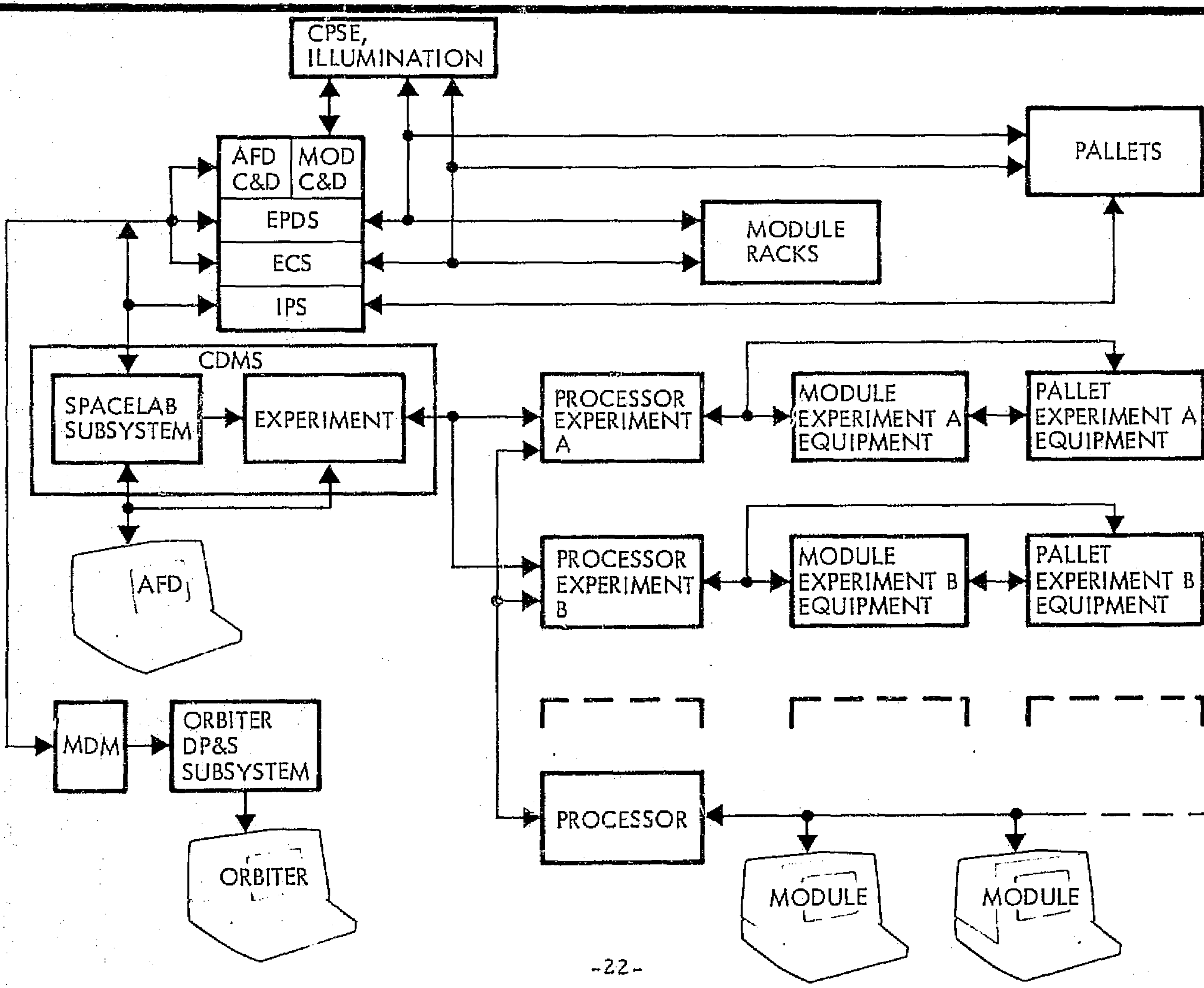
- REDUCES THE NUMBER OF SEPARATE SWITCHES REQUIRED TO ACTIVATE, MONITOR AND CONTROL SPACELAB SUBSYSTEMS
    - SIMPLIFIES INSTRUCTION IN OPERATION OF SUBSYSTEMS BECAUSE:
        - SUBSYSTEM OPERATIONS COMMANDED VIA KEYBOARD
        - LESS COMPLEX C&D PANELS
    - REDUCES OPPORTUNITIES FOR INADVERTENT SWITCH ACTIVATION
- ENABLES FULL CONTROL OF SPACELAB SUBSYSTEMS FROM AFT FLIGHT DECK

EFFECT OF REMOTE CONTROL ON OPERATIONS AND TRAINING

One of the major changes included in the Remote Control redesign was a great reduction in the number of backup switches in both the AFD and module work stations. The number has been reduced from about 160 to 26 and efforts are being made to reduce this still further to about 12. This has resulted in the consolidation of the C&D panels to one each at the AFD and module.

This will simplify instruction, reduce training equipment complexity and greatly reduce the probability of inadvertent switch activation in the zero-g environment. From an operational standpoint, full control of Spacelab subsystems can be accomplished from the AFD. Therefore, Spacelab operational procedures training can be readily accomplished with an AFD station interfaced to an instructors console for feedback and control.

SPACELAB SUBSYSTEMS CONTROL AND OPERATIONS
IMPACT OF DISTRIBUTED EXPERIMENT PROCESSING CONCEPT



IMPACT OF DISTRIBUTED EXPERIMENT DATA PROCESSING CONCEPT

As shown in the diagram, the dedicated mini-computer concept does not affect Spacelab subsystems operation and control. In this approach, the EXP-CDMS computer effectively acts as a "traffic cop", in controlling the data output from the mini-computers or micro-processors dedicated to each experiment. The EXP-CDMS accesses the addressable memories, formats and time tags the data and routes it to the Orbiter downlink.

Any experiment processor can be addressed from either of the two keyboards in the module. However, neither the SS-CDMS or EXP-CDMS can be addressed from these data entry devices.

Where the mini-computer and experiment equipment (module and pallet) are all dedicated to a single experiment the combination can be considered as a "stand-alone" experiment. Experiment operations proficiency training can be accomplished without interface training on the EXP CDMS. However, where experiments must share equipment (e.g., AMPS) the dedicated mini-computers and their connection to the experiment equipment combinations becomes far more complex than shown in the diagram. The possibility for "sneak paths" is also increased.

Though EXP-CDMS/experiment interface training is not required, the operator training in this latter case could become more complex.

EFFECT OF DEDICATED MINI COMPUTER CONCEPT ON OPERATIONS AND TRAINING

- LITTLE OR NO EFFECT ON SPACELAB SUBSYSTEM OPERATIONS
- MAY INCREASE COORDINATION REQUIREMENTS FOR USE OF IPS TO MEET PAYLOAD OBJECTIVES
- PRECLUDES OPERATION OF SPACELAB SUBSYSTEMS FROM MODULE
- REDUCES STANDARD DEDICATED TRAINING EQUIPMENT REQUIREMENTS

EFFECT OF DEDICATED MINI-COMPUTER CONCEPT ON OPERATIONS AND TRAINING

As shown in the preceding diagram, the dedicated mini-computer concept has little effect upon Spacelab subsystem operations with the possible exception of IPS operations. In this instance, payload specialist control of the IPS during his experiment operations in the module must be accomplished by voice communications with the AFD. This constraint may pose a major problem to satisfactory mission performance and should be further investigated.

Another area of possible operations concern with this concept is in relation to pallet only type missions. Isolation of the CDMS and mini-computers requires an additional keyboard/CRT for the experiments to be located in the AFD. If possible, the two keyboards should be compatible and interchangeable.

The dedicated computer concept eliminates the need for EXP-CDMS emulation at the PI/host center/experiment system contractor facility and the need for experiment/ EXP-CDMS interface training.

APPROACH TO CREW TRAINING REQUIREMENTS DEFINITION

- SPACELAB SYSTEMS ANALYSIS
- **MANNED OPERATIONS ANALYSIS**
- TRAINING PROGRAM REQUIREMENTS ANALYSIS
- TRAINING EQUIPMENT REQUIREMENTS ANALYSIS
- PLANNED EQUIPMENT EVALUATION
- EQUIPMENT RECOMMENDATIONS

MANNED OPERATIONS ANALYSES

- OPERATIONS FUNCTIONAL ANALYSIS
  - ON-ORBIT FUNCTIONS ANALYSIS
  - SECOND LEVEL ACTIVITIES ANALYSIS
- TASK ANALYSIS
  - PROCEDURES ANALYSIS
  - SKILL AND KNOWLEDGE REQUIREMENTS ASSESSMENT
  - TIME AND PERFORMANCE CRITICALITY ASSESSMENT
- TRAINING EQUIPMENT TYPES REQUIRED
  - SELECTION
  - ASSIGNMENT

MANNED OPERATIONS ANALYSIS

The manned operations analyses were composed of three basic efforts.

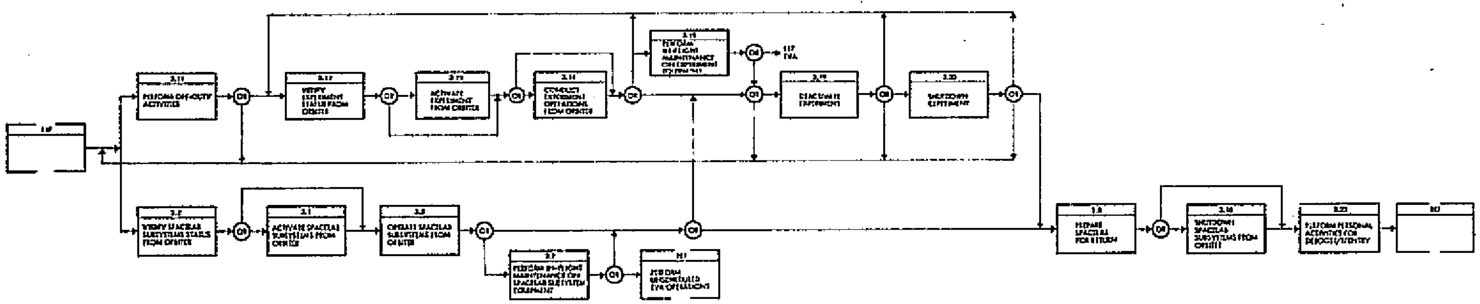
1) On-orbit phase of the flight was analyzed to identify and document the system (man/equipment) functions performed to achieve the flight objectives and the sequence of their performance. Each function was further analyzed to determine the subsystem and/or manned operations involved.

2) Each operation was further analyzed to define the tasks performed by the crew on or with the equipment and the time or performance criticality of each task. An assessment was made of the skills and knowledge required of the operator in order for him to satisfactorily perform the task within the constraints of time, environment or equipment complexity.

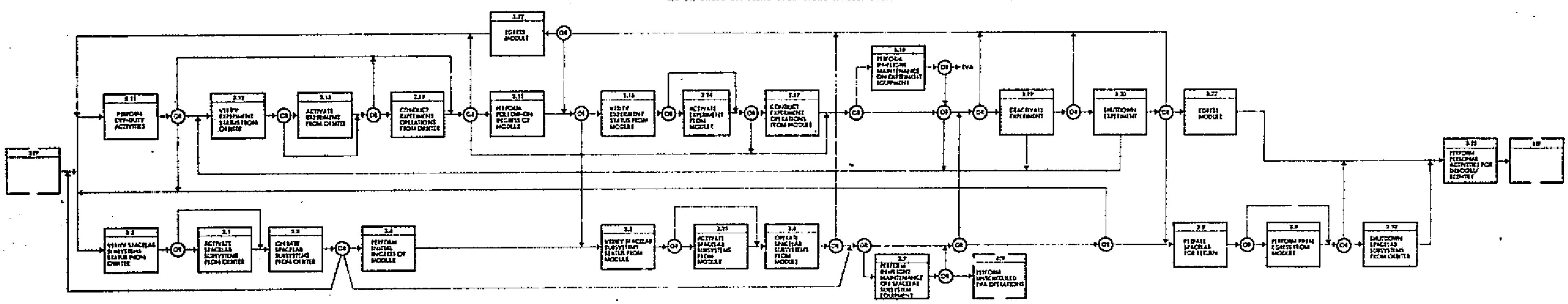
3) A determination was made as to the lowest complexity types of training device (mockup, trainer or simulator) required to impart the required skills and knowledge to the trainee crew member.

Documentation of these manned operations analyses is provided in Volume III of this final report.

The following charts and narrative were extracted from this report and provided to describe the procedures, processes and products used to accomplish this subtask.



3.0 ON ORBIT SPACELAB OPERATIONS (PALLET ONLY)



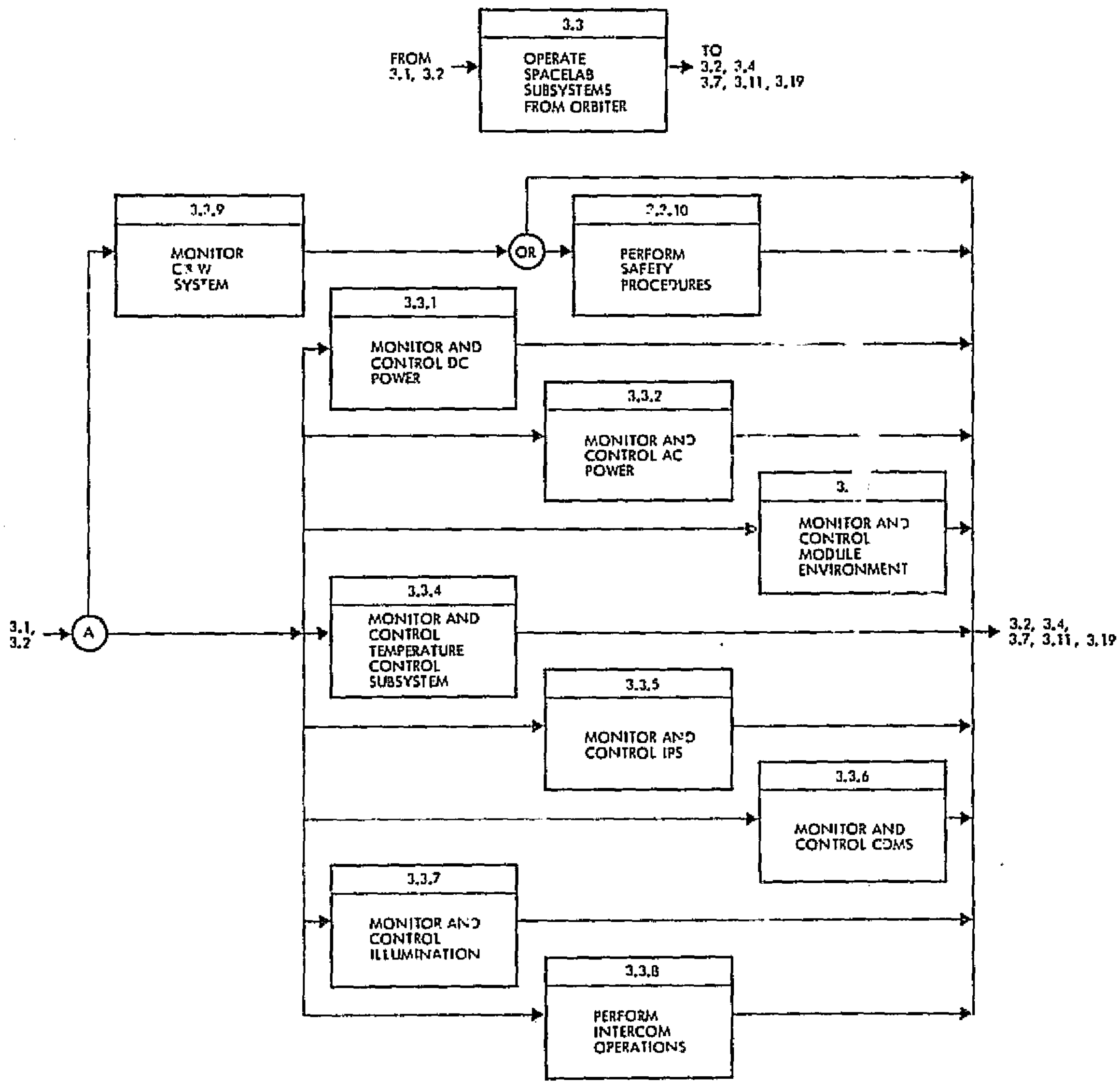
3.0 ON ORBIT SPACELAB OPERATIONS (MODULE OR MODULE-PALLET)

FUNCTIONAL FLOW DIAGRAMS - 1ST LEVEL

An analysis of the on-orbit, Spacelab systems manned operations requirements and operations sequences was accomplished as the first step in the task analysis. The results of this analysis are documented in functional flow diagram form. The initial analysis was performed to identify all manned operating functions for all Spacelab missions and configurations. The resulting flow diagram (Module or Module-Pallet) provides a baseline function numbering system and flow sequence which is employed to describe any Spacelab configuration and experiment payload combination. Each design reference mission (DRM) analyzed for this study and its top flow diagram will be keyed to this baseline and use the same number for identical functions. In this way, the same functions and/or tasks performed in multiple missions are readily identified and the analytic data developed from the initial analysis is referenced in the subsequent mission analyses. Thus, it becomes a relatively straight-forward task to identify both the common and special training requirements and training equipment required across all missions.

The diagrams should be expanded to include the flight crew functions associated with Shuttle vehicle systems operation and ground support operations (MCC/POCC).

SECOND LEVEL FUNCTIONAL FLOW DIAGRAM – 3.3 OPERATE SPACELAB SUSBYSTEMS FROM ORBITER



FUNCTIONAL FLOW DIAGRAMS - 2ND LEVEL

Each identified function in the 1st level diagram is subsequently analyzed to further define the activities and activity sequences essential to performance of the function.

The accompanying chart is an example of a second level flow diagram of the expansion of the function, 3.3 Operate Spacelab Systems from Orbiter. This diagram documents the analysis of the function and defines the major operator tasks which are performed within the function. Each of these activities is further analyzed to define its constituent operator tasks.

Though not reflected in this example, activities related to experiment equipment operations are also incorporated in the second level diagrams and the task analysis statements are keyed to the MSFC task analysis documentation of experiment operations.

TRAINING ANALYSIS WORKSHEET

TRAINING ANALYSIS WORK SHEET

MISSION AMPS
FUNCTION 3.3 Operate Spacelab Subsystems from Orbiter

TASK			EQUIPMENT			PERSONNEL, TRAINING AND TRAINING EQUIPMENT REQUIREMENTS				
NO.	TITLE	DESCRIPTION	NOMENCLATURE	LOCATION	TYPE	TASK ALLO	TIME REQD	SKILL/ KNOW-LEDGE	CRIT	TRNG & TRNG EQUIP REQUIRED
3.3.5	(Continued)	Coordinate with MS/PS as required	SS-CDMS Keyboard and CRT, video monitor	AFD	SLMI	C,P, MS,PS	T	pmk	4	
	monitor and control IPS	Identify IPS malfunctions	and IPS C&D Panel					pmK	3	
		Reconfigure IPS controllable items (TBD) to correct failure to maintain lock-on or pointing.	SS-CDMS keyboard and CRT, Orbiter DP&S Keyboard and CRT, Video Monitors					P̄mK	4	
		Operate IPS back-up controls to: • Retract and lock platform • Safe jettison of equipment	IPS C&D Panel, Intercoms CCTV video			C,P,MS	t	pmK	3	
								pmK	4	
		Note 1: The above functions are performed in coordination with Remote Manipulator Arm operation with IPS platform.			OMI	P		P̄M̄k	4	

TRAINING ANALYSIS WORKSHEET

Training Analysis Worksheets were used to document the analysis of each major activity to define the operator tasks that are performed to accomplish that activity. A sample is provided of a completed worksheet which is a continuation of the analysis of Function 3.3, Operate Spacelab Subsystems from Orbiter. All entries are self-explanatory with the exception of the following coded items:

Equipment Type: SLMI - Spacelab Mission Independent; SLMD - Spacelab Mission Dependent; OMI - Orbiter Mission Independent.

Task Allocation: C - Commander; P - Pilot; MS - Mission Specialist; PS - Payload Specialist.

Time Criticality Definition:

low (t) - Task performance is neither time nor sequence dependent or time critical.
medium (T) - Task performance is time and/or sequence dependent but not time critical.
high ($\overline{T}$) - Task performance is time and/or sequence dependent and time critical.
Sequence Dependent - Task operation must be performed in a specific sequence.
Time Dependent - Task operation must be performed within a specified, adequate period of time.
Time Critical - Task operation must be performed within a limited time period.

Skill/Knowledge Difficulties Level Definitions

Knowledge

low (k) - Task performance requires an understanding of basic engineering or scientific principles involved in order to comprehend and interpret the function and operation of the specific equipment in the context of the operational conditions. Minimal experience in the application of these principles to equipment operation is required to gain the requisite operation or maintenance proficiency.

medium (K) - Task performance requires applications experience and knowledge of the theory and principles of the engineering or scientific disciplines involved in order to comprehend and interpret the function and operation of the specific equipment in the context of the operational situation. Repetitive experience in task performance is required to gain the required operation or maintenance proficiency.

TRAINING ANALYSIS WORKSHEET (Continued)

High ($\overline{K}$) - Task performance requires detailed and highly specialized knowledge and experience in the engineering or scientific disciplines involved in order to comprehend and interpret the function and operation of the specific equipment in the context of the operational situation. Repetitive experience in task performance is required only to familiarize the operator with the specifics of the equipment's operation or maintenance proficiency.

Skills (Perceptual/Motor)

low (p) (m) - Task performance requires application of normal motor/perceptual skills which are relatively unaffected by the environment. Skill proficiency is gained as a normal consequence of task performance on the specific equipment.

medium (P) (M) - Task performance or the operational environment requires that normal motor/perceptual skills be modified or enhanced. Repetitive training on the specific equipment in the environment is required to develop the desired proficiency.

high ($\overline{P}$) ($\overline{M}$) - Task performance on the specific equipment requires unfamiliar or unnatural coordination of normal or modified skills, or the environment produces an unnatural or unfamiliar sensory stimulus, or the task requires extreme preciseness in skill performance. Realistic, repetitive application training is required to develop and maintain proficiency.

Performance Criticality

1) Of no direct consequence to achieving flight objectives.
2) Small consequence to achieving flight objectives
3) Would degrade flight objectives.
4) Probable serious consequence and may result in aborted flight.
5) Results in aborted flight, but not result in loss of crew or vehicle.
6) Results in aborted flight with probable loss of crew and vehicle.

SPACELAB SUBSYSTEMS OPERATIONS

- SAME BASIC TASKS PERFORMED FOR ALL TYPES OF MISSIONS
- NOMINAL OPERATIONS
    - ARE NOT TIME OR PERFORMANCE CRITICAL
    - DO NOT REQUIRE HIGH SKILL OR KNOWLEDGE LEVELS
    - ARE PROCEDURAL IN NATURE
    - EXCEPT FOR IPS, DO NOT REQUIRE DYNAMIC MANNED INTERACTIONS
- CONTINGENCY OPERATIONS
    - ARE PROCEDURAL AND FOLLOW A LOGICAL CAUSE AND EFFECT RELATIONSHIP
    - DO NOT REQUIRE HIGH SKILL OR KNOWLEDGE LEVELS
    - EXCEPT FOR RAPID PRESSURE CHANGE, FIRE, OR PPO_2 LEVEL, ARE OF LOW SAFETY CRITICALITY
- COMMANDER, PILOT AND MISSION SPECIALIST PERFORM ALL SPACELAB SUBSYSTEMS OPERATIONS
    - AFD AS SPACELAB SUBSYSTEMS OPERATIONS CENTER

TASK ANALYSIS RESULTS

The task analysis revealed that the same basic tasks are performed in operating the Spacelab subsystems in support of all types of payloads although, for pallet only modes, operator tasking is reduced by elimination of the module ECLS.

With the possible exception of the IPS activities, both nominal and contingency operation of Spacelab subsystems are procedural (step-by-step), follow a logical cause and effect relationship, are of low to moderate complexity and, to a great extent, can be scheduled.

TRAINING EQUIPMENT SELECTION

TRAINING ANALYSIS WORK SHEET

MISSION: AMPS
FUNCTION: 3.3 Operate Spacelab Subsystems from Orbiter

TASK			EQUIPMENT			PERSONNEL, TRAINING AND TRAINING EQUIPMENT REQUIREMENTS				
NO.	TITLE	DESCRIPTION	NOMENCLATURE	LOCATION	TYPE	TASK ALLO	TIME REQD	SKILL/ KNOW-LEDGE	CRIT	TRNG & TRNG EQUIP REQUIRED
3.3.5	(Continued)	Coordinate with MS/PS as required	SS-CDMS Keyboard and CRT, video monitor	AFD	SLMI	C,P, MS,PS	T	pmk	4	PT Simulator CDMS/IPS visual field
	monitor and control IPS	Identify IPS malfunctions	and IPS C&D Panel					pmK	3	PTT-AFD
		Reconfigure IPS controllable items (TBD) to correct failure to maintain lock-on or pointing.	SS-CDMS keyboard and CRT, Orbiter DP&S Keyboard and CRT, Video Monitors					PmK	4	PT Simulator SS-CDMS and IPS visual field, IPS/STS interaction
		Operate IPS back-up controls to: • Retract and lock platform • Safe jettison of equipment	IPS C&D Panel, Intercoms CCTV video			C,P,MS	t	pmK	3	PTT-IPS C&D Panel Orbiter Cargo Bay and AFD
								pmK	4	Mockup W/RMS
		Note 1: The above functions are performed in coordination with Remote Manipulator Arm operation with IPS platform.			OMI	P		PMk	4	

TRAINING EQUIPMENT DEFINITIONS

MOCKUP

General Description

Physical Fidelity - Dimensionally and geometrically accurate representation of equipment and/or facility. Visual fidelity is not required. May use static or animated overlays to exhibit operational configurations of controls and displays.

Functional Fidelity - Minimal, usually limited to mechanical equipment.

Types

System - Complete physical structure. May be of exterior shell and/or interior configuration.

Partial - A specific area and/or one or more work stations within the total structure.

Hi-Fidelity - Physical and visual fidelity required throughout. May include exterior as well as interior. Simple display and control devices may be functional.

Training Uses

Habitability, layout familiarization, stowage, restraint use, EVA/IVA path familiarization, safety procedures development.

TRAINER

General Description

Physical Fidelity - Dimensionally and geometrically accurate representation of the equipment and its confines. Specific areas may have visual fidelity dependent upon training requirements.

Functional Fidelity - Mechanically and electronically emulates the operational control, display and response characteristics of the equipment to the extent that non-complex procedural skills and operating sequences can be developed and transferred to the operational situation. May be electrically or manually controlled to modify visual indications of system, subsystem, assembly or component performance. Microprocessors may be employed for control of some functions. Alphanumeric, graphic and vector display overlays may be used or non-interactive video display presentation capability may be provided.

TRAINING EQUIPMENT DEFINITIONS (continued)

Types

Whole-Task - Complete physical structure. May be of exterior and/or interior configuration.

Part-Task - A work station or specific group of related work stations. Surrounds may be deleted.

Training Uses

Procedural task practice and malfunction analysis on non-complex, dynamically slow and minimally interactive operating functions.

SIMULATOR

General Description

Physical Fidelity - Dimensionally, geometrically and visually accurate representation of the equipment and its confines.

Functional Fidelity - Accurately emulates the operational control, display and response characteristics of the actual equipment and, if required, the perceptual environment. Equipment performance usually controlled by computer and/or direct manual or electrical intervention by an operator.

Types

Whole-Task - Complete reproduction of all equipment, operations and phenomena likely to occur in actual performance.

Part-Task - Complete reproduction of the phenomena and operations likely to occur in actual operations for a specific and interrelated group of equipments.

Training Uses

Procedural task practice and malfunction analysis of complex, interactive, rapidly dynamic and time critical operations.

TRAINING EQUIPMENT SELECTION CRITERIA

The following criteria were used to select the types of training equipment necessary for training of Spacelab flight crew. Selection of a specific type of equipment is dependent upon the level, type and complexity of the skills and knowledge required to perform the job operation.

MOCKUP

Mockups are most applicable for developing the following:

- Familiarzation with the general layout and configuration of the equipment and/or facility
- Mechanical skills associated with such activities as unit removal/replacement actions, stowage provisions and techniques, ingress/egress and translation paths, habitability and safety, etc.

TRAINER

Part task and whole task (system) trainers are most suitable for imparting the skills and knowledge necessary to perform operations which are:

> procedural in nature, require the application of perceptual and motor skills and knowledge in combination to accomplish job operations
>
> AND EITHER
>
> involve tasks that follow a logical cause and effect relationship and necessitate analysis, synthesis or interpretation of data in order to perform the next operation
>
> OR
>
> require a series of coordinated, procedural type, interactions with other operators.

SIMULATOR

Simulator type training devices are most applicable for imparting the requisite skills and knowledge necessary to perform operations which are:

> complex and require moderate to high perceptual and motor skills and/or knowledge in combination to accomplish the task(s),

TRAINING EQUIPMENT SELECTION CRITERIA (Continued)

AND EITHER

require a series of dynamic coordinated interactions with other operators,

OR

involve a series of dynamic manned interactions between two or more system elements necessitating the analysis, synthesis or interpretation of data derived from multiple sources in order to perform the next operation,

OR

require interaction with equipment whose display, control or response functions cannot be satisfactorily replicated or are too costly to replicate without recourse to computer technology and/or actual equipment.

A simulator may be of part task or whole task design, dependent upon the number of job operations and work stations which meet the above criteria.

System training devices may be part simulator, part trainer and part mockup.

APPROACH TO CREW TRAINING REQUIREMENTS DEFINITION

- SPACELAB SYSTEMS ANALYSIS
  - MANNED OPERATIONS ANALYSIS
    - **TRAINING PROGRAM REQUIREMENTS ANALYSIS**
      - TRAINING EQUIPMENT REQUIREMENTS ANALYSIS
        - PLANNED EQUIPMENT EVALUATION
          - EQUIPMENT RECOMMENDATIONS

TRAINING OBJECTIVES / PERSONNEL ASSIGNMENTS

TRAINING OBJECTIVES	PERSONNEL ASSIGNMENTS: CDR	PILOT	MISSION SPECIALIST	PAYLOAD SPECIALIST	TRAINING EQUIPMENT REQUIREMENTS — SPACELAB FACILITIES — MOCKUPS — WATER IMMERSION FACILITY: MODULE	TUNNEL	PALLET EQUIPMENT	MOCKUPS: MODULE	PART TASK TRAINER/SIMULATOR: AFD SL SUBSYSTEM C&D STATION TRAINER/SIMULATOR	AFD PAYLOAD C&D STATION TRAINER/SIMULATOR	MODULE SL SUBSYSTEM TRAINER/SIMULATOR	MODULE PAYLOAD TRAINER/SIMULATOR	ORBITER FACILITIES — MOCKUPS: WATER IMMERSION FACILITY ORBITER	ORBITER	PART TASK TRAINER/SIMULATOR: SHUTTLE MISSION SIMULATOR	SMS PART TASK TRAINER	ACTUAL EXPERIMENT	SPECIAL INTERFACE EQUIPMENT: MCC	POCC	CLASSROOM
SPACELAB SUBSYSTEMS OPERATION AND MAINTENANCE																				
• FAMILIARIZATION																				
— EQUIPMENT LAYOUT	X	X	X	X																
— SUBSYSTEM OVERVIEW/INTERACTION	X	X	X	X																
— CAPABILITIES AND CONSTRAINTS	X	X	X	X																
• PROCEDURES																				
— ACTIVATION	X	X																		
— NORMAL OPERATIONS	X	X	X																	
— CONTINGENCY OPERATIONS	X	X																		
— MAINTENANCE/REPAIR	X	X	X																	
• CONSUMABLES MANAGEMENT	X	X	X																	
PAYLOAD OPERATIONS AND MAINTENANCE																				
• FAMILIARIZATION																				
— EQUIPMENT LAYOUT	X	X	X	X																
— PAYLOAD OVERVIEW/SL SUBSYSTEM INTERACTION	X	X	X	X																
— CAPABILITIES AND CONSTRAINTS	X	X	X	X																
• PROCEDURES																				
— ACTIVATION/CALIBRATION			X	X																
— NORMAL OPERATIONS			X	X																
— CONTINGENCY OPERATIONS			X	X																
— MAINTENANCE/REPAIR			X	X																
• PLANNING																				
— EXPERIMENT PLANNING/REPLANNING REQUIREMENTS			X	X																
• CONSUMABLES MANAGEMENT			X	X																
• SPACELAB/PAYLOAD INTERFACE																				
— EXPERIMENT CDMS OPERATIONS			X	X																
— CPSE OPERATIONS			X	X																
STS/SL/PAYLOAD OPERATIONS INTERFACE																				
• FAMILIARIZATION																				
— EQUIPMENT LAYOUT	X	X	X	X																
— HABITABILITY PROCEDURES	X	X	X	X																
— SAFETY PROCEDURES	X	X	X	X																
— STOWAGE MANAGEMENT PROCEDURES			X	X																
• MOBILITY																				
— IVA PROCEDURES	X	X	X	X																
— EVA PROCEDURES		X	X																	
• PLANNING																				
— FDF MANAGEMENT	X	X	X	X																
— FLIGHT REPLANNING	X	X	X	X																
• RMS OPERATIONS		X	X	X																
INTEGRATED OPERATIONS																				
• COORDINATED FLIGHT OPERATIONS	X	X	X	X																

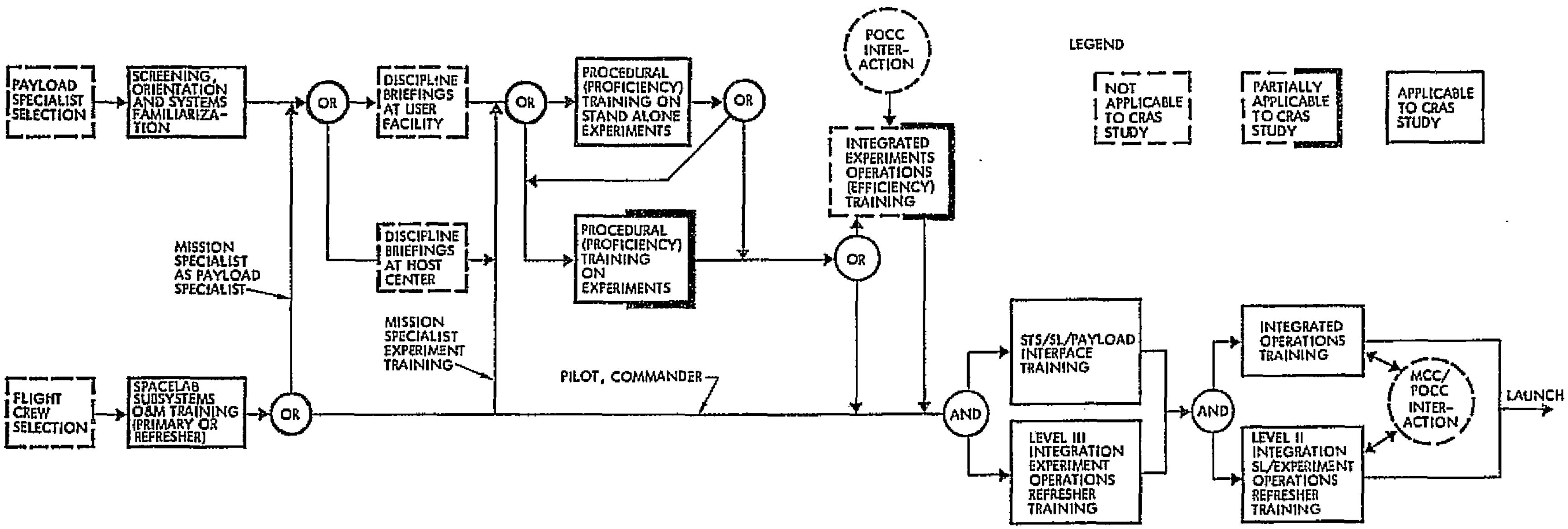
TRAINING OBJECTIVES/PERSONNEL ASSIGNMENTS

All tasks identified on the training analysis worksheets were analyzed and summarized according to on-orbit equipment group operations, then converted into categories of instruction and objectives of instruction within each category.

Personnel assignments, per NASA job descriptions, were made against each training objective.

The training equipments identified on the training analysis worksheets were assimilated into composite training devices and grouped according to training equipment types - mockup, part task trainer/simulator, actual equipment and special interface equipment. "Actual equipment" consists of restraint devices, flight planning kits, pressure garments, etc.

RECOMMENDED SPACELAB TRAINING SEQUENCE



RECOMMENDED SPACELAB TRAINING SEQUENCE

A Spacelab flight crew training program plan was then developed which incorporated the categories of instruction into a logical instructional sequence and was compatible with the STS program and operations schedule. This training flow is shown in the accompaning diagram.

Mission dependent (payload) training comprises one segment of the training program. This phase of instruction covers payload specialist (PS) discipline training and experiment operations proficiency and efficiency training of both PS and MS (mission specialist) on each experiment. This instruction was scheduled to be concluded at the conclusion of Level IV integration activities.

All professional crew members (commander, pilot and mission specialist) require detailed training on the operation of Spacelab subsystems. Following flight qualification and flight experience, instruction in this area can be reduced to a "refresher" training level to familiarize the crew with the latest modifications and regain proficiency prior to reflight.

The above instruction is followed by a combined crew training phase to develop team operating skills, team discipline and provide experience in mission sequence operations. This phase of instruction was scheduled to coincide with the Level I, II and III integration in order to provide as much "last minute", hands on experience as possible with the flight hardware using the operational procedures.

APPROACH TO CREW TRAINING REQUIREMENTS DEFINITION

- SPACELAB SYSTEMS ANALYSIS
  - MANNED OPERATIONS ANALYSIS
    - TRAINING PROGRAM REQUIREMENTS ANALYSIS
      - TRAINING EQUIPMENT REQUIREMENTS ANALYSIS
        - PLANNED EQUIPMENT EVALUATION
          - EQUIPMENT RECOMMENDATIONS

TRAINING OBJECTIVES / TRAINING EQUIPMENT REQUIRED

TRAINING OBJECTIVES	PERSONNEL ASSIGNMENTS				TRAINING EQUIPMENT REQUIREMENTS															
					SPACELAB FACILITIES								ORBITER FACILITIES					SPECIAL INTERFACE EQUIPMENT		
					MOCKUPS				PART TASK TRAINER/SIMULATOR				MOCKUPS		PART TASK TRAINER/SIMULATOR					
					WATER IMMERSION FACILITY															
	CMDR	PILOT	MISSION SPECIALIST	PAYLOAD SPECIALIST	MODULE	TUNNEL	PALLET EQUIPMENT	MODULE	AFD SL SUBSYSTEM C&D STATION TRAINER/SIMULATOR	AFD PAYLOAD C&D STATION TRAINER/SIMULATOR	MODULE SL SUBSYSTEM TRAINER/SIMULATOR	MODULE PAYLOAD TRAINER/SIMULATOR	WATER IMMERSION FACILITY ORBITER	ORBITER	SHUTTLE MISSION SIMULATOR	RMS PART TASK TRAINER	ACTUAL EXPERIMENT	MCC	POCC	CLASSROOM
SPACELAB SUBSYSTEMS OPERATION AND MAINTENANCE																				
• FAMILIARIZATION																				
– EQUIPMENT LAYOUT	X	X	X	X				X						X						X
– SUBSYSTEM OVERVIEW/INTERACTION	X	X	X	X																X
– CAPABILITIES AND CONSTRAINTS	X	X	X	X																X
• PROCEDURES																				
– ACTIVATION	X	X							X									X		X
– NORMAL OPERATIONS	X	X	X						X		X							X		X
– CONTINGENCY OPERATIONS	X	X							X		X							X		X
– MAINTENANCE/REPAIR	X	X	X						X		X							X		X
• CONSUMABLES MANAGEMENT	X	X	X						X		X							X		X
PAYLOAD OPERATIONS AND MAINTENANCE																				
• FAMILIARIZATION																				
– EQUIPMENT LAYOUT	X	X	X	X				X						X						X
– PAYLOAD OVERVIEW/SL SUBSYSTEM INTERACTION	X	X	X	X																X
– CAPABILITIES AND CONSTRAINTS	X	X	X	X																X
• PROCEDURES																				
– ACTIVATION/CALIBRATION			X	X						X		X							X	X
– NORMAL OPERATIONS			X	X						X		X							X	X
– CONTINGENCY OPERATIONS	X	X	X	X						X		X							X	X
– MAINTENANCE/REPAIR			X	X						X		X							X	X
• PLANNING																				
– EXPERIMENT PLANNING/REPLANNING REQUIREMENTS			X	X													X			X
• CONSUMABLES MANAGEMENT			X	X						X		X							X	X
• SPACELAB/PAYLOAD INTERFACE																				
– EXPERIMENT CDMS OPERATIONS			X	X						X		X							X	X
– CPSE OPERATIONS			X	X				X				X								X
STS/SL/PAYLOAD OPERATIONS INTERFACE																				
• FAMILIARIZATION																				
– EQUIPMENT LAYOUT	X	X	X	X				X						X						X
– HABITABILITY PROCEDURES	X	X	X	X				X						X			X			X
– SAFETY PROCEDURES	X	X	X	X				X						X			X			X
– STOWAGE MANAGEMENT PROCEDURES			X	X				X						X			X			X
• MOBILITY																				
– IVA PROCEDURES	X	X	X	X	X	X							X							X
– EVA PROCEDURES		X	X		X	X	X						X							X
• PLANNING																				
– FDF MANAGEMENT	X	X	X	X													X			X
– FLIGHT REPLANNING	X	X	X	X													X			X
• RMS OPERATIONS		X	X													X				
INTEGRATED OPERATIONS																				
• COORDINATED FLIGHT OPERATIONS	X	X	X	X					X	X	X	X			X			X	X	X

TRAINING OBJECTIVES/TRAINING EQUIPMENT REQUIRED

The training equipment required to accomplish the training necessary to meet training objectives were assigned to specific objectives.

Some of the training objectives can be met through classroom instruction without use of specially designed training equipments.

APPROACH TO CREW TRAINING REQUIREMENTS DEFINITION

- SPACELAB SYSTEMS ANALYSIS
  - MANNED OPERATIONS ANALYSIS
    - TRAINING PROGRAM REQUIREMENTS ANALYSIS
      - TRAINING EQUIPMENT REQUIREMENTS ANALYSIS
        - PLANNED EQUIPMENT EVALUATION
          - EQUIPMENT RECOMMENDATIONS

TRAINING APPLICABILITY OF

- CVT
- ENGINEERING MODEL
- HI-FI MOCKUP
- LEVEL III INTEGRATION FACILITY
- LEVEL II INTEGRATION FACILITY

CAPABILITIES AND LIMITATIONS

CVT-GPL

DESCRIPTION

- SLS - SPACELAB SIMULATOR – STRUCTURE AND ELECTRICAL
- SIS - SHUTTLE INTERFACE SIMULATOR – PAYLOAD INTERFACES
- SSE - SYSTEMS SUPPORT EQUIPMENT – ESE/MSE FOR SLS/SIS
- EXPERIMENT HARDWARE/SOFTWARE AND CORE
- EXPERIMENT CDMS EMULATION

FUNCTION

- SUPPORT DEVELOPMENT/VERIFICATION OF EXPERIMENT INTEGRATION CONCEPTS
- VERIFY CDMS/EPDS INTERFACES

TRAINING APPLICATION

- EXPERIMENT/EXPERIMENT CDMS PROFICIENCY TRAINING
- INTEGRATED EXPERIMENT OPERATIONS EFFICIENCY TRAINING
- MISSION EXPERIMENT SIMULATIONS

NEGATIVE FACTORS AS PRIMARY TRAINING DEVICE

- CANNOT SUPPORT FULL FLIGHT MODEL TRAINING LOAD
- CANNOT SUPPORT BOTH CVT AND TRAINING FOR 10 TO 12 FLIGHT BASELINE
- REQUIRES INTEGRATION OF TRAINING AND LEVEL IV SCHEDULES
- APPROXIMATELY SAME TRAINING BENEFITS COULD BE DERIVED BY INTEGRATING PART TASKS EXPERIMENT SIMULATORS

CVT/GENERAL PURPOSE LABORATORY SIMULATOR

The purpose of the CVT/GPL Simulator is to support, through simulations, the predesign and development phases of payloads and support potential users of the carrier in the development of experiments. In particular, it shall be designed to:

- Functionally simulate the Spacelab to support development/verification of selected experiment integration concepts
- Provide engineering "Test Bed" to support the development/verification of candidate experiment concepts and prototypes
- Functionally simulate the Spacelab-to-Orbiter and Spacelab-to-experiment interfaces, with emphasis on the CDMS and the EPDS
- Provide a capability to perform end-to-end simulations for all mission phases for selected payloads, with emphasis on the CDMS and ground data processing
- Provide an engineering "Test Bed" to accomplish the integration and verification of the approved prototype experiments into the ESA engineering model for the first two Spacelab flights
- Perform the verification of physical/functional/operational compatibility of selected experiment concepts and prototypes utilizing the ESA engineering model for the ongoing Spacelab program
- Provide an engineering "Test Bed" to support the development and verifications of operational concepts with particular emphasis on the following:
  - Man-machine interface and mission planning
  - Procedural development and requirements (flight and ground)
  - Experiment operations center concepts and requirements
  - Large centralized computer support versus decentralized computer support
  - Flexibility requirements for rapid turn-around of mission to mission changes
- Provide for the development of software required to operate the CVT engineering "Test Bed." Provide the identification/verification of software requirements and concepts to be utilized in the integration and checkout of experiment concepts and prototypes, both in the SLS and the engineering model.

CVT/GENERAL PURPOSE LABORATORY SIMULATOR (Continued)

The major elements of the CVT/GPLS for IOC are:

- Facilities to house and support the simulator systems
- Spacelab Simulator (SLS): basic structural and electrical elements of Spacelab to support the development and verification of selected experiment/payload integration concepts
- Shuttle Interface Simulator (SIS): in combination with the System Support Equipment provides for the functional simulation of the Shuttle Orbiter payload interfaces. Emphasis is placed on:
  - Orbiter furnished functions of electrical power, caution and warning, and data transmission, and
  - Payload supplied Controls and Displays (C&D)
- Systems Support Equipment (SSE): all Electrical Support Equipment (ESE) and Mecharical Support Equipment (MSE) required to support the SLS and SIS.

The CVT systems are to be designed to have a minimum operational life of five years when operated on a nominal 5 day, 40 hour, work week. The MTTR of line replaceable units shall not exceed 2.0 hours. No MTBF figure will be assigned.

The design of the CVT/GPLS limits its application in the Spacelab training program to Spacelab systems/experiment interface (proficiency) training and experiment operations (efficiency) training of payload and mission specialists.

This type of device would probably prove to be very beneficial for integrated experiment operations, CORE use and integrated experiment CDMS/experiment interface/experiment operations interaction training. Further, FDF development, crew activity planning and similar functions could be supported with such a device.

The CVT/GPLS must, for crew training purposes, be configured with the payload equipment complement for each flight. In support of 10-12 Spacelab flights per year (Central Experiment Training Facility concept), the flight and backup crews would have approximately four weeks of single shift operations available for training. If this training were scheduled for the final phase of experiment interface and operations training and was preceded by part-task trainer/simulator training, this would probably be adequate. The CVT could not effectively accommodate the training load imposed by the 29 flight/year model.

CVT/GENERAL PURPOSE LABORATORY SIMULATOR (Continued)

If experiment CDMS/experiment interface and experiment operations training were performed at the respective host center or payload system contractor facility, each location would have to have some equipment equivalent to the CVT's experiment CDMS.

Except for very low flight rates, the use of CVT/GPLS in support of both experiment development and training does not appear to be a plausible approach

A viable alternative to the CVT would be to design the part task trainer/simulators of the individual experiments such that they may be integrated and representative of the mission configuration as to work space and layout.

If each experiment has its own mini-computer and consists of a dedicated set of instruments, exclusive of CORE items, each could then be considered a "stand alone" experiment. Experiment procedural training interfacing with the Spacelab subsystems would be limited to use of CPSE. This approach would not obviate the need for integrated experiment operations training on some payloads, but might reduce the extent of such training and simplify real time replanning processes.

However, where experiments make common use of sensors and/or other equipments or when multiple experiments are conducted simultaneously, integrated operations training may be essential if required operations efficiencies are to be achieved.

It should be emphasized that as only one (1) set of experiment hardware (flight hardware) is programmed for Spacelab, the only time that the complete configuration is assembled or simulated for end-to-end operation to demonstrate the range of the equipments performance is during Level IV integration. Level III integration facilities and equipment are limited to interface verification and operational checkout of the experiment hardware and software.

Consequently, actual equipment operations training must occur prior to, during or immediately following Level IV integrations.

ENGINEERING MODEL

DESCRIPTION

- FUNCTIONALLY AND DIMENSIONALLY IDENTICAL TO FLIGHT UNIT
- GSE EQUIVALENT TO FLIGHT UNIT
- INTERFACE VERIFICATION EQUIPMENT SIMULATOR – ORBITER INTERFACE ADAPTER

FUNCTION

- VERIFICATION OF GROUND OPERATIONS, SOFTWARE INTEGRATION
- SUPPORTS SUSTAINING ENGINEERING AND IN-FLIGHT MALFUNCTION ANALYSIS

TRAINING APPLICATION

- ALL SPACELAB SUBSYSTEMS O&M PROCEDURES TRAINING

NEGATIVE FACTORS AS PRIMARY TRAINING DEVICE

- MODIFICATIONS FOR TRAINING COSTLY
- OPERATING COSTS HIGH
- TRAINING MODS WOULD DEGRADE USE FOR GROUND CREW TRAINING, SUSTAINING ENGINEERING, ETC.
- LIMITED AVAILABILITY

ENGINEERING MODEL (EM-1)

EM-1 is to be used to complete software development, confirm EMC and the standard interfaces (to segments and Orbiter) in the representative payload configurations. It is to serve in verification of all modes of operation (normal and emergency) and non-operative (standby) modes. Demonstrations of ground operations of inspection, access, replacement, maintenance, subsystem activation etc. can also be accomplished. The EM serves to verify and demonstrate all system level design parameters using the operational GSE (including simulators). Orbiter interfaces are verified using the IVE, (Orbiter simulator). The EM qualifies and confirms computer software integration, and operational procedures to be used on the Flight Model Spacelab.

The EM is functionally and dimensionally identical to the Flight Unit. It is made up of development hardware (Set No. 2) as summarized below. Included are sufficient system constituents necessary to assemble the baseline Spacelab configuration (per System Specification, SY-E- 0001), and other flight configurations (as noted in Mass Properties Report, RP-ER-0005). It resembles the Flight Unit in all respects as known at the time of the critical design review and will subsequently be maintained to reflect the flight configuration.

The EM consists of the following equipment:

- 1 core module structure assembly
- 1 forward end cone assembly
- 1 experiment module structure
- 1 aft cone assembly
- 1 set of utility bridges
- 5 pallet structure assemblies
- 1 complete crew habitability subsystem
- 1 complete CDMS (less standby computer)
- 1 complete EPDS (including Igloo equipment)
- 1 forward airlock
- 1 aft airlock
- 1 viewport
- 1 Igloo structure assembly
- 1 PSS equipment set (included in subsystem sets above)

The EM with a complete set of GSE and IVE simulators may be used for mission simulations of Spacelab operations less experiments, backup computer and, at present, the IPS and film vaults.

ENGINEERING MODEL (EM-1) (Continued)

As EM-1 is functionally and dimensionally identical to the Flight unit, includes the AFD PSS workstation and Orbiter interface adapter, all Spacelab O&M procedures can be performed on the EM as they would on the Flight Unit in a 1-G environment, with the exceptions noted above. In addition, as the components are identical to the flight hardware fault isolation, item remove/repair/replace actions can also be performed within the context of the 1-G environment.

If it is considered to be cost effective, the Shuttle Mission Simulator design can be made to be compatible at the EM interface to permit integrated Orbiter/SL(EM) operations without modification to EM subsystems. However, it is questionable if Spacelab sensors could be caused to function over their expected range, or if consumables usage could be simulated without some modifications to the EM. Failure to incorporate the dynamics of sensor response and power profile would not enable full replication of CDMS CRT status data displays.

There are several other impracticalities associated with the use of the EM as the principal Spacelab subsystem training device. First and foremost are the operating costs required just to keep the actual equipment up to the latest configuration and operating. Secondly, for malfunction training, faults would have to be inserted into the actual hardware in order to drive the display devices. This is time consuming as all components are not readily accessible and the insertion/removal process rapidly deteriorates the components.

Modifying the EM to make it an efficient and effective training device would be quite costly and may detract from its effective use as an inflight maintenance support or sustaining engineering tool.

The EM could in its present form, support SL habitability, familiarization, safety, both primary and refresher subsystem operations and maintenance and, to a limited extent, integrated flight crew operations training.

Use of the EM to train ground crews and flight crews, and in support of sustaining engineering and/or in support of in-flight maintenance operations precludes any determination as to its availability to support any of these functions without an analysis of the overall requirements.

It is recommended that the EM be located at the facility responsible for sustaining engineering and it be used for "refresher" operations and maintenance training of the flight crew prior to launch.

HI-FI MOCKUP

DESCRIPTION

- GEOMETRICALLY ACCURATE OF VEHICLE STRUCTURE
- HIGH FIDELITY OF INTERIOR CONFIGURATION

FUNCTION

- PROCEDURES TRAINING - INDIVIDUAL AND CREW
- SPACELAB FAMILIARIZATION
- STOWAGE MANAGEMENT

TRAINING APPLICATION

- DESIGNED FOR TRAINING PURPOSES
- RECOMMEND UPGRADE OF SPACELAB SUBSYSTEMS C&D TO "A" FIDELITY FOR USE AS PTT/S.

NEGATIVE FACTORS AS PRIMARY TRAINING DEVICE

- AVAILABILITY AT JSC FOR MODIFICATION

HI-FI MOCKUP

The HI-FI Mockup is a sophisticated, detailed, full-scale representation of the physical elements of the Spacelab module. The physical characteristics of the components, subsystems and structures are representative of the flight unit design. The unit consists of:

- Subsystem primary and secondary structures and fittings
- Subsystem pallet structure and fittings
- Subsystem utility connections
- Igloo structure and fittings
- Subsystem crew habitability items
- EPDS, ODMS, ECLS and TCS unit structures and fittings
- CPSE structures
- Trainer console.

The HI-FI Mockup is planned to be used by JSC as the Spacelab 1-G Trainer. The trainer is to be used in support of flight crew procedures training, hardware development, and flight crew training exercises for EVA, safety, stowage and habitability operations.

The mockup is designed to perform specific training functions within the planned training program at JSC.

It is recommended that the mockup be upgraded to full trainer status in the subsystems areas (see training device definitions). Experiment areas would remain as envelope fidelity only. The control and display elements would be electrically/electronically connected to replicate their system operating functions and be controlled through an instructor's console. CDMS display formats and control capability may well be capable of being simulated through an "intelligent" terminal, microprocessor approach as the functions it performs are, predominantly, procedural in nature.

LEVEL III INTEGRATION FACILITY

DESCRIPTION

- CORE SEGMENT SIMULATOR
- EGSE - INTERFACE EQUIPMENT, OPERATOR CONSOLE, POWER, COOLING
- EXPERIMENTS AND EXPERIMENT C&D PANELS - FLIGHT UNITS
- MGSE

FUNCTION

- PROVIDES EXPERIMENT ACTIVATION/OPERATION THROUGH SIMULATION OF SPACELAB ON-BOARD SUBSYSTEMS
- EMC TESTING

TRAINING APPLICATION

- EXPERIMENT/SPACELAB SUBSYSTEM INTERFACE OPERATIONS REFRESHER TRAINING

NEGATIVE FACTORS

- INTEGRATION TOOL - DOES NOT PROVIDE FOR FULL RANGE OF EXPERIMENT/SENSOR OPERATION
- INCREASES OPERATING TIME ON FLIGHT HARDWARE
- SEVERE TIME CONSTRAINTS ON AVAILABILITY
- NO TIE TO POCC

LEVEL III INTEGRATION FACILITY

The electrical ground support equipment (EGSE) used for Level III integration provides experiment equipment activation/operation through a flight type computer and actual flight software while simulating other subsystems. Its primary purpose is to verify the experiment flight software, experiment systems activation and electromagnetic compatibility.

The Level III integration facility consists of flight experiment hardware and electrical and support equipment to simulate Spacelab data interfaces, data handling and power distribution as shown in the accompanying figure.

The facility will also provide operator control and display and test and services.

The Level III integration facility consists of the following equipment:

- Spacelab core simulator
- Experiment flight hardware
- Electrical test and service equipment
- Air and fluid cooling units
- Ground power supply
- Measuring and stimuli units
- Operator console
- EGSE computer
- EGSE computer peripherals
- Interface unit
- Recording and timing unit
- PSS panels control and display

The Level III integration facility may be used for experiment activation through flight type interfaces, but not in the actual environment. The experiments may be constrained from operation at this time.

As shown in the sequence flow diagram the Level III integration activity is too close to launch to be acceptable for primary training. It will be suitable for refresher training on activation/operation procedures.

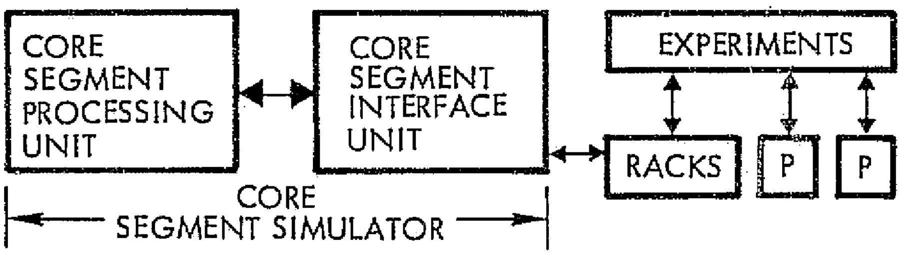
LEVEL III INTEGRATION FACILITY (CONTINUED)

EGSE FOR LEVEL III INTEGRATION PROVIDES EXPERIMENT ACTIVATION/OPERATION THROUGH SIMULATION OF SPACELAB ONBOARD SUBSYSTEMS

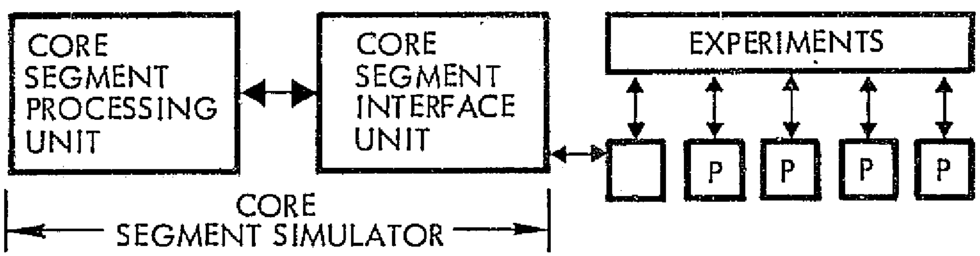
MAN/MACHINE INTERFACES

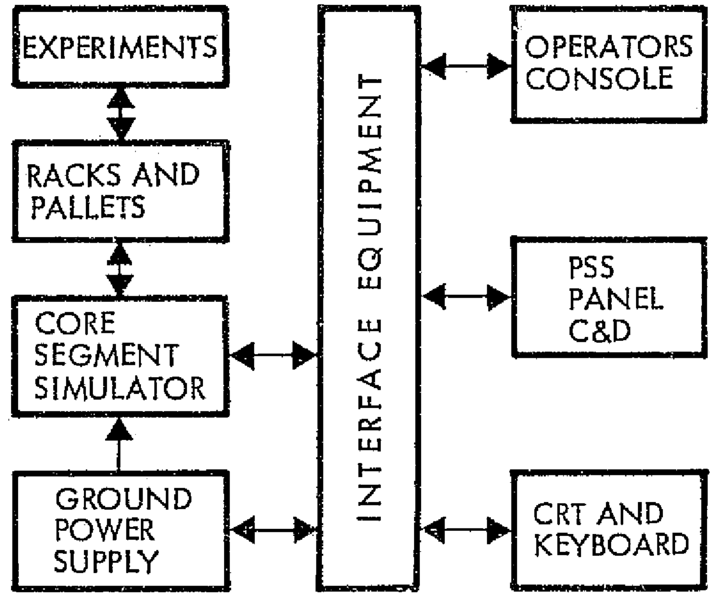
- DEDICATED EXPERIMENT CONTROL PANELS
- FLIGHT LIKE SUBSYSTEMS CONTROL PANELS
- FLIGHT LIKE CDMS KEYBOARD AND CRT

EXPERIMENT INTEGRATION INTO SECONDARY STRUCTURE/PALLETS



EXPERIMENT INTEGRATION ON PALLETS (PALLET ONLY MODE)

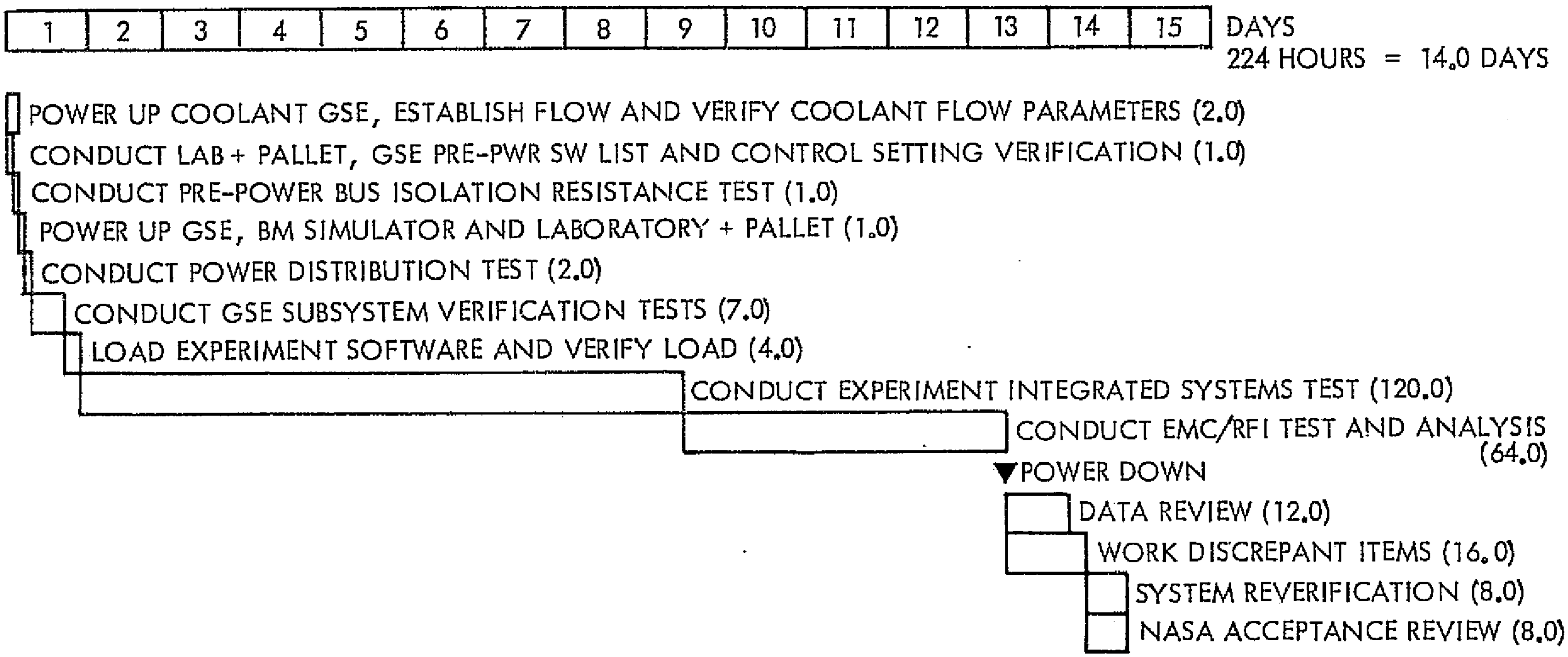




INTERFACE FUNCTIONS

- EXPERIMENT ACTIVATION/OPERATION
- DATA REDUCTION
- DATA RECORDING
- GENERATION OF COMMANDS
- SIMULATION OF SPACELAB SUBSYSTEMS
- DISPLAY OF CCTV
- VOICE INTERCOMMUNICATION
- DISPLAY OF CAUTION AND WARNING SIGNALS

LAB + PALLET BLOCK 3.0 EXPERIMENT LEVEL III INTEGRATION



LEVEL II INTEGRATION FACILITIES

DESCRIPTION

- ORBITER INTERFACE ADAPTER
- SPACELAB FLIGHT HARDWARE/SOFTWARE
- EXPERIMENT FLIGHT HARDWARE/SOFTWARE
- EGSE/MGSE

FUNCTION

- PROVIDES EXPERIMENT ACTIVATION/OPERATION THROUGH SPACELAB ON-BOARD SUBSYSTEMS, PSS EQUIPMENT AND SIMULATION OF ORBITER RESOURCES

TRAINING APPLICATION

- INTEGRATED MISSION SEQUENCING OF SPACELAB/EXPERIMENT OPERATIONS
- REFRESHER TRAINING ON SPACELAB AND EXPERIMENT OPERATIONS

NEGATIVE FACTORS

- INTEGRATION TOOL - DOES NOT PROVIDE FOR FULL RANGE OF SENSOR/ EXPERIMENT OPERATION
- INCREASES OPERATING TIME ON FLIGHT HARDWARE
- SEVERE TIME CONSTRAINTS
- NO TIE TO MCC/POCC

LEVEL II INTEGRATION FACILITY

The electrical ground support equipment (EGSE) used for Level II integration provides experiment equipment activation/operation through the Spacelab on board subsystems and payload specialist station. It is to serve in verification of experiment activation/operation, TM data processing, data reduction, data recording, generation of commands, CCTV operation voice intercom and caution and warning display. The primary purpose is to assure that subsystems are operational within design limits.

The Level II integration facility as shown in the figure consists of flight hardware and a series of electrical and support equipment to simulate Orbiter resources, supply power, provide operator control and display and test and services. The Orbiter interface adapter will simulate the Orbiter; it will include a PSS simulator, Spacelab/Orbiter signal simulator and power distribution.

The Level II integration facility consists of the following equipment:

- Orbiter interface adapter
- Spacelab flight hardware
- Experiment flight hardware
- Payload specialists station
- Electrical test and service equipment
- Air and fluid cooling units
- Ground power supply
- Measuring and stimuli units
- Operator console
- EGSE computer
- EGSE computer peripherals
- Interface unit
- Recording and timing unit

The Level II integration facility may be used for experiment activation through the actual Spacelab interfaces and to provide limited experiment operations. The constraints on operation are imposed by the experiment systems such as booms etc. which may not be operated prior to launch.

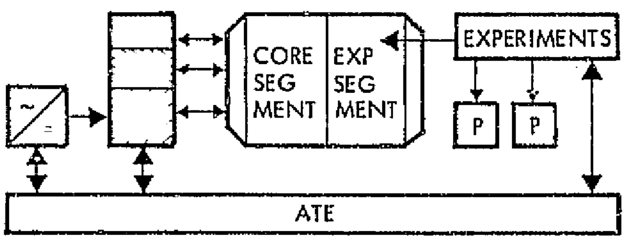
The Level II integration facility should be used for refresher training only. In addition to the limited experiment hardware operations capability, as shown in the sequence flow diagram, Level II integration will be accomplished over a period of approximately 5 days of 2-shift operations ending 2 weeks before launch. Under these time constraints the facility cannot be recommended for basic training. Further, it would not be desirable to put more operating hours on the flight units than is absolutely necessary.

EGSE FOR LEVEL II INTEGRATION PROVIDES EXPERIMENT ACTIVATION/OPERATION THROUGH THE SPACELAB ON-BOARD SUBSYSTEMS AND ORBITER PAYLOAD SPECIALIST STATION AND SIMULATION OF ORBITER RESOURCES

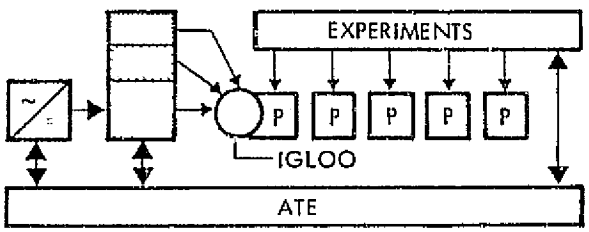
MAN/MACHINE INTERFACES

- DEDICATED MODULE EXPERIMENT CONTROL PANELS
- DEDICATED MODULE SUBSYSTEMS CONTROL PANELS
- MODULE CDMS KEYBOARD AND CRT
- SIMULATED AFD CDMS AND KEYBOARD AND CRT
- SIMULATED AFD EXPERIMENT CONTROL PANELS

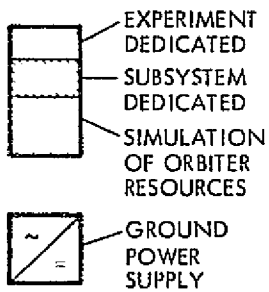
A) SYSTEM CHECKOUT — MODULE PLUS PALLET MODE

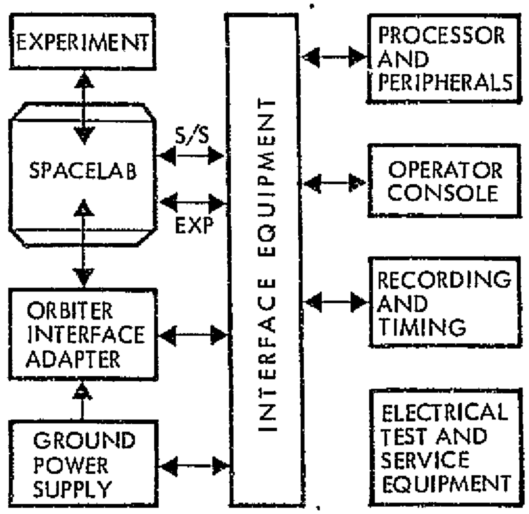


B) SYSTEM CHECKOUT — PALLET ONLY MODE



ORBITER INTERFACE ADAPTER



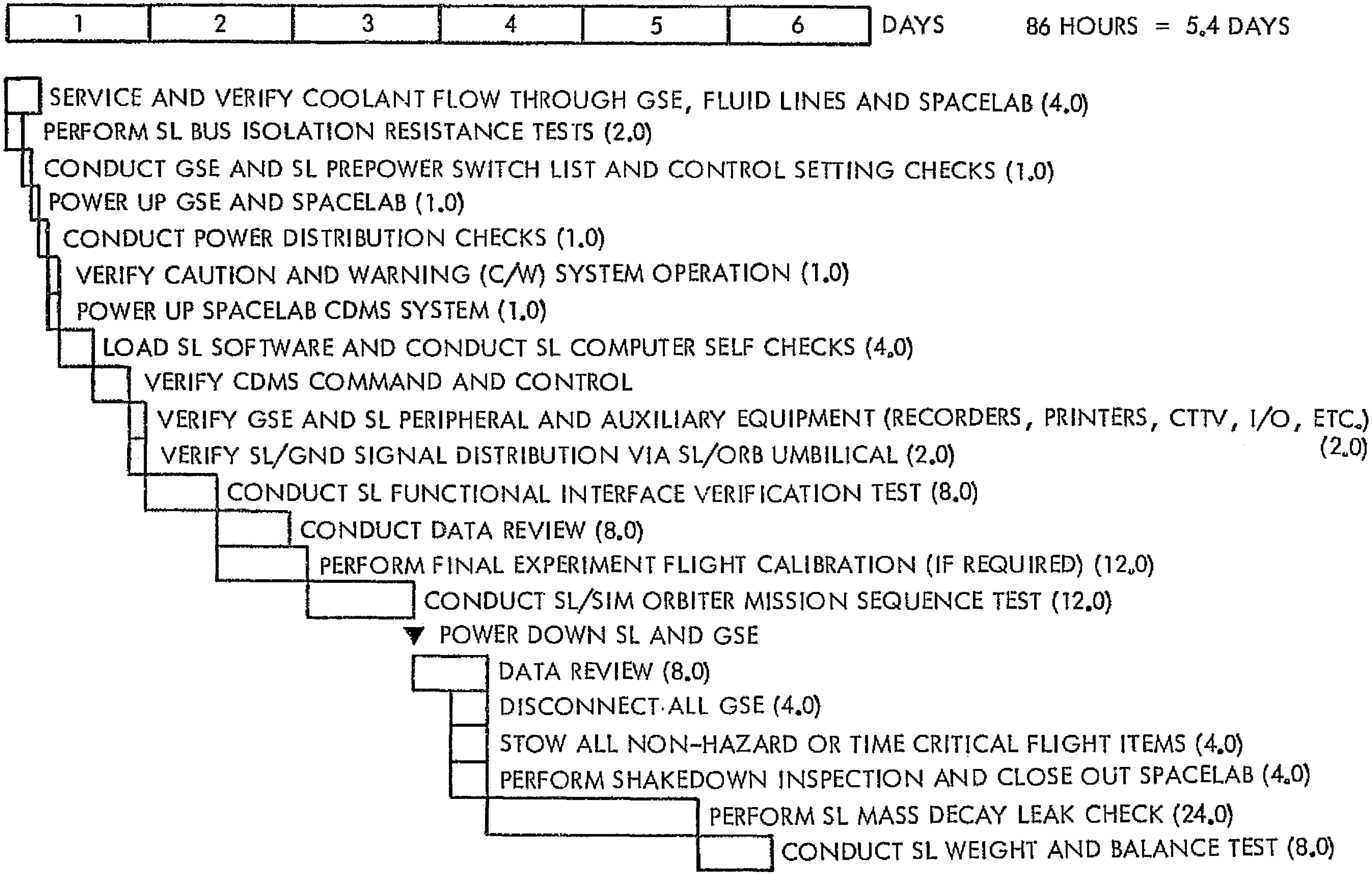


INTERFACE FUNCTIONS

- EXPERIMENT ACTIVATION/OPERATION
- SUBSYSTEM ACTIVATION/OPERATION
- DATA REDUCTION
- DATA RECORDING
- GENERATION OF COMMANDS
- DISPLAY OF CCTV
- VOICE INTERCOMMUNICATION
- DISPLAY OF CAUTION AND WARNING SIGNALS

LEVEL II INTEGRATION FACILITY (CONTINUED)

LAB + PALLET BLOCK 9.0 SPACELAB INTEGRATION



TRAINING OBJECTIVES/PLANNED EQUIPMENT USAGE

TRAINING OBJECTIVES	PERSONNEL ASSIGNMENTS				TRAINING EQUIPMENT REQUIREMENTS															
					SPACELAB FACILITIES								ORBITER FACILITIES					SPECIAL INTERFACE EQUIPMENT		
					MOCKUPS				PART TASK TRAINER/SIMULATOR				MOCKUPS		PART TASK TRAINER/ SIMULATOR					
					WATER IMMERSION FACILITY															
	CDR	PILOT	MISSION SPECIALIST	PAYLOAD SPECIALIST	MODULE	TUNNEL	PALLET EQUIPMENT	MODULE	AFD SL SUBSYSTEM C&D STATION TRAINER/SIMULATOR	AFD PAYLOAD C&D STATION TRAINER/SIMULATOR	MODULE SL SUBSYSTEM TRAINER/ SIMULATOR	MODULE PAYLOAD TRAINER/SIMULATOR	WATER IMMERSION FACILITY ORBITER	ORBITER	SHUTTLE MISSION SIMULATOR	RMS PART TASK TRAINER	ACTUAL EXPERIMENT	MCC	POCC	CLASSROOM
SPACELAB SUBSYSTEMS OPERATION AND MAINTENANCE																				
• FAMILIARIZATION																				
— EQUIPMENT LAYOUT	X	X	X	X				X						X						X
— SUBSYSTEM OVERVIEW/INTERACTION	X	X	X	X																X
— CAPABILITIES AND CONSTRAINTS	X	X	X	X																X
• PROCEDURES																				
— ACTIVATION	X	X							EM											X
— NORMAL OPERATIONS	X	X	X						EM (MOD)		EM (MOD)									X
— CONTINGENCY OPERATIONS	X	X							EM (MOD)		EM (MOD)									X
— MAINTENANCE/REPAIR	X	X	X						EM		EM									X
• CONSUMABLES MANAGEMENT									EM (MOD)		EM (MOD)									X
PAYLOAD OPERATIONS AND MAINTENANCE																				
• FAMILIARIZATION																				
— EQUIPMENT LAYOUT	X	X	X	X				X						X						X
— PAYLOAD OVERVIEW/SL SUBSYSTEM INTERACTION	X	X	X	X																X
— CAPABILITIES AND CONSTRAINTS	X	X	X	X																X
• PROCEDURES																				
— ACTIVATION/CALIBRATION			X	X						CVT		CVT								X
— NORMAL OPERATIONS			X	X						CVT		CVT								X
— CONTINGENCY OPERATIONS			X	X						CVT		CVT								X
— MAINTENANCE/REPAIR			X	X						CVT		CVT								X
• PLANNING																				
— EXPERIMENT PLANNING/REPLANNING REQUIREMENTS			X	X*													X			X
• CONSUMABLES MANAGEMENT			X	X						CVT		CVT								X
• SPACELAB/PAYLOAD INTERFACE																				
— EXPERIMENT CDMS OPERATIONS			X	X						CVT		CVT								X
— CPSE OPERATIONS			X	X				X				CVT OR EM								X
STS/SL/PAYLOAD OPERATIONS INTERFACE																				
• FAMILIARIZATION																				
— EQUIPMENT LAYOUT	X	X	X	X				X						X						X
— HABITABILITY PROCEDURES	X	X	X	X				X						X				X		X
— SAFETY PROCEDURES	X	X	X	X				X						X				X		X
— STOWAGE MANAGEMENT PROCEDURES			X	X				X						X				X		X
• MOBILITY																				
— IVA PROCEDURES	X	X	X	X	X	X*							X							X
— EVA PROCEDURES		X	X		X	X	X						X							X
• PLANNING																				
— FDF MANAGEMENT	X	X	X	X																X
— FLIGHT REPLANNING	X	X	X	X																X
• TAS OPERATIONS		X	X													X				X
INTEGRATED OPERATIONS																				
• COORDINATED FLIGHT OPERATIONS	X	X	X	X					LEVEL II (PARTIAL)	LEVEL II & III (PARTIAL)	LEVEL II (PARTIAL)	LEVEL II & III (PARTIAL)			X			X	X	X

TRAINING OBJECTIVES/PLANNED EQUIPMENT USAGE

The accompanying chart lists the use of planned equipments to provide instruction to meet training objectives. The prime consideration in the assignment of equipment was the applicability of each equipment to the training objectives as identified on previous charts. Generally speaking the planned equipments can be substituted for specially designed training equipments as follows:

- Hi-Fi mockup for module mockup
- Engineering model for AFD or module Spacelab subsystem trainer/simulator
- CVT/GPLS for AFD or module payload C&D station trainer/simulator

It should be noted that the engineering model would require modification to meet training objectives involving malfunction analysis on equipment.

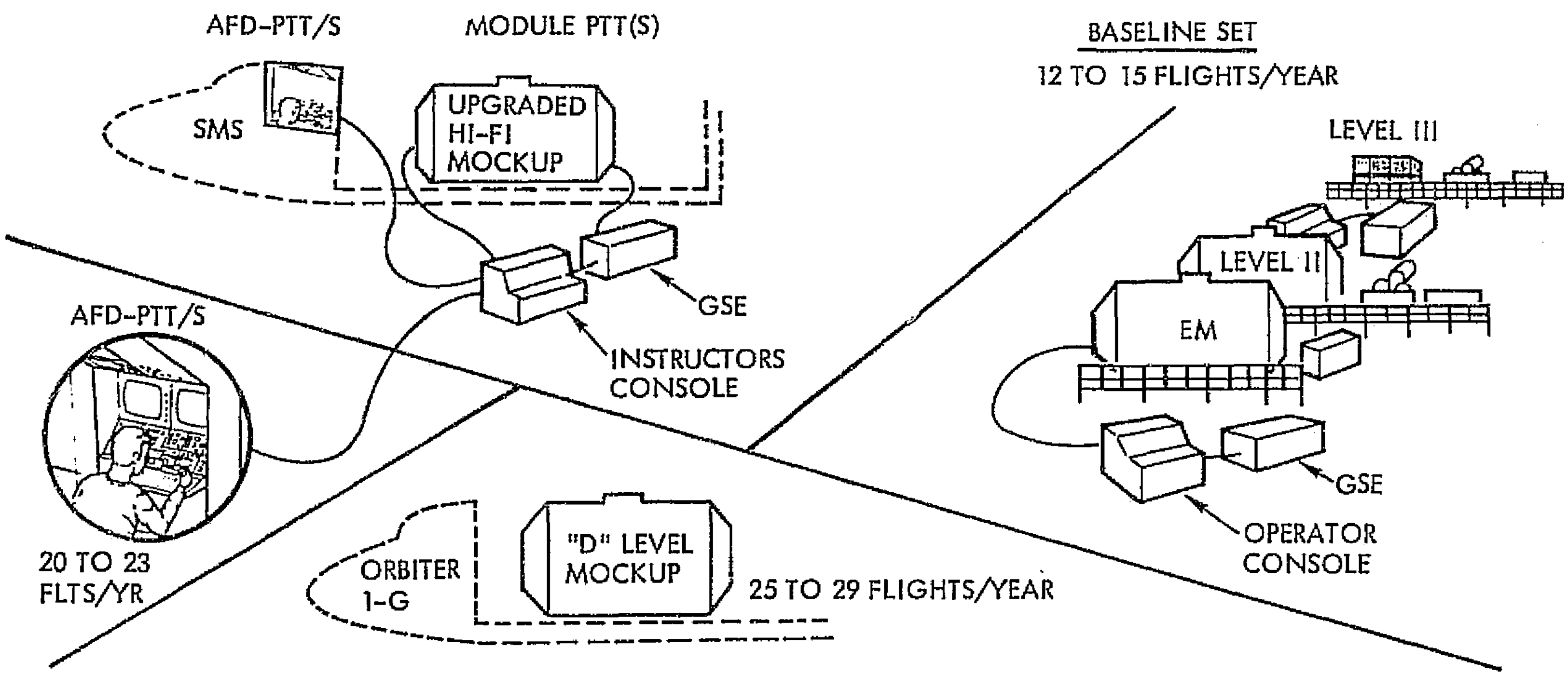
The use of Level II and Level III equipment setups for training are limited since the main purpose of Level II and III activities is checkout of integration compatibilities and not operation of sensors or experiment equipments over the full operational range.

APPROACH TO CREW TRAINING REQUIREMENTS DEFINITION

- SPACELAB SYSTEMS ANALYSIS
  - MANNED OPERATIONS ANALYSIS
    - TRAINING PROGRAM REQUIREMENTS ANALYSIS
      - TRAINING EQUIPMENT REQUIREMENTS ANALYSIS
        - PLANNED EQUIPMENT EVALUATION
          - EQUIPMENT RECOMMENDATIONS

TRAINING EQUIPMENT RECOMMENDATION

SPACELAB S-S TRAINING
STS/SL/PAYLOAD INTERFACE TRAINING
INTEGRATED OPERATIONS TRAINING



- SPACELAB SUBSYSTEMS O&M TRAINING — PRIMARY AND REFRESHER
- HABITABILITY, SAFETY, PLANNING AND MISSION "SIMS" TRAINING
  - COMBINE WITH SMS AND ORBITER 1-G
  - PROVIDE TELEMETRY AND VOICE LINK WITH MCC

TRAINING EQUIPMENT RECOMMENDATIONS (MISSION INDEPENDENT, INTERFACE AND INTEGRATED TRAINING)

The diagram identifies the types of equipment recommended for support of Spacelab Subsystems, STS/SL/Payload Interface and Integrated Operations training for various flight loads.

Baseline Set - Can Handle up to 12 to 15 Flights/Year

The baseline equipment set consists of an AFD Part Task Trainer/Simulator and Module PTT(S) with required GSE and Instructor's console for primary instruction. The EM and Level II and III integration facilities would be used to supplement the primary training.

As previously described, the Spacelab subsystems manned operations tasks in both the AFD and Module require a training device of no greater than trainer level complexity, except for IPS operations. Interconnection of the two through an instructor's console would enable their independent or integrated use. Because operations and displays are not dynamic but discrete, and control/response actions are relatively slow, control of components for malfunction insertion or level changes can be performed manually through the instructor station.

If the dedicated mini computer concept is implemented, the subsystem portion of the Module is not required to be of more than trainer complexity. The experiment areas of the Module Hi-Fi mockup would not be upgraded in any instance.

If the AFD-PTT/S and Module PTT/(S) are incorporated into the SMS, MDM inputs to the SL and outputs to the MDM could also be implemented through the instructor console. This arrangement could effectively support all JSC Spacelab operations, interface and integrated simulations training requirements. However, the lack of experiment equipment precludes actual hardware operations experience in this area.

The flight load which can be supported by the basic set is dependent upon the types of payloads. Pallet only configurations comprise nearly 50 percent of the missions and considerably reduce overall crew training requirements.

TRAINING EQUIPMENT RECOMMENDATIONS (Continued)
(MISSION INDEPENDENT, INTERFACE AND INTEGRATED TRAINING)

AFD-PTT/S Addition - Can Handle up to 20 to 23 Flights/Year

The addition of another AFD trainer would nearly double the Spacelab training capacity and provide considerable flexibility in training equipment scheduling.

"D" Level Mockup Addition - Can Handle up to 25 to 29 Flights/Year

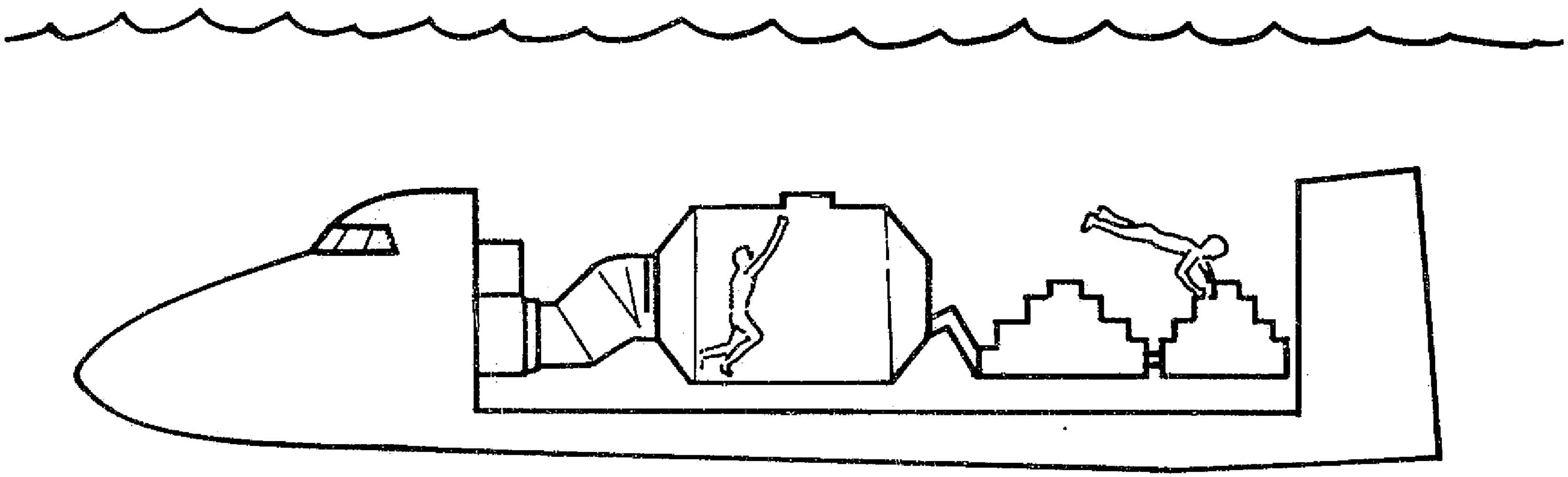
A low fidelity, envelope fidelity, mockup would enable off-loading of the Module trainer for basic familiarization, safety, and mission "SIMS" walk-through training of Payload Specialists. The mockup should be incorporated into the Orbiter 1-G trainer.

SPACELAB SIMULATOR EVALUATION

JSC SIMULATOR	TRW ALTERNATIVE
• BASIC INTERIOR MODULE AND AFD STRUCTURE	• SAME (HI-FI MOCKUP)
• AFD C&D (PLUG-IN)	• SIMILAR-INTELLIGENT TERMINAL'S (MDM AND RAU)
• ACTUAL FLIGHT COMPUTER (2)	• COMMERCIAL MINI OR MICRO PROCESSOR (IF REQUIRED)
• FULL COMPUTER DRIVEN SIMULATION OF ALL SS AND CPSE OPERATIONS AND PHENOMENA	• FULL FUNCTIONAL REPRESENTATION OF SS AND CPSE OPERATIONS
• DIRECT INTERFACE TO SMS COMPUTER AND SOFTWARE	• ISOLATED FROM SMS COMPUTER BY INSTRUCTOR'S CONSOLE
• PREPROGRAMMED MALFUNCTIONS	• REMOTE MANUAL MALFUNCTION INSERTION
• DYNAMIC TELEMETRY DATA	• POSSIBLE - COULD USE CANNED TAPES
• NO VISUAL-SMS SUPPLIED	• SAME

TRAINING EQUIPMENT RECOMMENDATIONS

IVA AND EVA MOBILITY



WIF MOCKUPS — "D" LEVEL NOMINAL/"C" MECHANICAL

- IVA
- EVA

TRAINING EQUIPMENT RECOMMENDATIONS (IVA & EVA MOBILITY TRAINING)

As indicated in the chart, water immersion (neutral bouyancy) facility mockups are required for IVA and EVA training of the crew. The level of fidelity required is "D" level (envelope fidelity) on both the module and pallets. However, mechanical equipment whose operation is affected by the zero-g environment requires "C" level fidelity (physical force, torque, movement fidelity).

TRAINING EQUIPMENT RECOMMENDATIONS

EXPERIMENT/SPACELAB SUBSYSTEM INTERFACE TRAINING (PROFICIENCY DEVELOPMENT)

- DEDICATED MINI-COMPUTER CONCEPT
    - NO COMMON PURPOSE TRAINING EQUIPMENT REQUIRED

- EXPERIMENT CDMS – BASELINE CONCEPT
    - EXPERIMENT CDMS EMULATION AND WORKSTATION (REQUIRED AT HOST CENTER AND/OR PI AND/OR PAYLOAD SYSTEM CONTRACTOR FACILITY)

TRAINING EQUIPMENT RECOMMENDATIONS EXPERIMENT/SPACELAB SUBSYSTEM INTERFACE TRAINING (PROFICIENCY DEVELOPMENT)

- DEDICATED MINI-COMPUTER CONCEPT

  No common purpose, Spacelab subsystem, training equipment is required for Payload Specialists experiment operations proficiency training. Familiarzation with the experiment/Spacelab interface can be accomplished at JSC with the AFD and Module trainers. Experiment training equipment should include work station layout of module or AFD mounted equipment.

- EXPERIMENT CDMS - BASELINE CONCEPT

  An EXP-CDMS emulation capability with keyboard and CRT must be provided as part of any experiment part-task work station simulator used for proficiency development of PS and MS crew members.

  This emulation capability must be provided at each facility responsible for experiment operations proficiency instruction.

TRAINING EQUIPMENT RECOMMENDATIONS

INTEGRATED EXPERIMENT OPERATIONS TRAINING (EFFICIENCY DEVELOPMENT)

- NOT REQUIRED FOR ALL PAYLOADS

  BUT

- WHERE TRAINING IS NECESSARY

  REQUIRES A FACILITY, TAILORED TO PAYLOAD, WHICH ENABLES LAYOUT AND OPERATION OF EQUIPMENT WITHIN REPRESENTATIVE WORK SPACE

  FOR EXAMPLE

  MSFC–CVT/GPL

  JSC–LIFE SCIENCES WORKSHOP

TRAINING EQUIPMENT RECOMMENDATIONS

INTEGRATED EXPERIMENT OPERATIONS TRAINING (EFFICIENCY DEVELOPMENT)

There will be some types of payloads where two or more crewmen must coordinate on experiment operations activities to accomplish experiment objectives. Though each crewman has attained proficiency in the nominal experiment operations, provisions must be made to practice joint/coordinated activities to develop the required efficiency.

Training on joint/coordinated activities requires a facility tailored to the payload which replicates the layout and operational configuration of the equipment within a workspace representative of the module.

Examples of such facilities are the MSFC-CVT/GPLS and JSC-Life Sciences Workshop.

TRAINING EQUIPMENT COST MATRIX

TRAINING ELEMENT	COST ESTIMATES: PROCUREMENT 78/78	PROCUREMENT TOTAL	OPERATING ($42K/MAN YR)	AVAILABILITY	GROUND RULES AND ASSUMPTIONS
SPACELAB SUBSYSTEMS O&M • AFD • HI-FI MOD • INST CONSOLE • ENGRNG	 $ 150K 500K 400K 500K $1550K	 $ 300K 500K 500K 600K $1900K	16MM/MONTH $56K/MONTH	100 HRS/MONTH	NUMBER OF OPERATING PERSONNEL BASED ON PROCEDURES AND SIMULATOR TRAINERS DATA - PROCUREMENT COST ROM
SPACELAB MOCKUP (WIF)	$204K	300K	2MM/MONTH $7K/MONTH	4 HRS/WK	1/3 SMS, 1/3 IUS, 1/3 SL
SPACELAB MOCKUP LO-FI		150K	1MM/MONTH 3.5K/MONTH	120 HRS/MONTH	
EM, LEVEL III + LEVEL II FACILITIES	N/A	N/A	SHARED	PER SCHEDULE	PROCURRED FOR OPERATIONS
EXPERIMENT PART TASK SIMULATOR (CDMS EMULATION) INTEGRATED EXPERIMENT TRAINER/ SIMULATOR	$4100K* ↓	NO. OF FACILITIES ↓	12MM/MONTH $42K/MONTH	64 HR/MONTH	BASED ON MSFC ESTIMATES - REDUCED BY USE OF EMULATED EXP-CDMS MOCK-UPS IN LIEU OF FLIGHT CONFIGURED CPSE. MAJOR COST ITEM IS SOFTWARE

*PROCUREMENT COSTS SHARED WITH EXPERIMENT OPERATIONS PROFICIENCY DEVELOPMENT TRAINING. DISTRIBUTED EXPERIMENT PROCESSING CONCEPT DELETES COST FOR CDMS EMULATION (HARDWARE AND SOFTWARE)

TRAINING EQUIPMENT COST MATRIX

The accompanying chart summarizes the estimated procurement and operating costs for the recommended list of Spacelab training equipment.

Spacelab Systems O&M Training

The FY '78/'79 procurement cost estimate consists of the baseline set of equipment (12 to 15 flights/year). Total costs reflect additional items (AFD, Instructor's console add-on and LO-FI Mockup) associated with increased flight rates. This baseline set when integrated with the SMS serves all Spacelab, familiarization and integrated operations training requirements as shown in the preceding charts.

Cost estimates are based upon using an "intelligent" terminal for the AFD-CDMS input and display element. IPS video and state vector data is provided by SMS.

Spacelab Mockup (WIF)

The basic cost figure was derived from POP 75-1. The additional cost is that estimated for mockups of pallet equipment for the full range of experiments.

EM and Levels II & III Integration

No costs allocated to training.

Experiment/Spacelab Interface Training

Where, of if, required these costs are shared with experiment training.

ANSWERS TO SPECIAL QUESTIONS

1) EVALUATE IMPACT OF REMOTE CONTROL ON TASK ANALYSIS

NO SIGNIFICANT CHANGES FROM INITIAL ANALYSIS. SOME MODIFICATIONS AS TO HOW AND WHERE FUNCTIONS ARE PERFORMED. SIMPLIFIED CONTROL AND DISPLAY PANELS

2) REEXAMINE NEED FOR $6M SPACELAB SIMULATOR

TRAINING DEVICES REQUIRED BUT FULL SIMULATION IS NOT MANDATORY.

3) EXAMINE APPLICABILITY OF HI-FI MOCKUP, CVT AND EM TO TRAINING

HI-FI MOCKUP	- UPGRADE TO TRAINER STATUS ON SUBSYSTEMS, LO-FI MOCKUP OF EXPERIMENT C&D
CVT	- CAN BE USED FOR PROFICIENCY DEVELOPMENT
EM	- USE FOR REFRESHER TRAINING

4) EXAMINE POSSIBILITY OF INCORPORATING LEVEL II AND III INTEGRATION INTO CREW TRAINING

USE FOR REFRESHER TRAINING WITH CREW AS TEST ENGINEERS

FLIGHT CREW TRAINING

RESULTS

- INCORPORATION OF REMOTE CONTROL SIMPLIFIES INSTRUCTION IN OPERATION OF SPACELAB SUBSYSTEMS

- INCORPORATION OF DISTRIBUTED EXPERIMENT PROCESSING CONCEPT REDUCES STANDARD DEDICATED TRAINING EQUIPMENT HOWEVER MAY INCREASE NEED FOR INTEGRATED IPS/ EXPERIMENT TRAINING

- SPACELAB SUBSYSTEMS FLIGHT CREW OPERATIONS TASKS ARE NOT DIFFICULT AND ARE NOT TIME OR PERFORMANCE CRITICAL

RECOMMENDATIONS

- USE UPGRADED HI-FI MOCKUP AND AFT FLIGHT DECK TRAINER/SIMULATOR COMBINED WITH SMS FOR TRAINING

- USE ENGINEERING MODEL AND LEVEL II AND III INTEGRATION FACILITIES FOR "REFRESHER" TRAINING

- EXPERIMENT CDMS EMULATION AND WORKSTATION REQUIRED BY EACH PAYLOAD CENTER FOR EXPERIMENT/SPACELAB SUBSYSTEM INTERFACE TRAINING

OBJECTIVE

ESTIMATE THE EQUIPMENT, FACILITIES AND MANPOWER FOR MINIMUM PAYLOAD OPERATIONS

- FOR EACH PAYLOAD DISCIPLINE
- FOR EACH TRAFFIC MODEL

- PAYLOAD OPERATIONS REQUIREMENTS
- DISPLAY AND COMMUNICATIONS REQUIREMENTS
- DATA HANDLING REQUIREMENTS
- POC EQUIPMENT ESTIMATES
- POC REQUIREMENTS BY TRAFFIC MODEL
- POC MANPOWER ESTIMATES

FACTORS INVOLVED IN PAYLOAD OPERATIONS

- MANEUVERING
- POINTING
- TIME DEPENDENCIES
- ORBITAL POSITION RELATIONSHIPS
- RESTRICTIONS ON ORBITER OPERATIONS
- SPECIAL COMMUNICATIONS
- ORDER OF EXPERIMENT PERFORMANCE
- OTHER SPECIAL CONDITIONS

FACTORS INVOLVED IN THE FLIGHT PLANNING FUNCTION

The major factors that influence the complexity of flight planning are:

- Maneuvering the spacecraft to change orbital parameters
- Pointing of the spacecraft or instruments to acquire specific targets with defined precision
- Time dependency of orbital operations to synchronize with ground operations, natural phenomena, or day/night conditions
- Orbital position relative to earth or stellar targets, magnetic and particle fields, etc.
- Restrictions on Orbiter operations such as RCS firings, radio communications, or venting and waste dumps
- Special communications to establish coordination with earth operations and observations such as ground truth operations and complementary astronomy observations
- Order of experiment performance where it strongly affects overall achievement of objectives
- Special conditions such as earth shadowing, Beta angle, and solar conditions.

FLIGHT PLANNING REQUIREMENTS BY PAYLOAD DISCIPLINE

CRAS DRM/ FLIGHT PLANNING FACTORS	COMBINED ASTRONOMY	LIFE SCIENCES	MULTI APPLICATIONS	AMPS	ATL	FIRST MISSION	SECOND MISSION OR HIGH ENERGY ASTROPHYSICS	SOLAR PHYSICS	SPACE PROCESSING	EARTH OBS.
Experiments	AS-01, AS-03 AS-04, AS-05	Core Base (Biology & Advanced Technology)	CN-04 OP-05 CN-08 SP-31 EO-20 OP-09	NAP 410 - 490 (8) (APdo)	ST 03 ST47 CN 12 ST 41 ST52 EO 07 ST 45 ST54 ST46 ST55 MB 05 ST57	EO-1 SOI- EO-15 EASNN 5054 ELSNN	Space Processing & high energy astrophysics	S001 - S020 less S006, S010, S019 (17)	SP-14 (14)	EOE 01-18 (18)
Maneuvers	None	None	Possible Orbit Correction	Operate During Phasing Orbit	None	None	None	None	None	Possible Orbit Correction
Pointing	Stellar Targets, Slew IPS 400 Times 2 IPS Momentum Damp 2/Day	None	Earth Oriented Full Time	30 Attitude Changes At times rotate to hold parallel to mag. lines	Earth Pointing Most of Time	15 Attitude Chgs. Earth Pointing Stellar Pointing	Anti-Earth Pointing Some Stellar Pointing	Continuous Solar Pointing	None	Earth Pointing Full Time Possible Bar-B. Q. Occasionally
Time Dependency	None	None	CN04 needs daylite over CONUS EO-20 with ground truth observations EO-20 4 hours for Battery Charge/oper	Max. night over North. Hem. Schedule around SAA & Belt encounters	Coordinate with Ground Operations	None	None	None	None	Coordinate with Ground Truth Operations
Earth Position Relationships	None	None	EO-20 has specific sites Accurate orbital Position required	At night over Alaska Magnetic Field Positions	Specific Sites, CONUS	Specific Sites	None	None	None	Specific Sites Worldwide
STS Inhibits	RCS & Vents while observing	RCS	Drifting Flight for SP Exp. Transmission during CN-04 Ops.	Restrict RCS during Observations	RCS 24 hour, once 2-4 hr/day, 5 times	RCS & Dumps Drifting Flt.	Restrict RCS and Dumps	Restrict RCS and Dumps	Acc. $<10^{-4}$g While Operating Exps.	Restrict RCS and Dumps
Special Communications	No	No	Coordinate with Ground Truth Ops.	Coordinate with Ground Observers Observe & Command Subsatellites	Coordinate with Ground Operations	No	Ground Control of Instruments	None	None	Coordinate with Ground Operations
Order of Performance	No	Major	Avoid major interaction between Exps.	Satellite Deployment, Balloon Deployment, Booms, Ejections	No	No	No	No	Some	Major
Special Conditions	Some Observations in Earth Shadow. Others at all times	None	Daylite over CONAS SP31 High Heat Rejection	Night over Northern Hemisphere Strong Dep. on Solar Conditions Satellite Maneuvering could drive timeline	No	No	None	Solar Conditions	No	Sun Angle at Targets
Science Results Change Plan	Very Low Prob.	High Prob.	Medium Prob.	High Prob.	Low Probability	Low Prob.	Medium Prob.	Low Prob.	Low Prob.	Certain
Science Results Change Procedures	Medium Prob.	High Prob.	Medium Prob.	High Prob.	Low Probability	Med Prob.	Low Prob.	Medium Prob.	Low Prob.	High Prob.
Payload Crew Size - Schedule (PSS)	2 Shifts	3 Work Together	4 Shifts	4 Shifts	4 Shifts	2 Shifts	1 Shift	4 Shifts	1 or 2 Shifts	2 Shifts

*(Scheduling Descriptors)

FLIGHT PLANNING REQUIREMENTS BY PAYLOAD DISCIPLINE

An analysis was made of eight discipline payloads and of the first* and second Spacelab missions, as they are defined in the DRM's and Level A and B sheets that were issued in the spring and summer of 1975. This analysis considered the requirements that each payload would have for each of the previously defined planning functions.

The facing sheet is a summary of this analysis.

*The first mission as defined in the 1975 DRM was considered to be far too complex for a first flight of the Spacelab. An experiment complement was postulated based on current Verification Flight Test objectives, the spacecraft attitudes required by the VFT program, and the current state of definition of various experiment hardware projects.

- PAYLOAD OPERATIONS REQUIREMENTS

• DISPLAY AND COMMUNICATIONS REQUIREMENTS

- DATA HANDLING REQUIREMENTS
- POC EQUIPMENT ESTIMATES
- POC REQUIREMENTS BY TRAFFIC MODEL
- POC MANPOWER ESTIMATES

PAYLOAD PLANNING AIDS REQUIRED

PAYLOAD PLANNING AIDS REQUIRED	COMBINED ASTRONOMY		LIFE SCIENCES		MULTIAPPLICATIONS		AMPS		ATL		FIRST MISSION		SECOND MISSION		SOLAR PHYSICS		SPACE PROCESSING		EARTH OBSERVATIONS	
STELLAR TARGET OPPORTUNITIES	x	x	-	-	-	-	-	-	x	x	x	x	x	x	-	-	-	-	-	-
	x	x	-	-	-	-	-	-	x	x	x	x	x	x	-	-	-	-	-	-
EARTH TARGET OPPORTUNITIES	-	-	-	-	x	x	x	x	x	x	x	x	-	-	-	-	-	-	x	x
	-	-	-	-	x	x	x	x	x	x	x	x	-	-	-	-	-	-	x	x
ORBIT POSITION	x	x	-	-	-	-	xx	x	-	-	x	x	-	-	-	-	-	-	-	-
	x	x		-	-	-	xx	x	-	-	x	x	-	-	-	-	-	-	-	-
MAGNETIC LINE ALIGNMENT	-	-	-	-	-	-	x	x	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	x	x	-	-	-	-	-	-	-	-	-	-	-	-
CONSUMABLES STATUS AND PLANNING	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o
	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
DATA STATUS AND PLANNING	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o	x	o
	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
SPECIAL RELATIONSHIP WITH STS	x	-	-	-	x	-	x	-	x	-	x	-	x	-	-	-	-	-	x	-
	x	-	-	-	x	-	x	-	x	-	x	-	x	-	-	-	-	-	x	-
COMMUNICATION COORDINATION (SPECIAL)	-	-	-	-	xx	-	x	-	xx	-	x	-	-	-	-	-	-	-	xx	-
	-	-	-	-	xx	-	x	-	xx	-	x	-	-	-	-	-	-	-	xx	-
WEATHER PREDICTION	-	-	-	-	x	-	-	-	x	-	-	-	-	-	-	-	-	-	x	-
	-	-	-	-	x	y	-	-	x	y	x	y	-	-	-	-	-	-	x	y
SOLAR ACTIVITY PREDICTION	-	-	-	-	-	-	x	-	-	-	x	-	-	-	x	-	-	-	-	-
	-	-	-	-	-	-	x	y	-	-	x	y	-	-	x	y	-	-	-	-
EXPERIMENT ACCOMPLISHMENT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	x	y	x	y	x	y	x	y	x	y	x	y	x	y	x	y	x	y	x	y
EXPERIMENT HARDWARE STATUS	-	o	-	o	-	o	-	o	-	o	-	o	-	o	-	o	-	o	-	o
	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
SCIENTIFIC RESULTS	-	o	-	o	-	o	-	o	-	o	-	o	-	o	-	o	-	o	-	o
	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
INSTRUMENT COMMANDING REQUIRED	-	x	-	-	-	-	-	-	-	-	-	-	-	x	-	x	-	-	-	-
	x	x	-	-	-	-	-	-	-	-	-	-	x	x	x	x	-	-	-	-

KEY

X = YES; XX = YES 2 FUNCTIONS	NEEDED FOR PREFLIGHT PLANNING?	COMPUTER ASSISTANCE REQUIRED?	X = YES COMPUTATION; O = YES DATA FORMATTING; — = NO
— = NO	NEEDED FOR REAL-TIME REPLANNING?	REAL-TIME DISPLAY REQUIRED?	X = COMPUTER DRIVEN; Y = HAND MAINTAINED OR EXTERNALLY PROVIDED; — = NO

ORIGINAL PAGE IS OF POOR QUALITY

PAYLOAD PLANNING AIDS REQUIRED

Based on the planning requirements established in the previous chart, a number of information displays and communication situations were postulated. These flight planning aids were developed so that a necessary and complete set of aids could be defined for each discipline.

The information displays are broken down into:

- Those that are of a dynamic nature and so would require computer assistance in their formulation either for formatting of data or computation of data products

- Those that become fixed when the actual orbit has been achieved, such as groundtrack, or those that are supplied by external agencies, such as weather prediction.

The facing sheet shows a matrix of planning aids required as related to the ten payloads that were analyzed.

PAYLOAD OPERATIONS DISPLAY AND COMMUNICATIONS SUMMARY

ALL DISCIPLINES

- HAND MAINTAINED DISPLAY
  - EXPERIMENT ACCOMPLISHMENTS
- COMPUTER DRIVEN DISPLAYS
  - STS STATUS
  - EXPERIMENT HARDWARE STATUS
  - CONSUMABLE STATUS AND PLANS
  - DATA STATUS AND PLANS
  - SCIENCE DATA
- COMMUNICATIONS
  - WITH STS OPERATOR
  - WITH FLIGHT CREW

DISCIPLINE SPECIFIC

	ASTRONOMY	LIFE SCIENCE	MULTI-APPLICATIONS	AMPS	ATL
• HAND MAINTAINED					
– WEATHER PREDICTION			X		X
– SOLAR ACTIVITY PREDICTION				X	
• COMPUTER DRIVEN					
– STELLAR TARGET OPPORTUNITIES	X				
– EARTH TARGET OPPORTUNITIES			X	X	X
– ORBIT POSITIONS	X			X	
– MAGNETIC LINE ALIGNMENT				X	
• COMMAND GENERATION	X				
• COMMUNICATIONS					
– COORDINATE WITH GROUND OBSERVERS			X	X	X
– COORDINATE WITH GROUND OPERATIONS			X		X

PAYLOAD PLANNING AIDS SUMMARY

The facing page gives a summary of the various displays and communication situations that should be provided in the POCC's as they are derived from analysis of the five baseline DRM provided for this study.

As can be seen certain aids are common to all disciplines, others are required only for specific disciplines. The shaded requirements are available from the MCC.

POCC EQUIPMENT RELATED TO LEVELS OF CREW AUTONOMY

- ASSISTANCE ONLY
  - PROVIDES FOR ASSISTANCE IN CASE OF MALFUNCTION OR UNUSUAL SCIENTIFIC DATA
- MINIMUM COMMAND
  - PROVIDES MINIMUM CAPABILITY CONSISTENT WITH GROUND COMMANDING OF INSTRUMENTS
- FULL CONTROL
  - PROVIDES ADEQUATE CAPABILITY TO POCC TO DO ALL REPLANNING AND INSTRUMENT COMMANDING

POCC EQUIPMENT RELATED TO LEVELS OF CREW AUTONOMY

In order to develop equipment requirements for the POCC, as the relate to the amount of planning and operational autonomy allowed to the crew, three levels of autonomy were defined.

A) Assistance Only. Full autonomy is allowed the crew except that the POCC must be ready to assist in diagnosis of malfunctions and in recommending remedial measures either through repair or through changes in procedures and plans.

B) Minimum Command. This level provides the minimum amount of equipment necessary for the POCC to command instruments when the crew is not available. It also allows the POCC to develop daily activity plans for recommendation to the crew.

C) Full Control. This level provides adequate equipment for the POCC to do all the planning and instrument commanding. It does not provide for a console dedicated to each instrument in those cases where all instruments will not be operated simultaneously.

The following pages are a more detailed description of the characteristics and requirements of the alternative POCC concepts.

POCC EQUIPMENT RELATED TO LEVELS OF CREW AUTONOMY (continued)

Assistance Only POCC

Characteristics

- MCC operates Spacelab systems, manages payload data flow.
- Flight crew does all experiment operation and activities replanning.
- POCC provides assistance in planning, daily planning aids such as weather predictions, malfunction analysis, and science data assessment.

Console Position Requirements

- All disciplines have one position for orbiter status functions and Spacelab systems status functions.
- Most disciplines need two console positions one for experiment housekeeping data, one for experiment science data.
- Multi-Applications and ATL do not generate sufficient science data to require an additional position for this data.

Minimum Command POCC

Characteristics

- MCC operates Spacelab systems, manages payload data flow.
- Flight crew does most of experiment operation, assists in activities replanning.
- POCC does daily activities planning, keeps track of equipment conditions, makes assessment of science data, commands some instruments when crew is not available.

Minimum Command POCC - continued

Console Position Requirements

- All disciplines have one position for orbiter status functions and Spacelab systems status functions.
- Positions provided for experiment housekeeping and science data display as required by instrument complement.
- Instrument commanding provided for astronomy and AMPS, commands to be sequenced through one console.

Full Control POCC

Characteristics

- MCC operates Spacelab systems, manages orbiter data flow.
- Flight crew functions as equipment operators, discusses scientific observations and accomplishments with POCC
- POCC dictates all replanning of activities, manages payload data flow, keeps close track of equipment, makes assessment of science data, commands some instruments.

Console Position Requirements

- All disciplines have one position for orbiter and Spacelab systems status functions. Additionally, a position may be provided for payload data management.
- Positions are provided for experiment housekeeping and science data display. In general, a two position console is provided for each major instrument. However, the number of consoles provided is no larger than the maximum number of instruments that can operate at once. In many cases each position will serve more than one instrument as the operational sequence dictates.
- Separate commanding positions are provided for all instruments that operate simultaneously.

POCC INFORMATION DISPLAY AND COMMUNICATIONS REQUIREMENT

	COMBINED ASTRONOMY			LIFE SCIENCES			MULTI-APPLICATIONS			AMPS			ATL			FIRST MISSION		
	①	②	③															
CRT DISPLAY POSITIONS																		
MCC PROVIDED DATA	2	2	3	2	2	3	2	2	3	2	2	3	2	2	3	2	2	3
POC PROVIDED DATA	2	4	5	2	2	4	1	3	6	2	6	12	1	3	7	2	2	4
TOTAL	4	6	8	4	4	7	3	5	9	4	8	15	3	5	10	4	4	7
DAILY DISPLAYS		1			1			3			3			3			2	
ONE-TIME DISPLAYS		2			0			0			3			1			3	
COMMAND POSITIONS	0	1	4		0			0		0	1	6		0			0	
SPECIAL COMMUNICATIONS		-			-		GROUND TRUTH OPERATIONS			GROUND OBSERVERS			GROUND TRUTH OPERATIONS					

① Assistance Only

② Minimum Command

③ Full Control

POCC INFORMATION DISPLAY AND COMMUNICATIONS REQUIREMENTS

The facing page summarizes the information display and communication requirements of the POCC's as dictated by required discipline information aids and by the levels of autonomy that might be allowed to the crew.

SCIENTIFIC COMMUNITIES' ATTITUDES TOWARD CREW AUTONOMY

- COMBINED ASTRONOMY
  - STRONGLY INTERESTED IN REAL-TIME ASSESSMENT OF SCIENCE RESULTS. WOULD LIKE TO COMMAND INSTRUMENTS
- LIFE SCIENCES
  - VERY INTERESTED IN REAL-TIME COMMUNICATION WITH CREW TO HELP IN PLANNING PROCEDURES
- MULTI-APPLICATIONS
  - MANY INVESTIGATORS WILL USE THE DATA IN DIFFERENT WAYS AND ARE ACCUSTOMED TO HAVING DATA TAKEN FOR THEM FOR LATER ANALYSIS
- AMPS
  - LEAN TOWARD CREW AUTONOMY. (HOWEVER, COMPLEX NATURE OF THE MISSION WILL MAKE GROUND ASSISTANCE NECESSARY.)
- ATL
  - NO EVIDENCE OF A DESIRE TO INFLUENCE FLIGHT PLANNING IN REAL TIME

SCIENTIFIC COMMUNITIES' ATTITUDES TOWARD CREW AUTONOMY

Discussions were held with key personnel in NASA Headquarters experiment sponsoring offices and with knowledgeable Field Center personnel regarding the attitudes of current Principal Investigators toward allowing autonomy to the flight crews. The results of these discussions were reinforced by examination of the planned experiment designs as evidenced in the Level A and B sheets.

It is recognized that individual investigators may differ from these community attitudes. Additionally, there is reason to believe that community attitudes will change as experience is gained in Spacelab operations. However, the present P.I. communities do have dominant attitudes and they differ from discipline to discipline as shown on the facing page.

Initial POCC planning should be based on these attitudes except when they demand extremes in equipment or manpower for the POCC.

MOST LIKELY POCC

	COMBINED ASTRONOMY	LIFE SCIENCES	MULTI-APPLICATIONS	AMPS	ATL	FIRST MISSION
	① ② ③					
CRT DISPLAY POSITIONS						
MCC PROVIDED DATA	2 2 3	2 2 3	2 2 3	2 2 3	2 2 3	2 2 3
POC PROVIDED DATA	2 4 5	2 2 4	1 3 6	2 6 12	1 3 7	2 2 4
TOTAL	4 6 8	4 4 7	3 5 9	4 8 15	3 5 10	4 4 7
DAILY DISPLAYS	1	1	3	3	3	2
ONE-TIME DISPLAYS	2	0	0	3	1	3
COMMAND POSITIONS	0 1 4	0	0	0 1 6	0	0
SPECIAL COMMUNICATIONS	-	-	GROUND TRUTH OPERATIONS	GROUND OBSERVERS	GROUND TRUTH OPERATIONS	

① Assistance Only

② Minimum Command

③ Full Control

MOST LIKELY POCC'S

The facing page shows the most likely POCC size that will accommodate the present investigator attitudes discussed on the previous page.

- PAYLOAD OPERATIONS REQUIREMENTS
  - DISPLAY AND COMMUNICATIONS REQUIREMENTS
    - DATA HANDLING REQUIREMENTS
      - POC EQUIPMENT ESTIMATES
        - POC REQUIREMENTS BY TRAFFIC MODEL
          - POC MANPOWER ESTIMATES

INSTRUMENT DATA CHARACTERISTICS

	INSTRUMENTS	NATURE OF DATA	HOUSEKEEPING DATA RATE (KBPS)	MAX. SCIENCE DATA RATE (KBPS)
COMBINED ASTRONOMY	AS-01 I.R. TELESCOPE AS-03 U.V. SURVEY TELESCOPE AS-04 1 M U.V./OPTICAL TELESCOPE AS-05 GALACTIC CAMERA	- 2 TELESCOPES AND CAMERA RECORD ON FILM - 1 (IR) TELESCOPE HAS 6 DETECTOR GROUPS, EACH GROUP USED SEPARATELY - EACH INSTRUMENT HAS A FIELD TELESCOPE FOR POINTING, USING T.V. AT ABOUT 2 KBPS DATA RATE	11	31.8
LIFE SCIENCES	CORE RASE	- THREE T.V. CAMERAS USED CONTINUOUSLY, BUT TRANSMITTED SEQUENTIALLY - SOME MEDICAL DATA REQUIRES SPECIAL DATA REDUCTION PROGRAMS	14	163
MULTI-APPLICATIONS	SP 31 BIOLOGICAL PROCESSING AND FURNACE WITH CORE CN 04 ELECTROMAGNETIC ENVIRONMENT. LINEAR ARRAY ANTENNA, VARIOUS MONOPULSE RECEIVERS, DATA PROCESSOR CN 08 OPEN TWT WITH DRIVERS, MASS SPECTROMETER OP 03 ARRAY ANTENNA, 5 RECEIVERS, 2 POLARIZERS OP 09 LASER RETROFLECTOR EO 20 IMAGING RADAR	- SP 31 HOUSEKEEPING DATA ONLY -- 2.5 KBPS - CN 04 HK 0.35 KBPS, SCIENCE 15 MBPS, STORED IN EXPERIMENT AND RETRANSMITTED BY EXPERIMENT - CN 08 0.56 KBS (0.07 HK, 0.49 SCIENCE) - OP 03 1.55 KBPS HK, 4 KBPS SCIENCE - OP 09 PASSIVE - EO 20 2 KBPS HK, 400 MBPS SCIENCE, STORED ONBOARD BY DEDICATED RECORDER	6.47	4.49
AMPS	REMOTE SENSING PLATFORM SYSTEM LIDAR SYSTEM ACCELERATOR SYSTEM TRANSMITTER COUPLER SYSTEM BOOM SYSTEM DEPLOYABLE UNIT SYSTEM DEPLOYABLE SATELLITE SYSTEM	WAVE CHARACTERISTICS -- 1.308 MBPS WAVE PARTICLE INTERACTION -- 1.635 MBPS WAVE AND SHEATH EXPERIMENTS -- 1.309 MBPS PROPULSION AND DEVICES -- 1.642 MBPS GLOBAL EMISSION SURVEY -- 1.577 MBPS ENERGETIC PARTICLE STABILITY -- 2.238 MBPS MAGNETOSPHERIC TOPOLOGY -- 1.654 MBPS PLASMA DYNAMICS -- 1.655 MBPS	13	2700
ATL	ST-08 IRT CONTAMINATION MONITOR ST-43 HOLOGRAPHIC IMAGING SYSTEM ST-45 UV SPECTROMETER-PHOTOMULTIPLIER ST-46 SAMPLE ARRAYS ON BOOM ST-47 STEAM GENERATOR ST-52 T.V., SIDELOOKING RADAR, DATA INTERFACING ST-54 REFRIG., INCUBATOR, CAMERA ST-55 REFRIG., INCUBATOR, CAMERA ST-57 REFRIG., INCUBATOR, CAMERA CN-12 INTERFEROMETER ANTENNAS, RECEIVER, RECORDER, DISPLAY EO-7 LIDAR TRANSMITTER, PHOTOMULTIPLIERS, SIGNAL PROCESSOR, CAMERA MB-54 REFRIG., INCUBATOR, CAMERA	SCIENCE DATA (KBPS) ST-08 97 ST-43 6 (STORED) ST-45 FILM ST-46 SAMPLES ST-47 LOGS ST-52 50,000 (DUMPED) ST-54 FILM ST-55 FILM ST-57 FILM CN-12 1000 (TAPE) EO-7 2000 (DUMP) MB-54 FILM	11	97

INSTRUMENT DATA CHARACTERISTICS

In order to determine the data handling requirements of the POC, the instrument complements of the reference missions were examined. The facing page summarizes the projected data rates for both experiment housekeeping data and scientific data. Additionally, some characteristics of the instruments are listed as they affect the nature and quantity of data to be produced.

DATA HANDLING CONSIDERATIONS

- MAXIMUM PAYLOAD DATA RATE TO JSC(MCC) IS 1.344 MEGABITS PER SECOND WITHOUT DOMSAT TERMINAL
- ALL PAYLOADS STUDIED CAN BE ACCOMMODATED WITHIN THIS DATA RATE EXCEPT AMPS AND SOLAR PHYSICS
- HIGH DATA RATE SCIENCE DATA IS NOT NEEDED FOR REAL TIME CONTROL OR PLANNING
- SAMPLING OF THE SCIENCE DATA ON-BOARD COULD RELIEVE MANY ELEMENTS OF THE SYSTEM FROM THE HIGH RATE DATA HANDLING REQUIREMENTS

DATA HANDLING CONSIDERATIONS

There are several considerations regarding handling of the expected data flow that strongly influence planning for POC facilities.

1. The nominal maximum data rate that can be transferred through NASCOM in circuits is 1. 344 megabits per second. Presently this rate applies to data transmission from the STADAN network or from the TDRSS terminal. Although there are discussions about ways to increase this transmission rate, a significant increase in the rate could be achieved only by transmission from the TDRSS terminal through a Domestic satellite link directly to JSC.

2. All payloads that were studied have total science and housekeeping data rates well below 1. 344 mbps with the exception of AMPS (2. 7 mbps) and Solar Physics (1. 32 mbps).

3. Although there are a number of instruments that generate data at very high rates, there is no practical way to present these data in realtime so that their totality can be considered by the investigators. Moreover, examination of the instruments and the type of data to be produced indicates that none of the projected investigations are concerned with statistical aspects of the high rate data.

4. In order to present high rate data to the investigators in the POCC, it will be necessary to either bring the data stream to the POC for appropriate sampling or perform this action onboard the spacecraft. Onboard sampling can reduce the rate so that it can be easily handled by existing communication equipment. In contrast data rates in the range of tens of megabits per second have been discussed. Several elements of the communications network will require technological development work to assure accurate operation at these rates.

SCIENCE DATA SAMPLING

- BEFORE DOMSAT A SUBSET OF AMPS (AND SOLAR PHYSICS) DATA MUST BE SELECTED ON-BOARD IF POCC IS TO HAVE SCIENCE DATA IN NEAR REAL TIME
- OTHER INSTRUMENTS GENERATE DATA WELL ABOVE 1 MBPS BUT PLAN DUMPING OR ON-BOARD STORAGE. INSTRUMENT MODIFICATIONS AND SNAP SHOT PROCESSING WOULD BE REQUIRED TO GET SCIENCE DATA TO THE POCC
- PAYLOAD DEVELOPERS SHOULD CONSIDER THE COST EFFECTIVENESS OF SAMPLING DATA ON-BOARD VERSUS IN THE POCC

TAKE SNAP SHOTS ON-BOARD SPACELAB

PRO	CON
• REDUCES GROUND DATA HANDLING REQUIREMENTS	• GIVES THE POCC IN REAL TIME ONLY WHAT COULD BE SEEN ON-BOARD
• REDUCES SEARCH TIME FOR DESIRED DATA	• INCREASES PAYLOAD COSTS

SCIENCE DATA SAMPLING

Before a DOMSAT transmission link is established from the TDRSS terminal to JSC, high data rate experiments, such as those on AMPS and Solar Physics, must be sampled onboard the spacecraft if science data is to be available to the investigators in the POCC.

Additionally, a number of other instruments generate very high data rates. These are predominantly of an earth sensing, scanning nature. Although these latter instruments do not plan to make science data available to the crew or to the POCC during the flight, frequently there is evidence of instrument malfunction in the science data that is not evident in the housekeeping data. Experience has shown that sampling of science data to assess instrument condition can be very helpful in assuring maximum scientific accomplishment during the mission.

Because of the communication system implications of transmitting very high data rates from the Orbiter to the POCC, each payload developer should consider the concept of onboard sampling of science data. One method for forcing this consideration would be to establish programmatic responsibility for the development and installation of the high data rate communications system.

The bringing of high rate data to the POCC can be very expensive. Additionally, the precise time for sampling of desired data can be most effectively established onboard. These facts are countered by increased payload costs and by restriction in the amount of data available in the POC for investigator consideration.

- PAYLOAD OPERATIONS REQUIREMENTS
  - DISPLAY AND COMMUNICATIONS REQUIREMENTS
    - DATA HANDLING REQUIREMENTS
      - **POC EQUIPMENT ESTIMATES**
        - POC REQUIREMENTS BY TRAFFIC MODEL
          - POC MANPOWER ESTIMATES

ASPECTS OF A MINIMUM POC

- MAJOR JOB OF THE POC EQUIPMENT IS PRESENTATION OF EXPERIMENT HOUSEKEEPING AND SCIENCE DATA TOGETHER WITH APPROPRIATE SPACECRAFT STATUS DATA

- ONLY REAL TIME ACTION REQUIRED OF THE POC IS COMMANDING OF INSTRUMENTS

- POC NEED NOT HANDLE AND PRESENT WIDE BAND PAYLOAD DATA IN REAL TIME

ASPECTS OF A MINIMUM POC

In order to minimize the hardware (and software) in a POC it is necessary to limit the functions that it will perform. If an attempt is made to satisfy all stated and implied requirements a very sophisticated system would evolve.

The basic job of the POC is to present sufficient data to payload personnel so that they can assist in optimizing the scientific observations. Except for the commanding of instruments, little can be done by the POC in real time. Most of the decisions in the POC will have a time scale on the order of hours as contrasted to the short time scale of safety related decisions. This aspect, in relieving much POC equipment from the necessity of having to operate in real time, effects a considerable simplification in the computational and display components.

EQUIPMENT REQUIREMENTS

- FRONT END PROCESSOR

  FUNCTION: BIT SYNC, DECOMMUTATE, POSITION AND TIME CORRELATE DATA ROUTE TO STORAGE

  CAPABILITY: PRE-DOMSAT, UP TO NASCOM LINE DATA RATE (1.34 MBPS)
  WITH-DOMSAT, AS REQUIRED BY SCIENCE (2 TO 3 MBPS)

- DATA STORAGE

  FUNCTION: HOLD DATA FOR ACCESS BY POC COMPUTER SYSTEM

  CAPABILITY: TAPE MAJOR PORTIONS OF DATA STREAM
  QUICK ACCESS (DISK) STORAGE OF WORKING DATA (1 TO 2 M BYTES)

- COMPUTER SYSTEM

  FUNCTION: ACCESS DATA FROM POC STORAGE AND FROM MCC, DEVELOP DISPLAYS, SIMPLE SCIENTIFIC CALCULATIONS, GENERATE COMMAND LOADS, INTERRUPT/PRIORITIZE

  CAPABILITY: NOT REAL TIME, FORTRAN COMPATIBLE, ACCESS FROM THREE SOURCES, INTERROGATED BY UP TO 10 PERIPHERALS

- CONSOLES

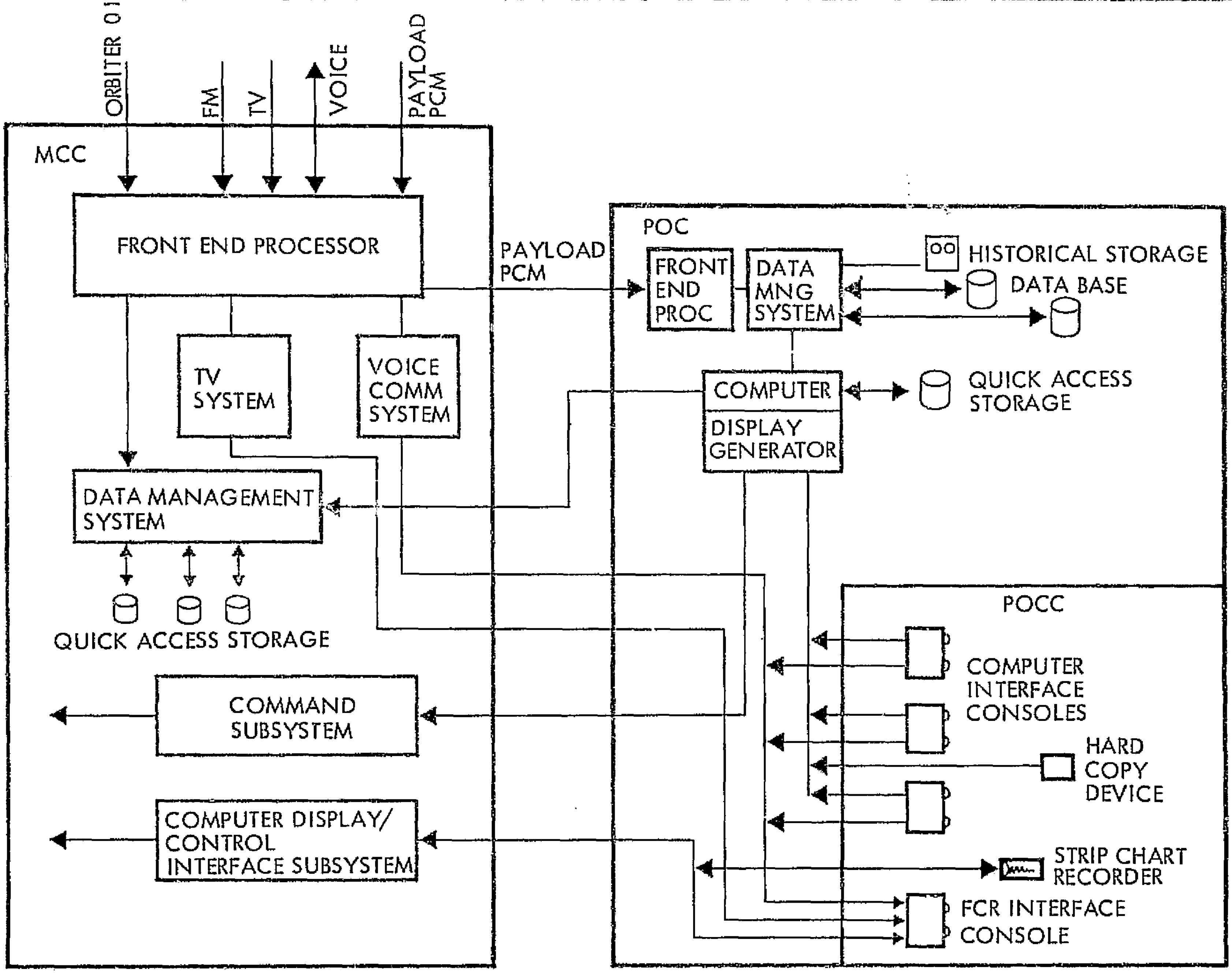
  FUNCTION: REQUEST AND DISPLAY DATA, TRANSFER COMMANDS

  CAPABILITY: NO SOFTWARE, ALPHA/NUMERIC-DISPLAY/ENTRY, GRAPHICS, SYMBOL GENERATOR, DISPLAY REFRESHMENT, PARTIAL DISPLAY UPDATE

EQUIPMENT REQUIREMENTS

The facing page lists the salient features of each POC equipment group. These features were evolved by balancing the capabilities of a number of types of equipment against the various requirements imposed on the POC's.

GENERALIZED POC SCHEMATIC



GENERALIZED POC SCHEMATIC

It is assumed that: (a) payload PCM data will be routed to the POC by the MCC directly as received, (b) any payload data that is interleaved with Orbiter instrumentation data will be stored in the MCC data base and is accessible by the POC computer, and (c) the POC can directly access Orbiter and Spacelab systems data and trajectory information in MCC format.

The POC will provide for historical storage of all payload data; for formatting and display of these data as requested by investigators; for formatting of commands to the payload; for voice communication with the Spacelab; and for display of Spacelab T. V.

The POCC consoles will be selected to interface with the POC computer and display generator. It would be advantageous if they had similar characteristics to those in the FCR so that all consoles could access Orbiter data. If this is not practical a special FCR type console will have to be provided.

The number of consoles and other peripherals to be used can be adjusted, over a reasonable range, as demanded by the particular flight.

REPRESENTATIVE POC EQUIPMENT

- COMMERCIAL EQUIPMENT ESTIMATES

FUNCTION	EQUIPMENT	ESTIMATED COST (1000)	NUMBER REQUIRED	SYSTEM COST (1000)
FRONT END PROCESSOR 1 MBS	COMM. PROCESSOR DATA MANAGER 100 MBYTE DISK TAPE RECORDER	20 70 30 30	1 1 2 2	210
FRONT END PROCESSOR 3 MBPS	PROCESSOR DATA MANAGER LARGE DISKS DISK CONTROLLER TAPE RECORDER	 70 30	1 1 2 1 2	810
GENERAL PROCESSOR	PDP 11/70 ECLIPSE 200	70	1	70
DISPLAY GENERATOR	PDP 11/70 ECLIPSE 200	70	1	70
CONSOLE	RAMTEC GX100 DISPLAY COMMUNICATION	25	X	X
ANCILLARY EQUIPMENT	HARD COPY STRIP CHART RECORDER	10 10	1 1	20
SUPPORT EQUIPMENT	TAPE READER CARD READER		1	30

REPRESENTATIVE POC EQUIPMENT

The tables on the facing page present types of commercially available equipment that can fulfill the required functions. In some instances specific equipment is mentioned. In others a price is stated which covers a range of equipments that are considered adequate to do the job.

The equipment selection was done by TRW personnel who are actively engaged in the design of data handling systems. However, the study was performed only to the depth that would develop a general understanding of the equipment needed to perform the functions. Actual design of a POC and sizing of the components will require an in-depth analysis of the nature of the data and its flow rates.

- FRONT END PROCESSOR AND DATA BASE

  1) OPERATE ONLY DURING FLIGHT. AT MAXIMUM FLIGHT RATE THEY OPERATE ABOUT 12 MONTHS PER YEAR

  2) AT MAXIMUM FLIGHT RATE TWO SPACELABS WOULD BE IN-FLIGHT SIMULTANEOUSLY FOR ABOUT 3 MONTHS OUT OF A YEAR

  3) TWO SETS REQUIRED FOR THE MAXIMUM TRAFFIC RATE. THERE IS TIME FOR MAINTENANCE AND SOFTWARE INSTALLATION

  ∴ THIS EQUIPMENT SHOULD BE CENTRALIZED TO HANDLE ALL POCC'S. CAN BE BOUGHT IN TWO INCREMENTS

- DISPLAY COMPUTER AND PERIPHERALS

  1) REQUIRED FOR TRAINING AND SIMULATIONS AS WELL AS FLIGHT

  2) COMPUTER HAS THE MAJOR SOFTWARE CHANGES FROM FLIGHT TO FLIGHT

  3) COMPUTER COULD BE CENTRALIZED OR ONE PER POCC

  4) TOTAL COST WOULD BE ROUGHLY COMPARABLE

  5) CENTRALIZED COMPUTER NEEDS TO BE SIZED FOR MAXIMUM EXPECTED TRAFFIC

  6) DEDICATED COMPUTERS CAN BE BOUGHT AS NEEDED

  ∴ DEDICATE COMPUTERS TO POCC'S. PURCHASE AS TRAFFIC DEVELOPS

CENTRALIZED VERSUS DECENTRALIZED EQUIPMENT

A question that should always be examined is whether it is more advantageous to provide a large centralized data handling facility or a group of smaller facilities keyed to the demand.

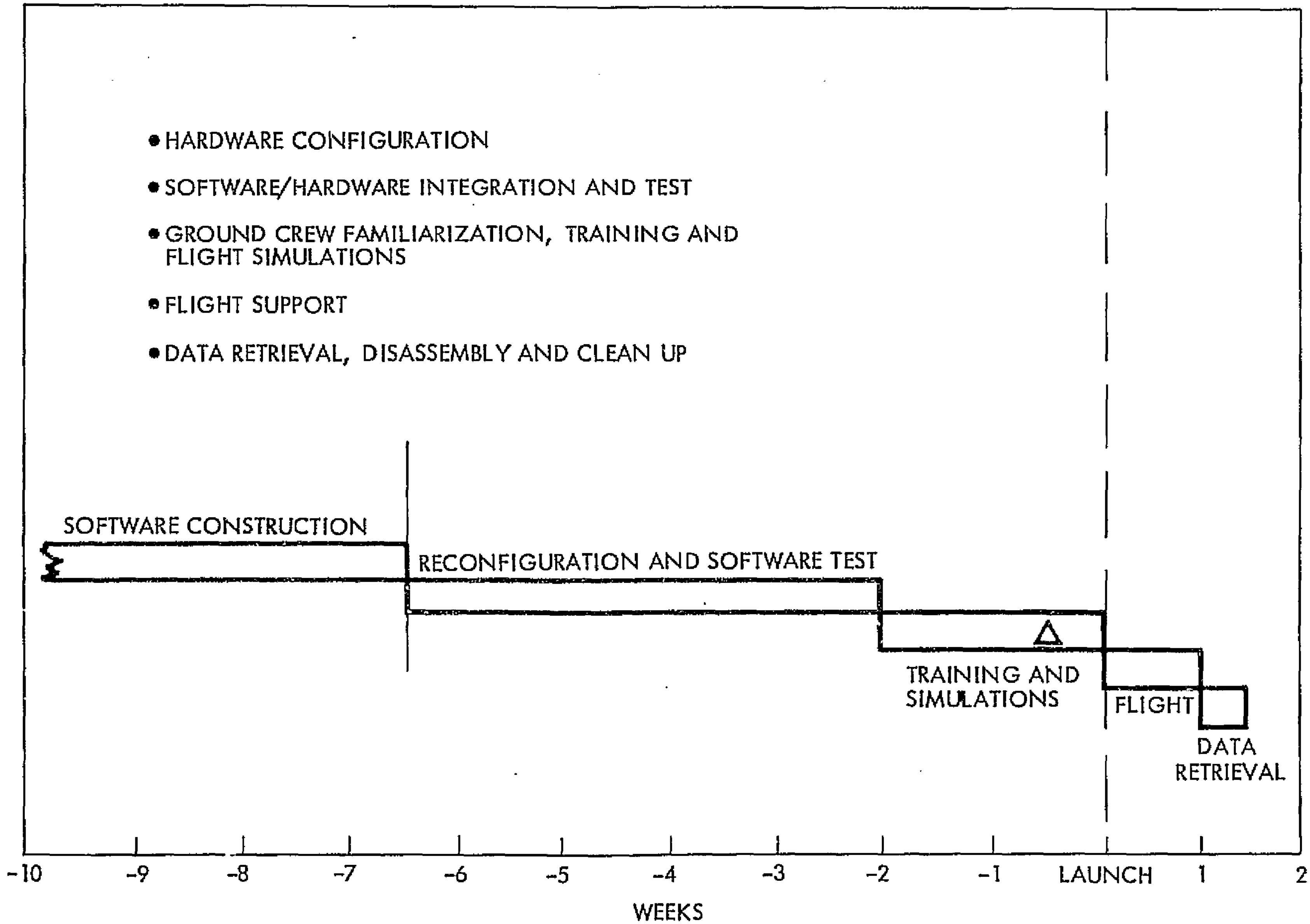
The front end processor and data base operate for only about twelve months per year at the 29 per year rate (Traffic Model TM-1). Therefore, one set of equipment should, nominally, be able to handle the traffic. However, unless adequate ground handling facilities are provided to accommodate to variable launch timing, the occurrence of six 30-day flights in the traffic model means that there will be two Spacelabs in orbit simultaneously for about 3 months of the year. Thus, two sets are required at higher flight rates. As there are more than two POCC's needed at these rates, it would be more economical to have this equipment centralized to service all POCC's.

The computer system could also be centralized or distributed. However, these elements together with the peripherals are used for POCC personnel training. Additionally, the major software changes from flight to flight will be in this computational system.

In a first order estimate, one could assume that the total cost for computational equipment will be about the same whether it is centralized or distributed. However, the centralized computer system must be sized, at the outset, for the maximum expected traffic. Because the ultimate traffic to be accommodated is not known at this time, and because a centralized system imposes high early costs, it is concluded that the computers should be dedicated to POCC's. Additional ones can be purchased as the traffic rate dictates.

- PAYLOAD OPERATIONS REQUIREMENTS
    - DISPLAY AND COMMUNICATIONS REQUIREMENTS
        - DATA HANDLING REQUIREMENTS
            - POC EQUIPMENT ESTIMATES
                - POC REQUIREMENTS BY TRAFFIC MODEL
                    - POC MANPOWER ESTIMATES

POC TURNAROUND TIME



POC TURNAROUND TIME

Software is constructed on lead center institutional computers using programs that emulate the POC computer.

For mature operations, when the emulation programs have been proven, it is estimated that installation and test of the software in the POC will take about one month. This time will vary with the complexity of the flight. In all cases however, the payload software will change from flight to flight and must be tested in the POC environment.

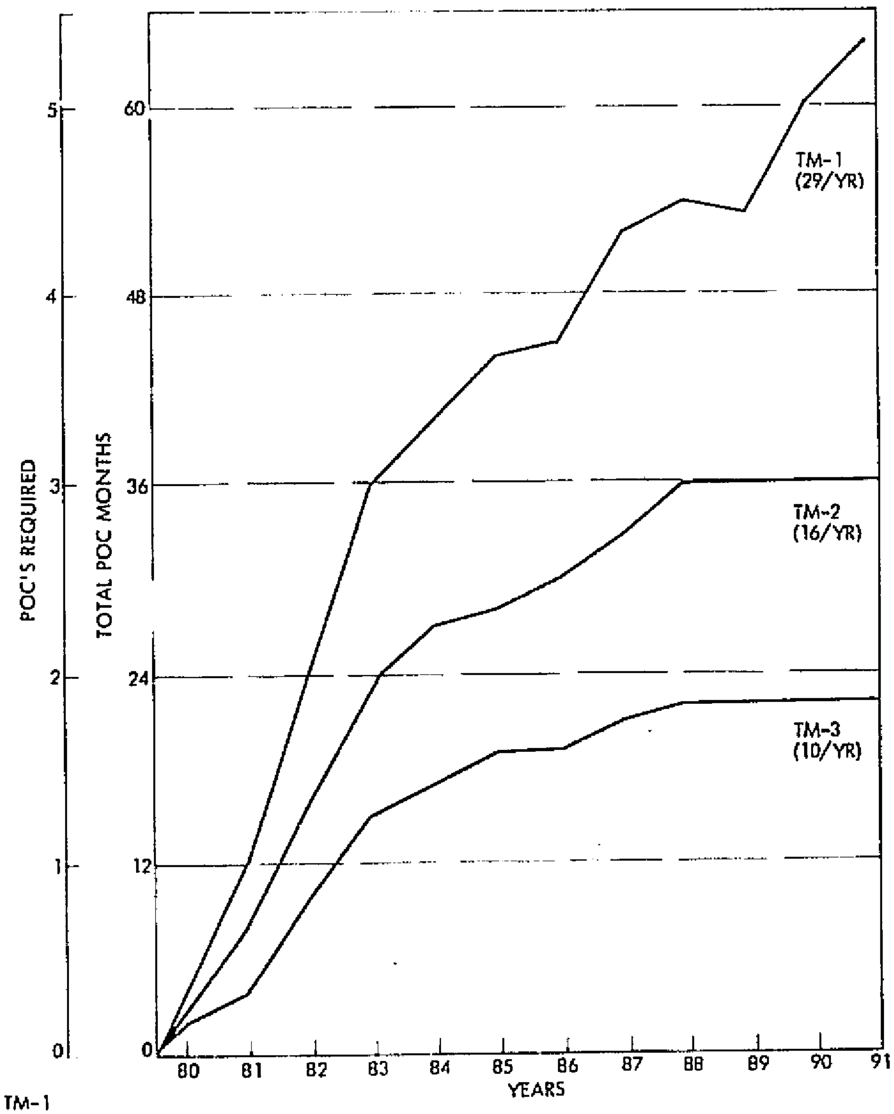
It is further estimated that about two weeks should be allocated to training of the POC team and in integrated simulations with the STS flight control team. Equipment and software used in this training should be identical to those to be used during flight.

It can be demonstrated that use of facilities separate from the POC for software testing and POC team training will not effect a significant overall saving in equipment.

Overall, the POC will be in use for 50 to 60 days for each seven day flight and for 75 to 85 days during a 30 day flight.

The remainder of this analysis will assume use of the POC's for the software and training functions and hence a 60-day turnaround for POC's (7 day flights).

SPACELAB GROUND CONTROL FACILITY REQUIREMENTS
(60-DAY TURNAROUND)



TM-1

7 DAY FLIGHTS	2	6	12	15	17	19	18	20	18	19	21	23
30 DAY FLIGHTS				2	2	2	3	4	6	5	6	6

SPACELAB GROUND CONTROL FACILITY REQUIREMENTS

Each of the traffic models have specific numbers of 7-day and 30-day flights. This dictates that POC facilities are needed for total numbers of months, depending on the length of time that a POC is used.

In the facing chart, these numbers are plotted against time for each traffic model. It uses the assumption that a POC is occupied for 60 days for a 7-day flight, and for 90 days for a 30-day flight.

NUMBER OF POC'S NEEDED – 60 DAY TURNAROUND

YEAR		80	81	82	83	84	85	86	87	88	89	90	91
TM-1	29/YEAR	1		2	3	4			5				→
TM-2	16/YEAR	1		2		3							→
TM-3	10/YEAR	1			2								→

NUMBERS OF POC'S NEEDED

Based on the previous chart, the facing page shows the number of POC's needed as a function of time and traffic model. It should be noted that the maximum rate traffic model (TM-1), in 1991 requires 64 months of POC occupancy. This would call for one more POC than the 5 listed. Because no attempt has been made to determine the relationship between turn-around time and flight discipline, this is considered within the precision of the study.

TOTAL POC EQUIPMENT REQUIREMENTS

- BASED ON 60 DAY POCC TURN AROUND AND MOST LIKELY POCC'S

CY	80	81	82	83	84	85	86	87	88	89	90	91
FRONT END AND DATA BASE												
(1) TM-1	2			4								4
TM-2	2				4							4
TM-3	2											2
ANICLLARY EQUIPMENT												
(2) TM-1	1		2	3	4			5				5
TM-2	1		2		3							3
TM-3	1			2								2
OPERATOR CONSOLES												
(3) TM-1	9		16	25	32			39				39
TM-2	9		16		25							25
TM-3	9			16								16
POCC COMPUTERS												
TM-1	2		4	6	8			10				10
TM-2	2		4		6							6
TM-3	2			4								4

(1) REDUNDANT SETS - ALSO INCLUDES SOFTWARE INSTALLATION AND TEST EQUIPMENT

(2) HARD COPY DEVICE, STRIP CHART RECORDER

(3) ASSUMING SIMILAR CONSOLES TO THOSE IN THE FCR'S

TOTAL POC EQUIPMENT REQUIREMENTS

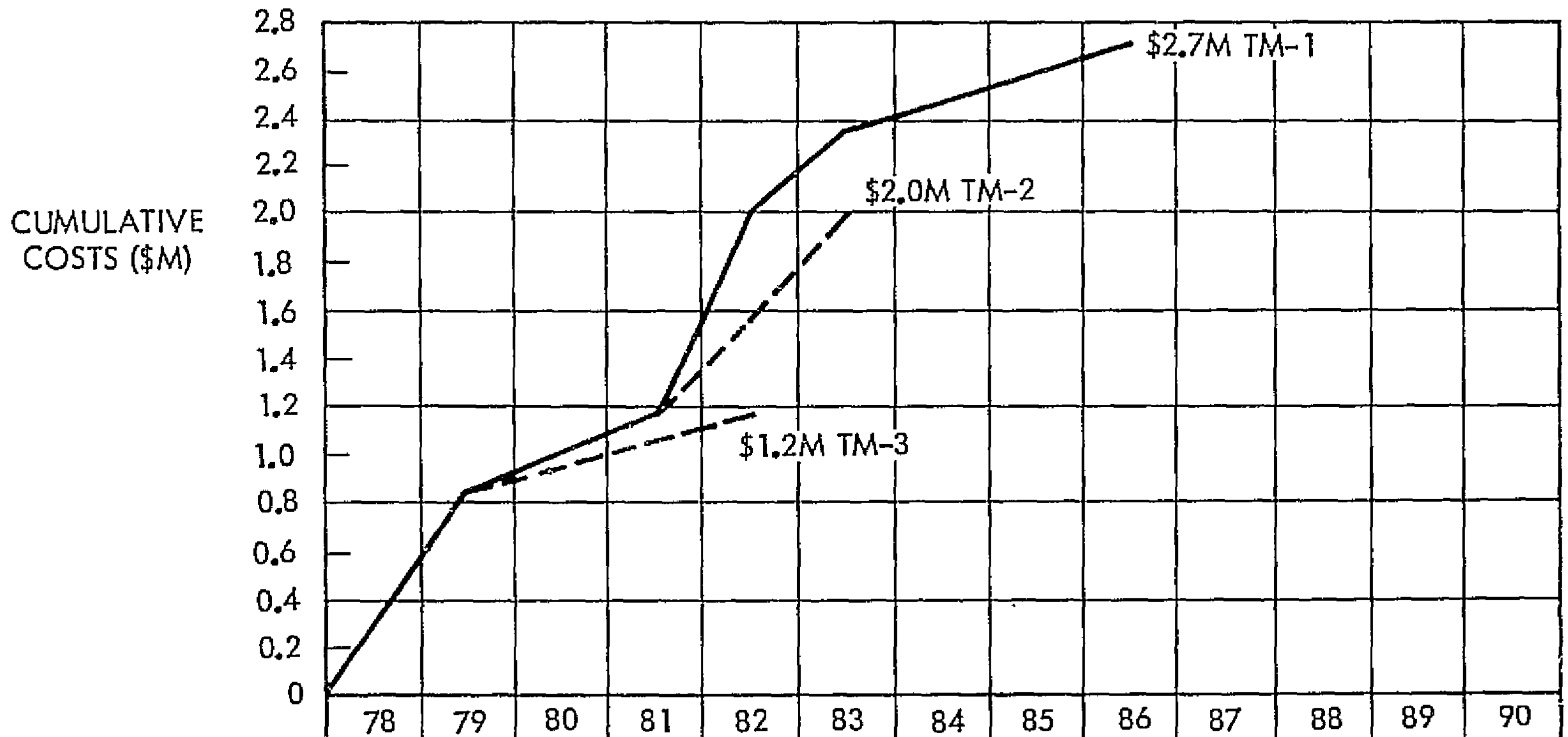
The facing chart shows total numbers of each type of POC equipment by year as a function of the traffic models. This is based on the previously determined numbers of POC's needed and partially on the equipment requirements of the most likely POCC's.

In analyzing the most likely POCC's, it can be seen that only one discipline (Life Sciences) would use the minimum sized POCC. Because of this, all POCC's were considered to be either Minimum Command size or Full Control size. The latter was used for all astronomy, hi-energy physics, and solar physics payloads.

Because there is a difference in the number of consoles needed between disciplines for either size of POCC, the number used was 7 for Minimum Command and 9 for Full Control. This should be conservative enough to provide sufficient peripheral equipment so that POCC's can be tailored to the specific requirements of each flight.

POC CUMULATIVE EQUIPMENT COSTS

- 1 MBPS FRONT END AND DATA BASE
- MOST LIKELY POCC's



YEARLY COSTS $M

	78	79	80	81	82	83	84	85	86	87	88	89	90
TM - 1	0.3	0.6		0.4	0.8	0.3			0.3				2.7
TM - 2	0.3	0.6		0.3		0.8							2.0
TM - 3	0.3	0.6			0.3								1.2

POC CUMULATIVE EQUIPMENT COSTS

Based on the previously shown equipment requirements and cost estimates, the facing page shows total and time phased equipment costs.

These costs are based on use of the ≈1 megabit per second front end processor.

TOTAL POC EQUIPMENT COSTS - THRU 1991
(DOLLARS IN MILLIONS)

TRAFFIC MODEL	MAX. NOS.	MCC PROVIDED FRONT END AND DATA BASE	POC PROVIDED ≈ 1 MBPS FRONT END	POC PROVIDED ≈ 3 MBPS FRONT END
TM - 1	(29)	1.8	2.7	5.1
TM - 2	(16)	1.2	2.0	4.4
TML -3	(10)	0.8	1.2	2.4

TOTAL POC EQUIPMENT COSTS - THROUGH 1991

The facing page shows the total cost for POC equipment for the three traffic models through 1991.

This chart demonstrates the sensitivity of total costs to the cost of the Front End Processor. Three instances are shown:

1) With the JSC MCC providing front end processing and data storage for the POC, no attempt was made to estimate the cost of augmenting the MCC to provide this service.
2) With a ≈1 megabit per second front end in the POC.
3) With a 2 to 3 megabit per second front end in the POC.

No attempt was made to develop costs for a front end processor that would operate at higher data rates because it is believed that this will require new technology development.

POC EQUIPMENT CONCLUSIONS

- BETWEEN 2 AND 5 POC'S ARE REQUIRED DEPENDING ON TRAFFIC MODEL
- THE MAJOR COST DRIVER IS THE FRONT END PROCESSOR AND DATA BASE
- SCIENCE DATA RATE DICTATES THIS ELEMENT, COULD BE ALLEVIATED THROUGH PAYLOAD DESIGN
- SPACELAB POC'S COULD BE IMPLEMENTED WITH OFF-THE-SHELF HARDWARE, AT MODERATE COST

- PAYLOAD OPERATIONS REQUIREMENTS
  - DISPLAY AND COMMUNICATIONS REQUIREMENTS
    - DATA HANDLING REQUIREMENTS
      - POC EQUIPMENT ESTIMATES
        - POC REQUIREMENTS BY TRAFFICE MODEL
          - **POC MANPOWER ESTIMATES**

POC SOFTWARE DEVELOPMENT, TEST AND INTEGRATION MANPOWER ESTIMATES

SOFTWARE PROGRAM	SIZE		FIRST FLIGHT MANMONTHS	REFLIGHT MANMONTHS
	WORDS	INSTRUCTIONS		
SYSTEM SPECIFICATION	–	–	9	–
OPERATING SYSTEM	–	–	18	–
DATA STORAGE AND RETRIEVAL	100K	3.3K	24	–
DISPLAY GENERATOR • 40 FORMATS	100K	3.3K	24	3
DATA BASE STRUCTURING	–	–	18	9
MATH MODEL CONVERSION • AVG 8 EXPERIMENT SYSTEMS	(200K) 50K	1.7K	12	12
SPECIAL PLANNING PROGRAMS CONVERSION	–	–	6	6
INTEGRATION AND TEST	–	–	42	12
TOTAL SOFTWARE DEVELOPMENT			153	42

POC SOFTWARE DEVELOPMENT, TEST AND INTEGRATION MANPOWER ESTIMATES

The facing page shows the estimated manpower required to develop, test and integrate software to support experiment operations in the POC. The estimates are based on experience and a general understanding of the functions to be performed. The software requirements will vary from discipline to discipline and a much more detailed study would be required to make a more accurate estimate. Program word size estimates were made based on similar existing programs; these were then converted to instructions by an average of 30 words per instruction. Manmonths were then estimated using approximately $31/instruction and $50,000 man year as the conversion factors. The estimates for system specification and integration were based on the proportion of these efforts to total manpower from past software programs. For program conversion a "rule of thumb" of 1/4 the manpower of new code was used.

POC SOFTWARE DEVELOPMENT, TEST AND INTEGRATION MAN LOADING AND SCHEDULE

- FIRST PAYLOAD FLIGHTS

MONTHS BEFORE LAUNCH

SOFTWARE FUNCTION	48	36				24				12			LAUNCH	
GROUND SUPPORT REQUIREMENTS	━━━													• PART OF PRELIMINARY OPERATIONS PLAN
GROUND SUPPORT SYSTEM SPECS		1	2											
OPERATING SYSTEM														• MODIFICATIONS TO STANDARD OPERATING SYSTEM
DATA STORAGE AND RETRIEVAL														
DISPLAY														
SYSTEMS PROGRAM DEVELOPMENT														
OPERATING SYSTEM				4	2									
DATA STORAGE AND RETRIEVAL					2	2	2	2						
DISPLAY GENERATOR						2	2	2	2					
DATA BASE STRUCTURING									2	2	2			
DATA STRUCTURE														
DATA														
APPLICATIONS PROGRAM DEVELOPMENT														
PLANNING PROGRAMS														• SUPPLIED BY MCC
ENGINEERING MATH MODELS									2	1	1			• CONVERSION OF ENGINEERING S/W
SPECIAL PLANNING PROGRAMS										1	1			• CONVERSION OF FLIGHT PLANNING S/W
INTEGRATION AND TEST														
EMULATOR										2	2	5		
POC													5	
TOTAL MAN LOADING		1	2	4	4	4	4	4	6	6	6	5	5	

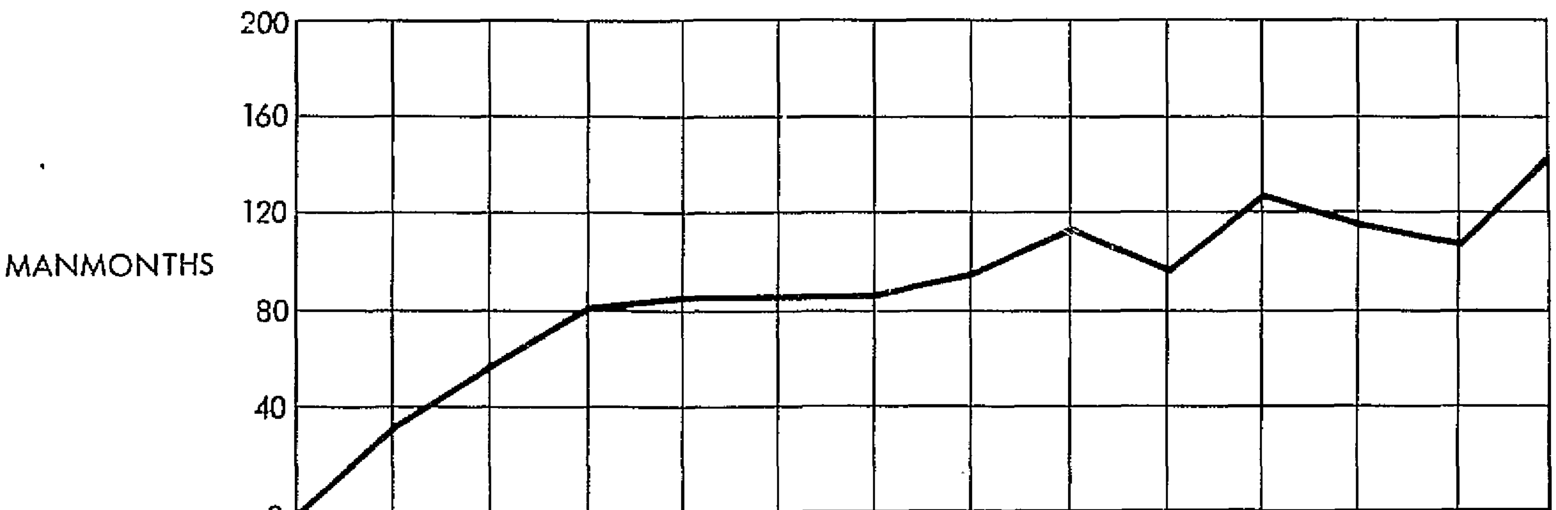
POC SOFTWARE DEVELOPMENT, TEST AND INTEGRATION MANLOADING AND SCHEDULE

An estimate of the dislribution of manpower is presented on the facing page. The distribution is based on the estimates of the previous chart, is presented by quarter and is in equivalent manpower.

MANPOWER ESTIMATES FOR POC SOFTWARE BY FLIGHT RATE

- 4 FLIGHTS PER YEAR (TM-3)

- 153 MANMONTHS FIRST FLIGHT
- 42 REFLIGHT



	78	70	80	81	82	83	84	85	86	87	88	89	90
MANMONTH ESTIMATE	33	54	80	84	84	84	96	114	96	126	114	108	144
EQUIVALENT MANPOWER	3	5	7	7	7	7	8	10	8	11	10	9	12

MANPOWER ESTIMATES FOR POC SOFTWARE BY FLIGHT RATE

The facing chart shows a typical manloading estimate for a lead payload center supporting a maximum of four flights per year (MSFC traffic for TM-3). The buildup of manpower is unique at each center depending on the traffic model and payload assignments.

LEAD CENTER POC SOFTWARE DEVELOPMENT MANPOWER ESTIMATES

- MANPOWER IN MAN YEARS
- 153 MANMONTHS FIRST FLIGHT
- 42 MANMONTHS REFLIGHT

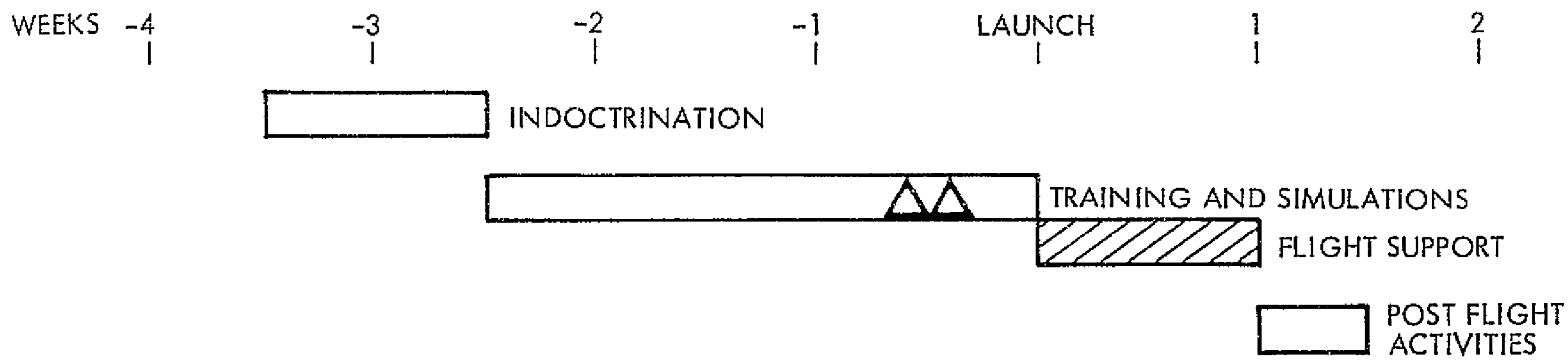
TRAFFIC MODEL		LEAD CENTER				
		MSFC	GSFC	LaRC	JSC	ARC
TM-1	(29)	290	185	132	73	69
TM-2	(16)	163	128	65	55	51
TM-3	(10)	107	100	41	41	34

LEAD CENTER POC SOFTWARE DEVELOPMENT MANPOWER ESTIMATES

Based on the data presented on the previous three charts, an estimate of the total equivalent manpower needs of each of the potential lead centers was made. This is shown on the facing page in man years by lead center and traffic model.

POC MANNING, TRAINING AND OPERATIONS

SCHEDULE



MANPOWER

	NO. NEEDED			SHIFTS	TOTAL NO. PEOPLE		
	AO	MC	FC		AO	MC	FC
PAYLOAD MANAGER	1	1	1	1	1	1	1
CHIEF SCIENTIST	1	1	1	2	2	2	2
PAYLOAD FLIGHT PLANNER	1	1	1	3	3	3	3
EXP DEVELOPMENT ENGINEER	1	3	4	3	3	9	12
PRINCIPAL INVESTIGATOR	1	3	4	3	3	9	12
EQUIPMENT SUPPORT	1	4	5	1	1	4	5
					13	28	35

AO = ASSISTANCE ONLY
MC = MINIMUM COMMAND
FC = FULL CONTROL

POC MANNING, FOR TRAINING AND OPERATIONS

In order to develop estimates of manpower requirements for the POC a scenario was generated that is illustrated on the facing page. It is estimated that about three weeks would be required for indoctrination and training so that the POCC team would be capable of operating effectively with the STS Operator and Crew in integrated simulations. This means that about 3-1/2 weeks would be required preflight.

At least a half week post flight should be provided for POC participants to investigate the nature of the recorded data and to establish with the MCC the type of Orbiter and Spacelab data needed for the scientific analyses. Thus, the participants are expected to be in residence 5 weeks for a 7-day flight and 8 weeks for a 30-day flight.

The payload manager should be in residence and have primary responsibility for payload operations.

Based on Apollo and Skylab experience, there should be a chief scientist who has responsibility for making decisions between investigators where there are conflicting demands on flight resources. He should be available for each days' activities planning and for preplanning strategy sessions. This could take as much as 16 hours each day.

There should be a payload flight planner in charge of each shift.

Experiment development engineers and investigators should be operating in the POC on all shifts. The number of these depends on the number required by the payload. For this analysis the numbers are matched to the number of consoles provided in the most likely POCC's.

Total numbers of personnel in-residence are listed as a function of the POCC size.

The equipment support personnel are required only for payload unique equipment. The operations and maintenance of other POC equipment can be best supplied by MCC personnel.

MANPOWER FOR TRAINING AND OPERATIONS

- MANNING REQUIREMENTS

  MINIMUM CONTROL POC-28 MEN FULL CONTROL POC-35 MEN

- MANNING DURATION

  7 DAY FLIGHT - 5 WEEKS 30 DAY FLIGHT - 8 WEEKS

- AVERAGE MANPOWER REQUIREMENT - ALL TRAFFIC MODELS

  40 MANMONTHS PER FLIGHT

MANPOWER FOR TRAINING AND OPERATIONS

Using the previous scenario it is estimated that POCC manning should be about 28 for a Minimum Control POCC and 35 for the Full Control POCC. They should be in residence for about 5 weeks for a 7-day flight and about 8 weeks for a 30-day flight.

With the most likely POC's proscribed, the manpower requirement averaged across each traffic model is about 40 manmonths per flight.

RESULTS

- FUNCTIONS PERFORMED IN REAL TIME VARY SIGNIFICANTLY WITH PAYLOAD DISCIPLINE
- TOTAL EQUIPMENT COSTS VARY FROM 1 TO 5 MILLION DEPENDING ON FLIGHT RATE AND AMOUNT OF DATA PROCESSING PROVIDED BY MCC
- AVERAGE MANPOWER ESTIMATE IS ≈145 MANMONTHS PER FLIGHT INCLUDING FLIGHT PLANNING (65), POC SOFTWARE (40) AND POC OPERATION (40)
- AS MANY AS FIVE POC FACILITIES ARE REQUIRED TO PROVIDE RECONFIGURATION, TRAINING AND REAL-TIME SUPPORT

RECOMMENDATIONS

- PLAN FOR A MODULAR POC, BASED ON THE USE OF MINI/MICRO PROCESSORS
- REVIEW THE REAL NEED FOR HIGH RATE SCIENCE DATA IN THE POC

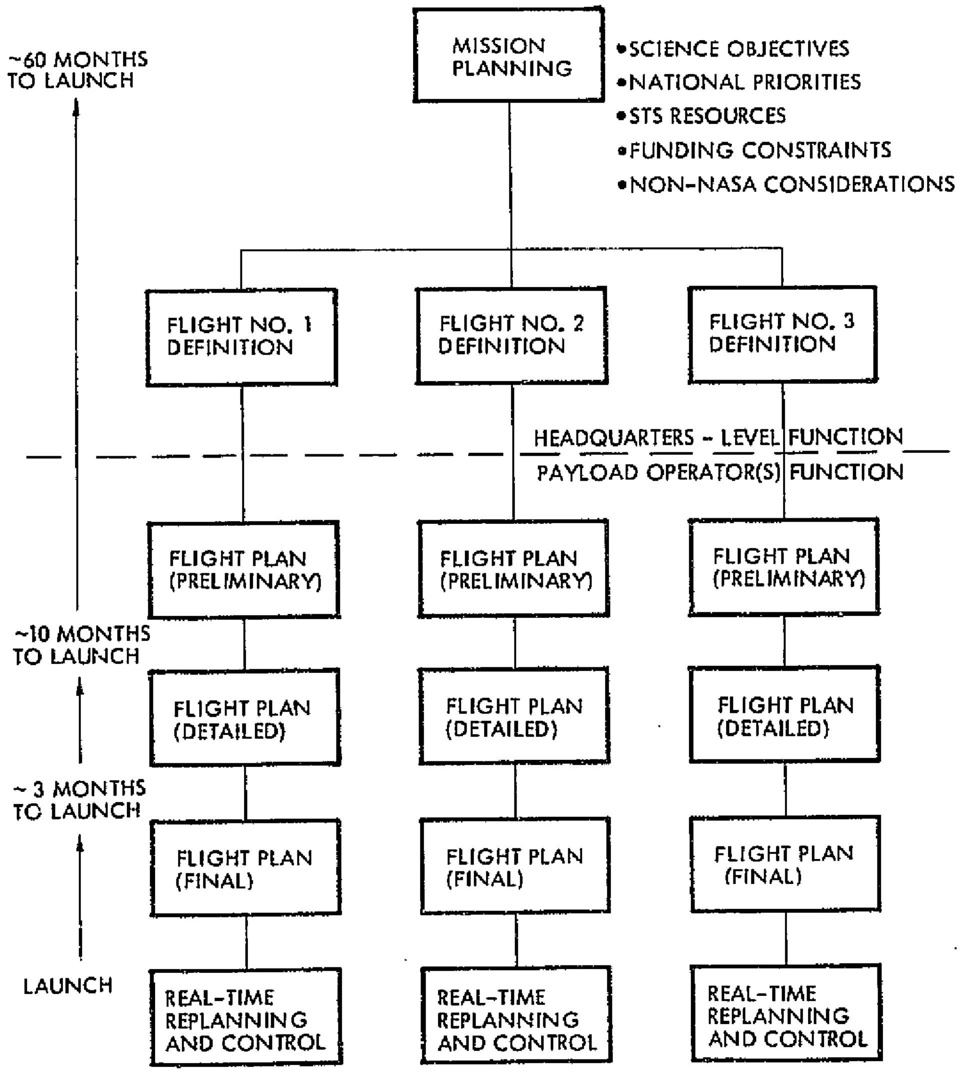
OBJECTIVE

IDENTIFY WAYS TO REDUCE COSTS OF EXPERIMENT
FLIGHT OPERATIONS AND PLANNING

OPERATIONS CONCEPTS THAT REDUCE MANPOWER

The objective of this study task is to develop concepts that will reduce NASA costs for Spacelab payload flight planning. Both recurring (e.g., manpower and computer time) and non-recurring (computer and software procurement) are to be considered, and a set of representative Spacelab payloads are to be used in the analysis. This section of the Cost Reduction Alternative Study (CRAS) report is devoted to pre-flight planning activities, beginning after identification of the payload and culminating at launch of the payload.

DEFINITION OF MISSION AND FLIGHT PLANNING



DEFINITION OF MISSION AND FLIGHT PLANNING

Mission planning and flight planning are defined as shown on the facing chart, for the purposes of the study. Mission planning is assumed to include definition of payloads in whatever number is needed to achieve a scientific objective, and is assumed to be a NASA/Headquarters - level function.

Payload flight planning is the preparation of all the payload-related analyses, procedures, and operational data necessary to perform a single flight of a Spacelab payload. As an example, this study is concerned with the planning to be performed by the Payload Operator for any one of the three flights that have been postulated on the facing chart.

The real-time Replanning and Control of the Spacelab payload, during the flight, is treated separately in this report.

FLIGHT PLANNING FUNCTIONS FOR EXPERIMENT OPERATIONS

FUNCTIONS	USES
1) IDENTIFY EXPERIMENT OPERATIONAL REQUIREMENTS	A) INSURE ACHIEVEMENT OF SCIENTIFIC OBJECTIVES
2) SELECT ORBITS, TRAJECTORIES AND SCHEDULES	B) MAXIMIZE EXPERIMENT SCIENCE RETURN
3) DEVELOP EXPERIMENT TIMELINES	C) IDENTIFY REQUIREMENTS FOR PAYLOAD SUPPORT (STS AND ANCILLARY AGENCIES)
4) PERFORM CONSUMABLES PLANNING	D) PROVIDE OPERATIONAL INPUT TO EXPERIMENT DESIGNS AND PROCUREMENT
5) DEVELOP ATTITUDE AND POINTING PLAN	
6) DEVELOP EXPERIMENT PROCEDURES	
7) PREPARE FLIGHT DATA FILE	

FLIGHT PLANNING FUNCTIONS FOR EXPERIMENT OPERATIONS

An analysis has been performed to identify the flight planning functions that must be performed for Spacelab payloads. The seven functions listed in the table, and their uses, are generic to the Spacelab payloads identified for use in the study. These flight planning functions are consistent with experience gained on Skylab, Apollo and ASTP, and they provide a baseline for development of low cost alternative concepts.

EACH PAYLOAD/CARGO IS DEVELOPED AND OPERATED BY A LEAD CENTER

- REDUCES DUPLICATION OF FUNCTIONS BETWEEN STS AND LEAD CENTER
- CENTRALIZES MANAGEMENT OF INTERDEPENDENT PAYLOAD SYSTEMS ENGINEERING AND FLIGHT PLANNING
- BRINGS OPERATIONS INFLUENCE TO DESIGN OF EXPERIMENT EQUIPMENT
- MINIMIZES FLIGHT PLANNERS TRAVEL COSTS
- MINIMIZES DOCUMENTATION
- STIMULATES INTERCHANGE OF SYSTEMS ENGINEERS
- MAXIMIZES REAL TIME RESOLUTION OF EXPERIMENT COMPETITION FOR FLIGHT RESOURCES

<u>EACH PAYLOAD/CARGO IS DEVELOPED AND OPERATED BY A LEAD CENTER</u>

Early in the study, an analysis was conducted to evaluate the desirability of payload flight planning by a centralized, dedicated organization, by the STS operator, by a contractor, or by the Lead Center. The complete range of Spacelab payloads was considered, including single-discipline payloads, multi-applications payloads, mixed U.S.-foreign payloads, and NASA-DoD payloads. For the reasons shown, payload flight planning by the assigned Lead Center is preferable and is recommended for Spacelab payloads. In particular, the Lead Center's role in payload systems engineering dictates that it should also perform the highly-interrelated flight planning functions.

COST/MANPOWER REDUCTION FACTORS

- MINIMIZE CONTINGENCY/MALFUNCTION PLANNING
- MINIMIZE FLIGHT PLANNING ITERATIONS
- MAXIMIZE USE OF INSTITUTIONAL COMPUTER SYSTEMS
- MAXIMIZE COMMON USE OF MANPOWER

COST/MANPOWER REDUCTION FACTORS

Lower costs for payload flight planning can be achieved by careful attention to the four major factors on the facing page. These four factors have been identified as important for reducing both non-recurring costs (e.g., new computers and software) and recurring costs (e.g., manpower per flight). In the material that follows, each factor is analyzed to determine its contribution to cost-savings, and implementation methods for achieving these lower costs.

MINIMIZE MALFUNCTION/CONTINGENCY PLANNING

- PROVIDE MALFUNCTION/CONTINGENCY PLANNING FOR SAFETY OF FLIGHT ONLY
    - MOST CONTINGENCIES ARE SOLVED BY CHANGES TO THE EXPERIMENT TIME LINE
    - EQUIPMENT MALFUNCTIONS REQUIRE ASSESSMENT OF SCIENCE AND EQUIPMENT DATA FOR FAULT ISOLATION

MINIMIZE MALFUNCTION/CONTINGENCY PLANNING

The range of possible malfunctions and contingencies is wide and unpredictable. Pre-flight planning for malfunctions and contingencies can be extremely expensive, and even then there will always be the likelihood of an unforeseen event that requires corrective analysis during the flight. It is for such unforeseen events that a Payload Operations Center (POC) is established, staffed to analyze malfunctions/contingencies and to recommend corrective approaches.

Only safety of flight considerations, relative to the payload, are mandatory flight planning activities. Experience on previous manned flights indicates that changes to experiment timelines and near-real-time workaround analyses (for equipment malfunctions) are satisfactory substitutions for extensive malfunction/contingency planning.

MOST CONTINGENCIES ARE SOLVED BY CHANGE TO THE TIMELINE

<table>
<tr><th>EXPERIMENT CONTINGENCY FACTOR</th><th>PROBABLE CAUSE</th><th>PROBABLE ACTION</th><th>GENERAL CHARACTERISTICS</th></tr>
<tr><td>EXPERIMENT EQUIPMENT PERFORMANCE</td><td>EQUIPMENT BREAKDOWN</td><td>• FAULT ISOLATION
• WORK AROUND</td><td rowspan="5">• LARGE NUMBER OF VARIATIONS
• LARGELY UNPREDICTABLE
• GENERALLY ONLY CAUSES LOSS OF EXPERIMENT TIME
• MOST LIKELY ACTION IS A CHANGE IN THE TIME LINE</td></tr>
<tr><td>ORBITAL DEVIATIONS</td><td>VARIATION IN LAUNCH TIME, INSERTION ORBIT, ETC.</td><td>• REVISED TIME LINE</td></tr>
<tr><td>NATURAL PHENOMENA</td><td>OCCURENCE OF FLARES, WEATHER, ETC.</td><td>• REVISED TIMELINE</td></tr>
<tr><td>HUMAN FACTORS</td><td>VARIATION OF CREW PERFORMANCE IN ZERO-G ENVIRONMENT</td><td>• REVISION OF EXPERIMENT PERFORMANCE TIME
• REVISED TIME LINE</td></tr>
<tr><td>SCIENTIFIC DATA</td><td>SCIENTIFIC PHENOMENA NOT AS EXPECTED</td><td>• RECONFIGURATION OF EQUIPMENT</td></tr>
</table>

MOST CONTINGENCIES ARE SOLVED BY CHANGES TO THE TIME LINE

The likely payload contingencies, their causes and remedial actions have been identified. It is important to note that all elements of the flight (Orbiter, Spacelab, experiment equipment and procedures, crew timelines) will be developed to minimize the occurence of malfunctions or contingencies; accordingly, it should be expected that malfunctions and contingencies will decrease as the STS and payload technology mature. The need for payload contingency planning will correspondingly decrease.

The Probable Actions shown in the facing table are all within the capabilities of the POC and its supporting complement of Principal Investigators, experiment engineers and flight planners. The resources of the MCC will provide comparable support for workaround procedures for orbit insertion errors and Spacelab subsystem malfunctions. From Skylab, experience shows that the flight crew is also capable of corrective actions for payload malfunctions and contingencies.

EQUIPMENT MALFUNCTIONS REQUIRE ASSESSMENT OF SCIENCE AND EQUIPMENT DATA

SCIENCE AND EQUIPMENT DATA MUST BE EVALUATED TO

- DETERMINE VALIDITY OF SCIENTIFIC DATA
- ISOLATE FAILED EQUIPMENT
- DEFINE EQUIPMENT WORKAROUND PROCEDURES OR CONFIGURATIONS

MUST BE PERFORMED IN REAL TIME

EQUIPMENT MALFUNCTIONS REQUIRE ASSESSMENT OF SCIENCE AND EQUIPMENT DATA

Payload equipment is designed, manufactured and tested so as to minimize malfunctions, i.e., all anticipated possibilities for malfunction have been eliminated. Therefore, planning for malfunctions and contingencies is logically restricted to providing resources for determining causes of unforeseen malfunctions and work-around procedures. Both the POC and the flight crew are expected to participate in this activity.

Since all possible malfunctions cannot be predicted or pre-planned, and because of the POC/crew capabilities for analyses and corrective actions, no man hours are required for payload contingency planning.

ADVANTAGES

- REDUCES TOTAL PLANNING MANPOWER
- ALLOWS USE OF PLANNERS FOR OTHER SYSTEMS ANALYSIS ACTIVITIES DURING HARDWARE DEVELOPMENT
- REDUCES COMPUTER USAGE

FACTORS

- DEVELOP FLIGHT PLANS ONLY WHEN REQUIRED TO SUPPORT PAYLOAD OPERATIONS PLANNING OR DESIGN
- REPLAN ONLY WHEN HARD TEST DATA BECOME AVAILABLE

MINIMIZE EXPERIMENT PLANNING ITERATIONS

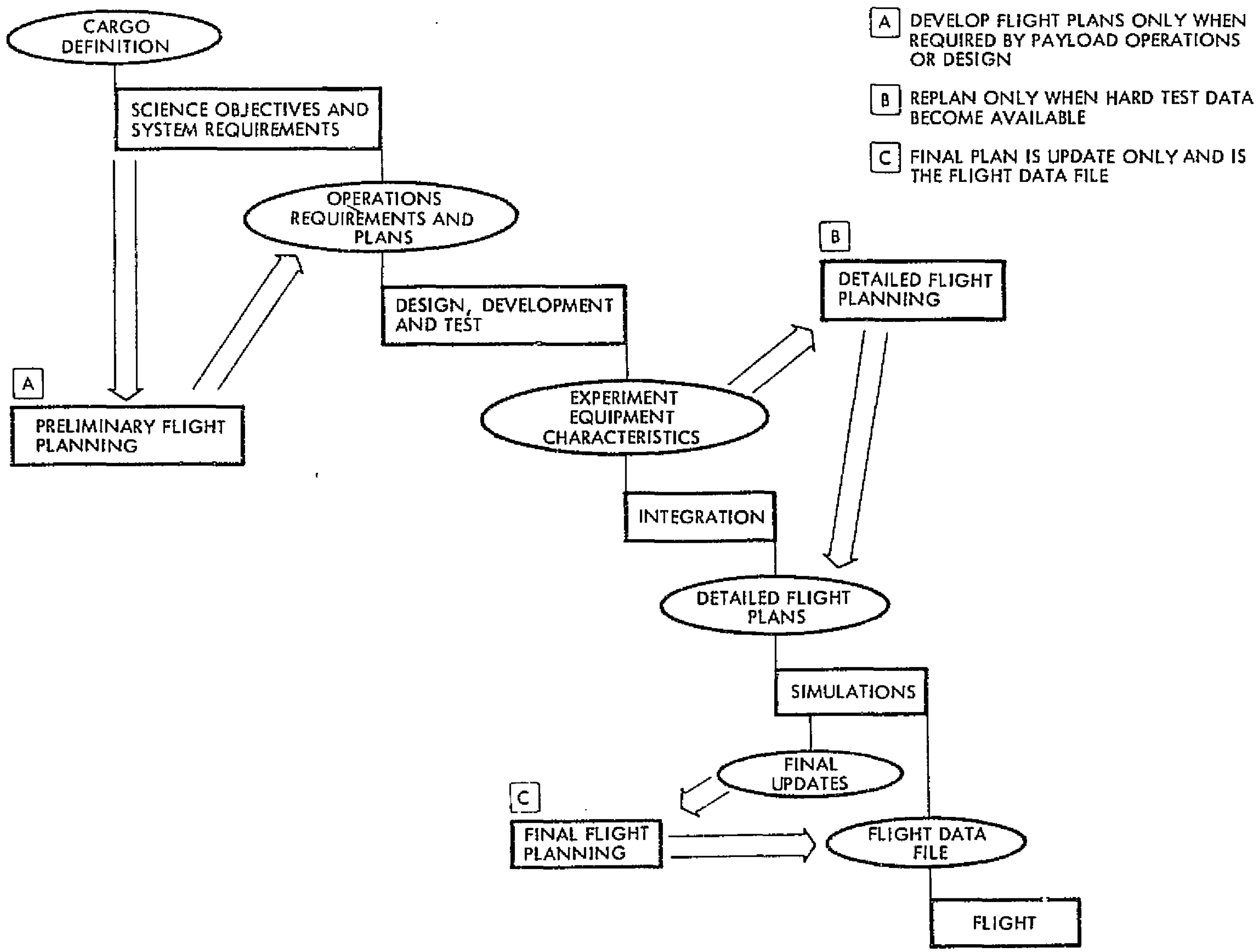
Manpower and computers hours for payload flight planning are directly related to the number of times the flight plan is updated. It is recommended that a new plan, or an update of an existing plan, be accomplished only at the following times:

- When a flight plan is needed to support experiment equipment design specifications, or to assemble requirements for flight support from the STS, the launch site, communications networks and other support agencies.

- When hardware test data become available for integrating into detailed timelines, procedures, consumables and pointing analyses. As a subset, refinement of a detailed flight plan may be necessary on the basis of simulation of experiment operations and training exercises.

The advantage of limited iterations is in a reduction of costs (manpower and computers) from the costs of continuous flight planning during the preflight periods.

EXPERIMENT FLIGHT PLANNING ITERATIONS

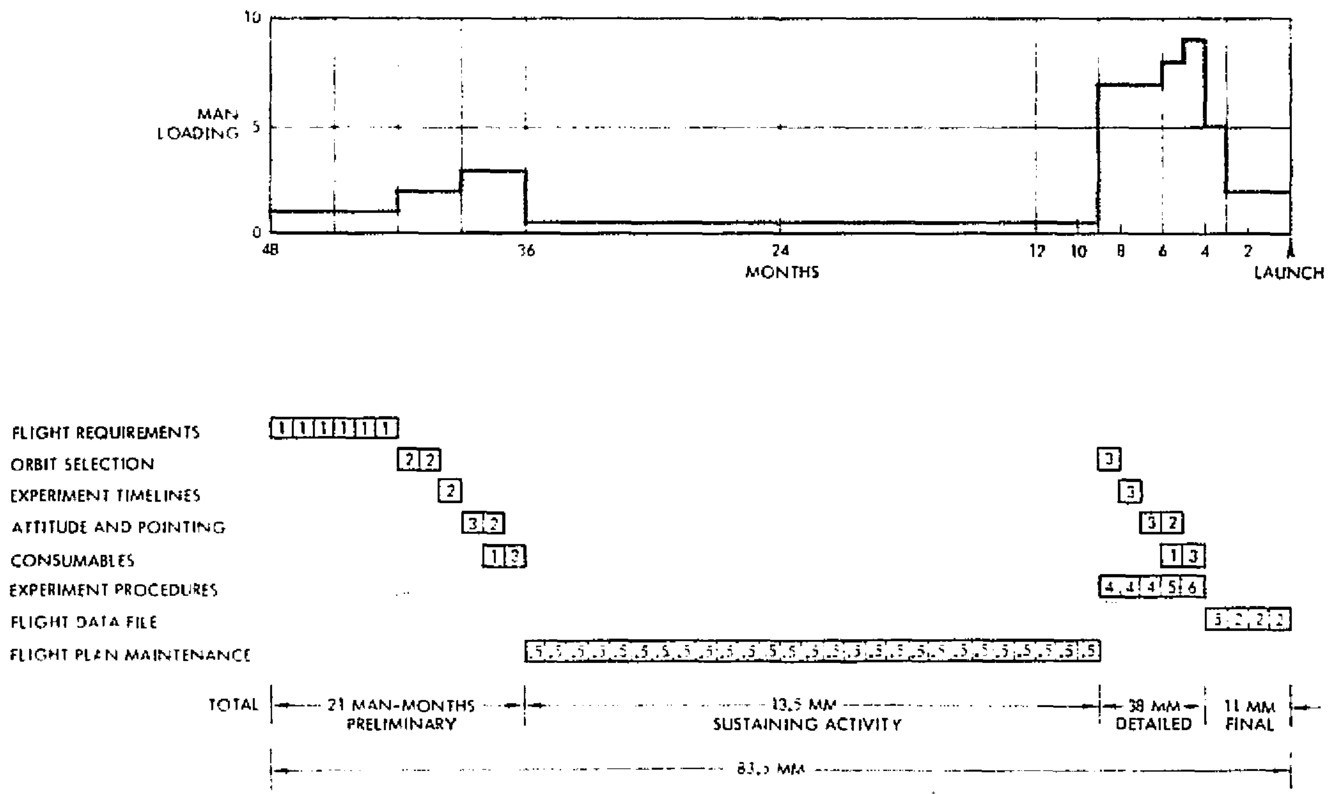


EXPERIMENT FLIGHT PLANNING ITERATIONS

For Spacelab payloads, the minimum flight-plan iterations are shown, together with their intended purpose. Flight plan "A" will be used to define total flight characteristics and constraints that must be considered in design and test of the experiment equipment. Flight plan "B" is a detailed plan that will include experiment timelines, procedures, consumable and pointing, all of which should be compatible with the actual flight hardware. Flight plan "C" is an update that considers the impact of simulations and integrated crew training; this flight plan becomes parts of the Flight Data File.

NOMINAL-PAYLOAD MAN-MONTH ESTIMATES FOR FLIGHT PLANNING

- Minimum malfunction/contingency planning
- First flight
- Performers are experienced
- Average payload ~ multi-applications



NOMINAL-PAYLOAD MAN-MONTH ESTIMATES FOR FLIGHT PLANNING

To establish manpower estimates, a set of ground rules have been postulated, consistent with low costs and with the early years of Spacelab payloads.

Experienced flight planners are available both within NASA and in industry, and it is assumed such people would be assigned to the flight planning function. The estimates for manpower were provided by TRW people who supported the flight planning for Skylab, Apollo and ASTP, and who have reviewed the candidate Spacelab payloads.

As a baseline, Multi-Applications payloads are considered to be of average complexity and are used for initial manpower estimates.

Manpower estimates are shown for the three iterations to the flight plan and for a limited degree of flight plan maintenance. The values are consistent with the ground rules and constraints listed on the previous chart.

Flight plan maintenance is shown for a period that is typical of the manufacture and test of new experiment equipment. For reflights, this period would be shorter because this equipment would require only refurbishment or minor modifications. Flight plan maintenance would be reduced accordingly.

The manpower estimates are also consistent with use of the computer hours estimated elsewhere in this report. It is also assumed that the flight planners are collocated with the payloads's system engineer and have ready access to Principal Investigators.

SUMMARY OF PAYLOAD OPERATIONAL REQUIREMENTS

PAYLOAD	NUMBER OF EXP. SYSTEMS	COMPLEXITY		
		CONSTRAINED ATTITUDE/ POINTING	CONSTRAINED ORBITAL CONDITIONS	CONSTRAINED ORDER OF PERFORMANCE
AMPS	8	30		
ATL	12	EARTH		
LIFE SCIENCES	2	NO		
MULTI-APLS	6	EARTH		
COMB. ASTRO	4	400 IPS		

HIGH	(shaded)
MODERATE	(hatched)
LOW	(blank)

SUMMARY OF PAYLOAD OPERATIONAL REQUIREMENTS

Variations from the baseline manpower estimates will be caused by differences in complexity among the candidate payloads. The accompanying chart summarizes the degrees of complexity to be expected, with AMPS as the most complex and Life Sciences the least complex in terms of flight planning.

The three factors that contribute to complexity relate to the difficulty of developing optimum flight plans. Attitude and pointing become difficult when multiple experiments compete for available RCS capability, available time(s) on orbit, and available access to targets. Constrained orbital conditions represent difficulties in scheduling experiments during darkness, through the limb of the earth, while all other experiments are inoperative, etc. Constrained order of performance can severely reduce flexibility in scheduling individual experiments to achieve all payload objectives.

FLIGHT PLANNING MAN-MONTH REQUIREMENTS BY PAYLOAD DISCIPLINE

	REFERENCE PAYLOADS					
PLANNING FUNCTION	AMPS	ATL	LIFE SCIENCE	MULTI-APPLICATION	COMB-ASTRO	FIRST MISSION
FLIGHT REQUIREMENTS	12	12	6	6	6	2
ORBIT SELECTION	14	10	2	7	7	2
EXPERIMENT TIMELINES	10	10	5	5	5	10
ATTITUDE & POINTING	16	8	0	8	12	2
CONSUMABLES	10	16	5	10	10	10
EXPERIMENT PROCEDURES	23	36	23	23	23	23
FLIGHT DATA FILE	11	16	11	11	11	11
SUSTAINING ACTIVITY	13	13	13	13	13	13
TOTALS	109	121	65	83	87	73

FLIGHT PLANNING MAN-MONTH REQUIREMENTS BY PAYLOAD DISCIPLINE

Manpower estimates reflect the varying complexity among payloads. In general, the number of experiments in the payload is directly related to complexity and to manpower estimates for payload flight planning. Payloads that require a great deal of pointing (e.g, AMPS) will require more planning than payloads insensitive to attitude and pointing (e.g., Life Sciences). Conversely, all payloads will require a similar amount of sustaining activity during the equipment-procurement cycle.

The First Spacelab Mission is a unique case in that some flight planning functions are beyond the control of the payload users, e.g., flight requirements, orbit selection, attitude and pointing. The options within these functions will be evaluated and selected on the basis of the flight's primary purpose, which is to test the Spacelab and its systems. The payload planners will probab'y coordinate on the options, but will not require extensive analyses of their own.

FLIGHT PLANNING MAN-MONTH REQUIREMENTS BY FLIGHT TYPE

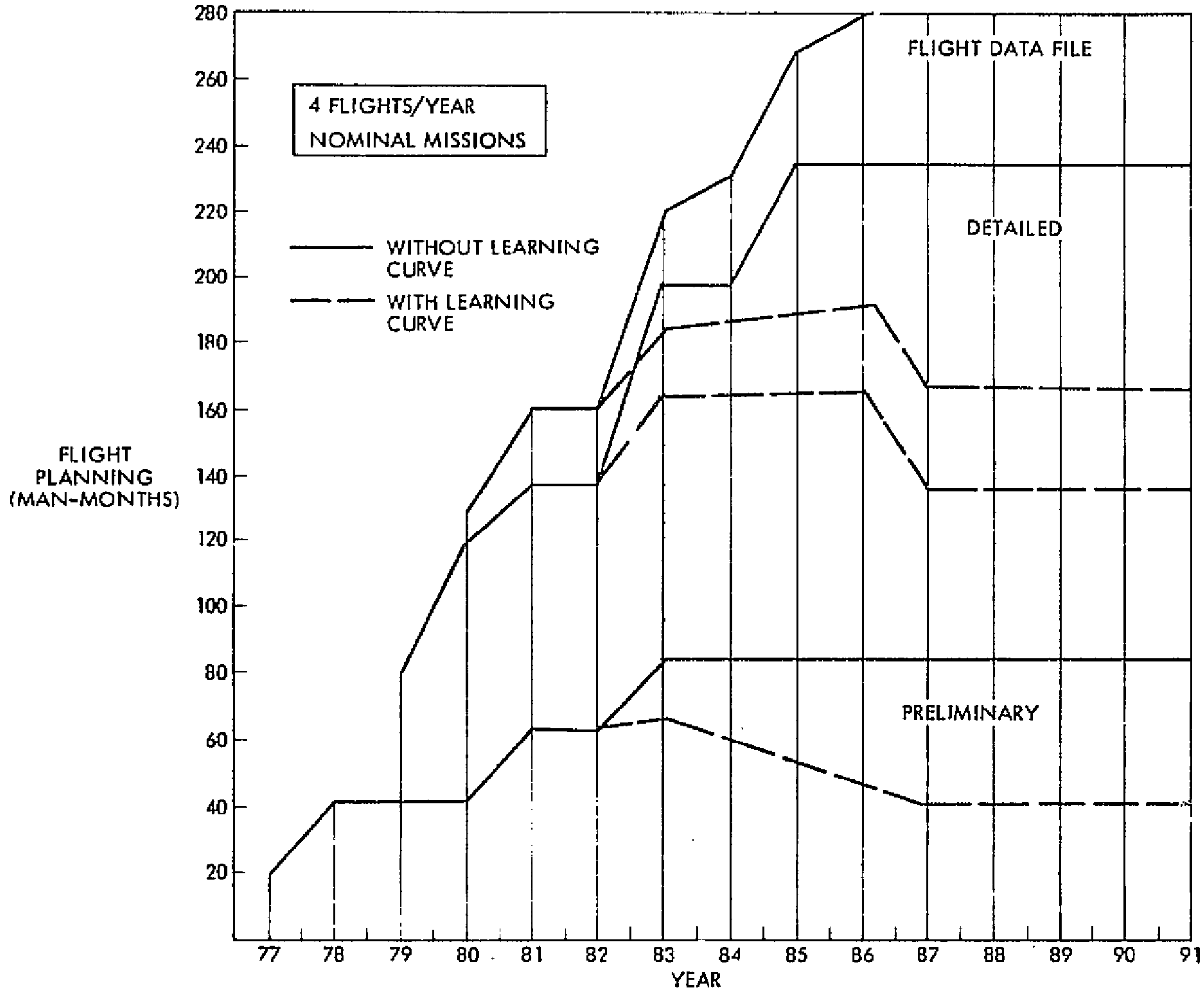
PAYLOAD DISCIPLINE	MANPOWER REQUIRED ~ MAN MONTHS		
	FIRST FLIGHT	RE-FLIGHT	30-DAY FLIGHT
AMPS	109	62	123
ATL	121	56	139
LIFE SCIENCES	65	18	70
MULTI-APPLICATIONS	83	36	95
COMBINED ASTRONOMY	87	40	100
FIRST MISSION	73	-	-
MAJOR DIFFERENCE IN PLANNING ACTIVITY	-	• EXPERIMENT PROCEDURES • FLIGHT DATA FILE • SUSTAINING ACTIVITY	• ATTITUDE AND POINTING • CONSUMABLES

FLIGHT PLANNING MAN-MONTH REQUIREMENTS BY FLIGHT TYPE

Spacelab payload equipment is expected to be used on successive flights with only slight modification between flights. It will thus be possible to reuse large portions of the previous flight plan, resulting in lower manpower requirements for planning. For example, procedures for operating the equipment will change only slightly and much of the Flight Data File can be used again. Also, sustaining activity will be appreciably lower than for the first flight of the payload because the equipment-procurement cycle will be greatly reduced in scope and time. Based on the above, estimates for man-months to plan repeat flights are significantly lower than for the first flight of a payload, as shown in the table.

For 30-day flights, attitude and pointing must be planned for a larger number of targets, and consumables planning becomes more complicated because the Spacelab's limited resources must be stretched out over a longer period.

SPACELAB PAYLOADS FLIGHT PLANNING MAN-MONTHS



SPACELAB PAYLOAD FLIGHT/YEAR				1	2	2	2	3	3	4	4	4	4	4
FP MAN-MONTHS	21	42	80	129	161	161	220	231	269	280	280	280	280	280
EQUIVALENT PERMANENT EMPLOYEES	2	4	7	11	13	13	19	20	23	24	24	24	24	24
EQUIVALENT EMPLOYEES USING LEARNING CURVE					13	13	16	16	16	16	14	14	14	14

SPACELAB PAYLOADS FLIGHT PLANNING MAN-MONTHS

Man-months for the recommended flight planning iterations have been compiled for a Lead Center supporting up to four average-payload flights/year. Each flight has first been estimated as if it were the first flight of that payload, i.e, the data are quite conservative in that no learning curve is included. The preliminary, detailed and Flight Data File activities are also scheduled as for a first flight, leading to the man-months shown in advance of the first Spacelab flight in 1980.

As an extension of the first-flight estimates, a learning curve has been used and the resulting man-month estimates are shown (dotted lines). Use of these latter data will significantly lower the number of employees required.

Breakpoints in the learning curve were based on the following data from the CRAS 12-flights/year model, specifically the MSFC portion:

- By 1982 every discipline has flown at least one payload
- By 1985 every discipline has flown at least two payloads
- By 1986 every discipline has flown at least three payloads
- By 1987 every discipline has flown at least four payloads
- By 1988 every discipline has flown at least five payloads
- By 1989 every discipline has flown at least six payloads.

A mixture of first flights and reflights was assumed down to the fourth flight, beyond which all flights are reflights and that manpowe r would remain constant. The summations along the bottom of the chart are for the number of permanent flight planners required at the Lead Center.

MAXIMIZE USE OF EXISTING COMPUTER RESOURCES

ADVANTAGES

- REDUCE NEW HARDWARE EXPENDITURES
- REDUCE SOFTWARE CONVERSION/DEVELOPMENT
- AVOID LEARNING COSTS OF NEW SYSTEMS

FACTORS

- COMPUTATIONAL WORK LOAD
- SENSITIVITY TO FLIGHT RATE
- CAPABILITIES OF POTENTIAL LEAD CENTERS
- AVAILABILITY OF APPLICATIONS SOFTWARE

MAXIMIZE USE OF EXISTING COMPUTER RESOURCES

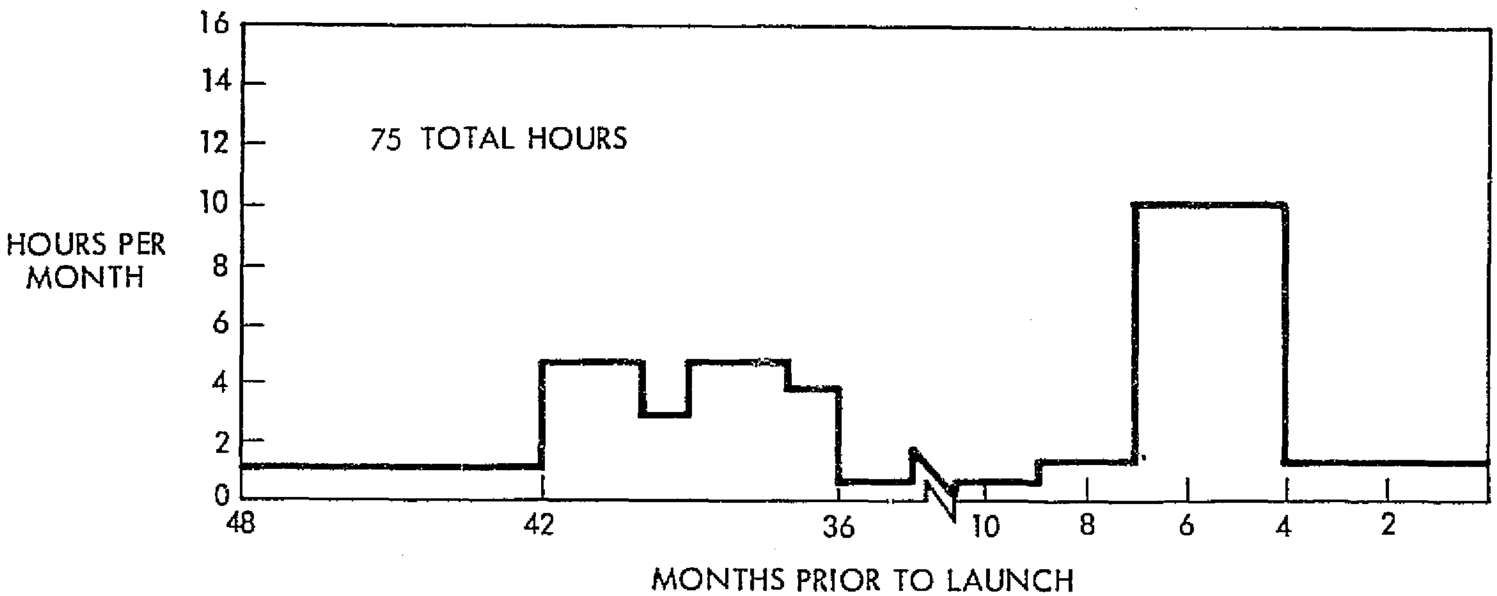
Payload flight planning involves use of computers for many analyses, such as determination of pointing angles, consumables profiles and crew timelines. Within NASA, a great amount of computer hardware and software is available and can be used for Spacelab payload flight planning. This capability is enhanced by the fact that preflight planning is not time-critical, making it possible to use institutional resources in a batch-processing mode if interactive capability is not available.

The analysis has considered the capabilities of payload Lead Centers to support the anticipated flight rates, leading to recommendation that existing computer resources be used for payload flight planning.

TYPICAL COMPUTATIONAL WORKLOAD

PER FLIGHT

- BATCH PROCESSING
- MULTI-APPLICATIONS
- NOMINAL FLIGHT PLANS
- 1108 COMPUTER HOURS
- USAGE PER FLIGHT
- MINIMUM ITERATIONS



TYPICAL COMPUTATIONAL WORKLOAD PER FLIGHT

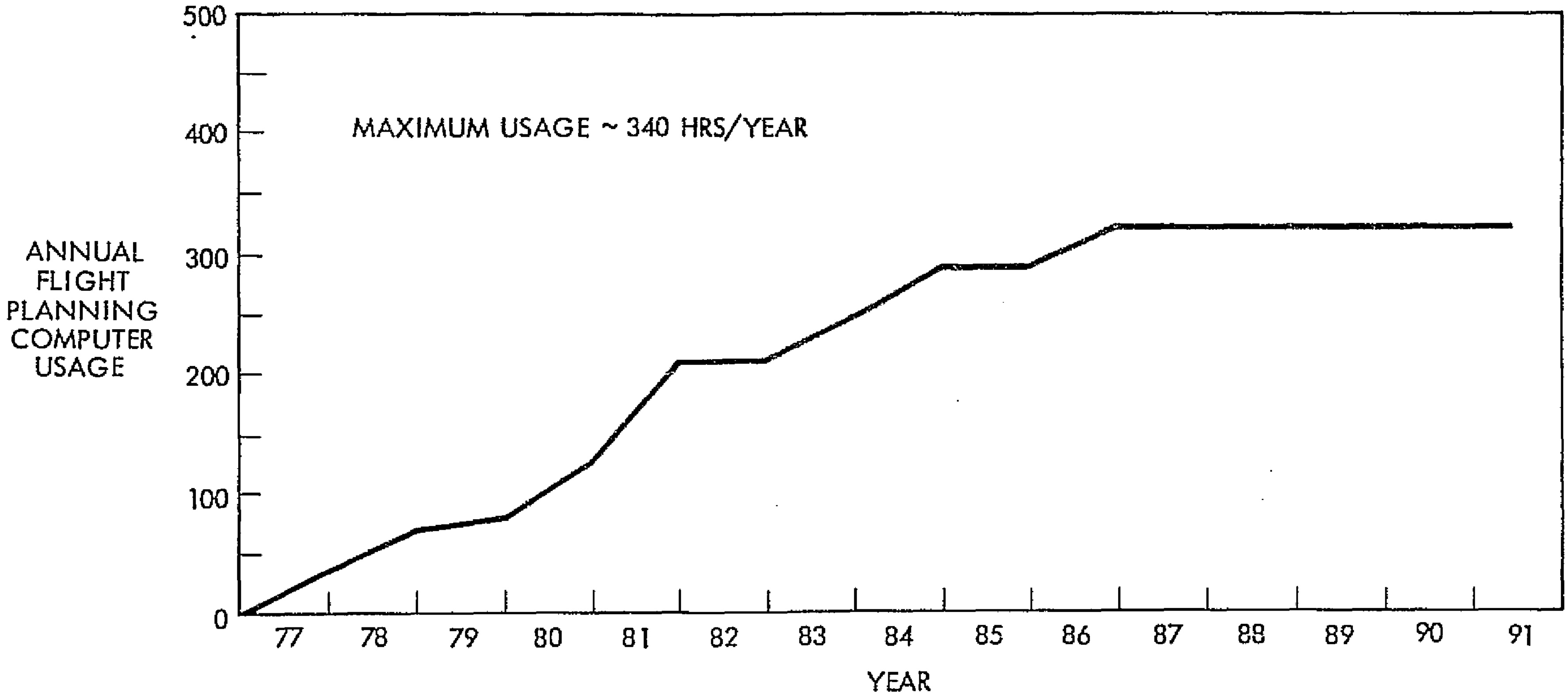
Estimates for the computional workload for payload flight planning have been developed as part of the analysis. The level of flight planning has been taken to be full and complete except for malfunctions and contingencies. Univac 1108's have been used for estimating computer hours because this computer is widely used by candidate Lead Centers. Since payload flight planning is not time-critical, batch-processing has been assumed, thus enhacing the availability of institutional resources. Iterations of the flight plan occur only when a flight plan is needed to proceed with development of equipment and support planning, or when experiment test and operations data become available.

The Multi-Applications have been found "average" for the Spacelab payloads, and the computational workload for this payload is shown. The computational hours/month are for the first flight of Multi-Application payloads, using the ground rules of the previous chart. The periods of major computer usage are related to the following:

- Between 42-36 months, a preliminary flight plan is needed to support experiment-equipment design and procurement, and to define flight support required from POC, MCC, KSC and other ancillary agencies.
- Between 8-4 months, experiment test data and operating procedures are integrated into a detailed payload flight plan.

TYPICAL COMPUTATION WORK LOAD
PER YEAR

- NOMINAL FLIGHT PLANS
- MULTI-APPLICATIONS
- MAXIMUM FOUR FLIGHTS/YEAR
- 1108 COMPUTER HOURS
- BATCH PROCESSING
- TM-3 TRAFFIC MODEL



TYPICAL COMPUTATION WORKLOAD PER YEAR

The impact of flight rate on computer hours has been analyzed, assuming the ground rules of the previous chart and a maximum flight rate of four flights per year at the Multi-Applications Lead Center. In the totality of payload flight planning activities, an average of about one hour per day of Univac 1108 support is estimated.

The assumption of a maximum of four flights per year at a given Lead Center is consistent with Traffic Model-3, as defined for the purposes of this study. For other flight rates, the computer hours can be approximated from the base of four flights per year.

Impacts of learning curves, repeat flights and other-than-average payloads are treated in the following charts.

COMPUTER WORKLOAD FOR FLIGHT PLANNING BY PAYLOAD TYPE

- NOMINAL PLANNING
- 1108 COMPUTER
- BATCH PROCESSING
- MINIMUM PLANNING ITERATIONS

	REFERENCE PAYLOAD ~ COMPUTER HOURS					
PLANNING FUNCTION	AMPS	ATL	LIFE SCIENCE	MULTI-APPLICATION	COMB-ASTRO.	FIRST MISSION
FLIGHT REQUIREMENTS	12	12	6	6	6	2
ORBIT SELECTION	10	8	5	10	5	2
EXPERIMENT TIME LINES	6	6	1	3	3	6
ATTITUDE & POINTING	42	21	0	21	40	5
CONSUMABLES	23	32	10	23	15	15
EXPERIMENT PROCEDURES	-	-	-	-	-	-
FLIGHT DATA FILE	8	10	8	8	8	8
SUSTAINING ACTIVITY	10	10	10	10	10	10
TOTALS	111	99	40	81	87	48

COMPUTER WORK LOAD FOR FLIGHT PLANNING BY PAYLOAD TYPE

There is a wide variation in complexity among the candidate Spacelab payloads, and an accompanying variation in hours of computer support for flight planning. Using the Design Reference Missions and the individual flight planning functions, estimates of computer hours have been developed as shown. AMPS will require significantly more computing support than the 87 hours needed for combined Astronomy, while Life Sciences needs appreciably fewer hours.

Sustaining activity is included for every payload to provide minimum flight planning support between major iterations. An estimate of 10 computer hours has been allocated for this function.

COMPUTER WORKLOAD FOR FLIGHT PLANNING BY FLIGHT TYPE

- NOMINAL PLANNING
- 1108 COMPUTER
- BATCH PROCESSING
- MINIMUM PLANNING ITERATIONS

	COMPUTER HOURS REQUIRED		
PAYLOAD DISCIPLINE	FIRST FLIGHT	RE-FLIGHT	30-DAY FLIGHT
AMPS	111	93	144
ATL	99	79	136
LIFE SCIENCES	40	22	50
MULTI-APPLICATIONS	81	63	109
COMBINED ASTRONOMY	87	69	112
FIRST MISSION	48	-	-
MAJOR DIFFERENCE IN PLANNING ACTIVITY	-	• EXPERIMENT PROCEDURES • FLIGHT DATA FILE • SUSTAINING ACTIVITY	• ATTITUDE AND POINTING • CONSUMABLES

COMPUTER WORK LOAD FOR FLIGHT PLANNING BY FLIGHT TYPE

Re-flights of payloads will benefit from computer analyses for the earlier flight(s), even though minor modifications to experiment equipment and procedures are anticipated. Based on experience from Skylab, automated satellite programs and other manned programs, an estimate has been developed for computer hours for flight planning, by payload type. Except for Life Sciences, repeat flights will require only about 80 percent as many computer hours as the first flight (Life Sciences requires a lower percentage, about 47 percent) because three flight planning activities (consumables, flight data file and sustaining activity) are a major portion of the original flight work and need not be entirely redone for every subsequent flight.

Thirty-day flights vary between 130-140 percent of original-flight computer hours. Most of the increase is due to extension of the consumables and pointing analyses.

AVAILABILITY OF APPLICATIONS SOFTWARE FOR EXPERIMENT FLIGHT PLANNING

- CRAS REFERENCE DATA FILE
- STS PAYLOAD MISSION CONTROL STUDY

- EXTENSIVE FLIGHT PLANNING SOFTWARE IS AVAILABLE WITH NASA

  MANNED ACTIVITY SCHEDULERS
  TRAJECTORY/ORBIT ANALYSIS
  INSTRUMENT POINTING
  ANTENNA POINTING
  COMMUNICATION
  CONSUMABLES

- MATH MODELS FOR EXPERIMENT SYSTEMS WILL EVOLVE DURING THE PAYLOAD DESIGN AND DEVELOPMENT PROCESS
  - POWER USAGE
  - PROCEDURES

AVAILABILITY OF APPLICATIONS SOFTWARE FOR EXPERIMENT FLIGHT PLANNING

From information gathered during this study and during the STS Payload Mission Control Study, it is apparent that a great deal of applicable software is available. An overview of the types of available software is shown on the facing page. Using proven technology and low-cost communications, software and hardware can be used to support Lead Centers other than the one where the resources are located, if local institutional resources are not available.

Experiment-peculiar software will be developed as part of the experiment design, procurement and testing, either by the Principal Investigators or the experiment contractor.

FLIGHT PLANNING CAPABILITIES OF POTENTAL LEAD CENTERS

- TM-3 10 12 FLIGHT / YEAR
- INSTITUTIONAL CAPABILITIES

	CAPABILITIES		REQUIREMENTS			ASSESSMENT
FACILITY	HARDWARE	SOFTWARE	PAYLOAD DISCIPLINES	PROBABLE MAXIMUM FLTS/YEAR	COMPUTER WORK LOAD HOURS/YEAR	
ARC	IBM 360 (2) CDC 7600	INCOMPLETE	LIFE SCIENCE ASTRONOMY	2	120	WORK LOAD LIGHT POSSIBLE CONVERSION ORUSE OF NASA RESOURCES
MSFC	UNIVAC 1100'S (3)	ADEQUATE	SPACE PROCESSING AMPS MULTI-USER MULTI-APPL	4	340	CAPABILITY EXISTS WORK LOAD NOT EXCESSIVE
GSFC	IBM 360(3)	PROBABLY ADEQUATE	SOLAR PHYSICS HI-ENERGY PHYSICS ASTRONOMY MULTI-APPL	4	350	LIMITED SCHEDULING S/W WORK LOAD NOT EXCESSIVE
LARC	CDC 6000 (5)	MANNED PROGRAMS MARGINAL	ATL	1	95	SOFTWARE UPDATES REQUIRED WORK LOAD LIGHT
JSC	UNIVAC 1100's (5)	ADEQUATE	LIFE SCIENCE MULTI-APPL	2	120	WORK LOAD LIGHT CAPABILITY EXISTS

FLIGHT PLANNING CAPABILITIES OF POTENTIAL LEAD CENTERS

An overall analysis has been prepared for computer-support requirements including consideration of reflights, and capabilities for the candidate Lead Centers. Only ARC and LaRC need additional capability to do flight planning for their payloads in Traffic Model-3 (10-12 Spacelab Flights per year). This support can be provided by agreement with other Centers (e.g., JSC), since only three flights per year (total) are included for ARC and LaRC in Traffic Model-3.

For the heaviest indicated computer-workloads, at MSFC and GSFC, the indicated requirements are only about one hour per day. Both MSFC and GSFC operate extensive institutional computer complexes and are judged capable of assimilating the indicated workload.

In summary, computer hardware and software exist within NASA to support 10-12 Spacelab flights per year, assuming support to ARC and LaRC by other Centers.

USE PAYLOAD AND MISSION SPECIALISTS IN FLIGHT PLANNING

ADVANTAGES

- REDUCES LEAD CENTER MANPOWER REQUIREMENTS
- MAXIMIZES USE OF HIGHLY QUALIFIED PEOPLE
- ENHANCES CONTINUITY FROM FLIGHT PLANNING THROUGH OPERATIONS

FACTORS

- PAYLOAD USERS WILL SELECT DISCIPLINE-QUALIFIED PAYLOAD SPECIALISTS
- MISSION SPECIALISTS ARE TO BE INVOLVED IN EXPERIMENT OPERATIONS
- TIME FOR FLIGHT PLANNING WILL BE AVAILABLE
- BACKUP SPECIALISTS CAN BE PART OF POC ACTIVITY

USE PAYLOAD AND MISSION SPECIALISTS IN FLIGHT PLANNING

Payload and Mission Specialists will be intimately involved with PI's and equipment designers. They will also participate in testing experiment equipment. Their participation in payload flight planning therefore offers definite advantages, including those shown on the facing page. In addition to reducing the Lead Center's manpower requirements, the use of Payload and Mission Specialists for flight planning improves their understanding of mission objectives. Most important, the preparation of experiment timelines and procedures by the people who will implement them on-orbit enhances the chances for a successful flight.

The factors pertaining to the use of Payload and Mission Specialists are discussed in the material that follows.

MISSION AND PAYLOAD SPECIALISTS QUALIFICATIONS FOR FLIGHT PLANNING

- PAYLOAD SPECIALISTS WILL BE DISCIPLINE-ORIENTED AND HAVE BEEN INVOLVED IN THE EXPERIMENT DEVELOPMENT
- PAYLOAD AND MISSION SPECIALISTS WILL BE TRAINED ON THE FLIGHT EQUIPMENT, BY PRINCIPAL INVESTIGATORS AND EQUIPMENT DESIGNERS
- PAYLOAD AND MISSION SPECIALISTS WILL PARTICIPATE IN LEVEL II AND III INTEGRATION
- MISSION SPECIALIST WILL MANAGE EXPERIMENT OPERATIONS ON-ORBIT

MISSION AND PAYLOAD SPECIALISTS QUALIFICATION FOR FLIGHT PLANNING

The Payload Specialist will be selected by the payload sponsors, with one criterion being a solid background in the payload's scientific discipline. The Mission Specialist will be a scientist and career astronaut, who is expected to become proficient in operation of the experiments. It is anticipated that they will participate in Level III and Level II integration of the flight hardware, in addition to operation of experiment equipment under the guidance of the Principal Investigators and equipment designers. With these basic qualifications and with the planned training sequences, the Payload and Mission Specialists are highly qualified for planning experiment timelines and procedures, for selection of orbits, and for consumables planning.

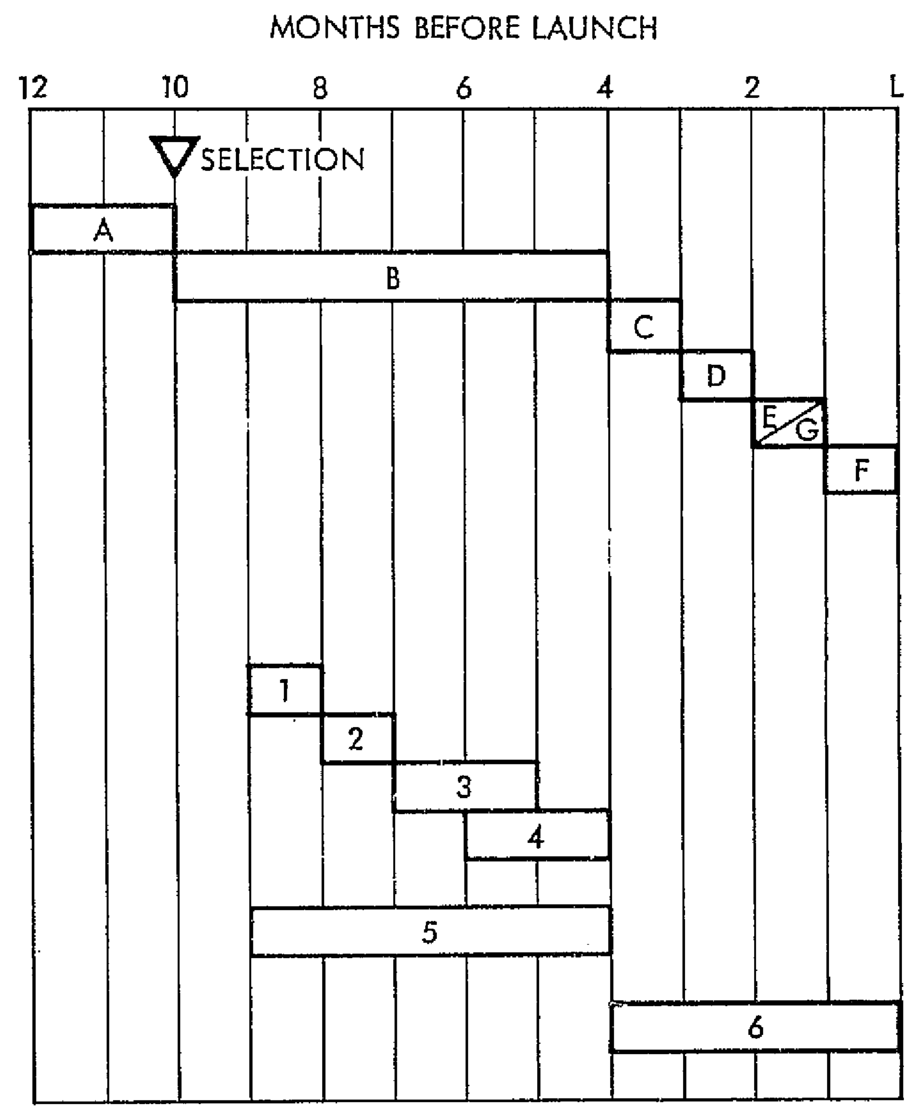
THE PAYLOAD FLIGHT CREW CAN PARTICIPATE IN FLIGHT PLANNING

TRAINING SEQUENCE

- (A) SCREENING, ORIENTATION AND SYSTEM FAMILIARIZATION
- (B) PROCEDURAL TRAINING ON EXPERIMENTS
- (C) EXPERIMENT/SPACELAB INTERFACE TRAINING
- (D) COMBINED EXPERIMENTS TRAINING
- (E) HABITABILITY AND SAFETY TRAINING
- (F) INTEGRATED OPERATIONS TRAINING
- (G) STS/SPACELAB SYSTEMS O&M TRAINING

PLANNING SEQUENCE

1. ORBIT SELECTION
2. EXPERIMENT TIMELINES
3. ATTITUDE AND POINTING
4. CONSUMABLES
5. EXPERIMENT PROCEDURES
6. FLIGHT DATA FILE

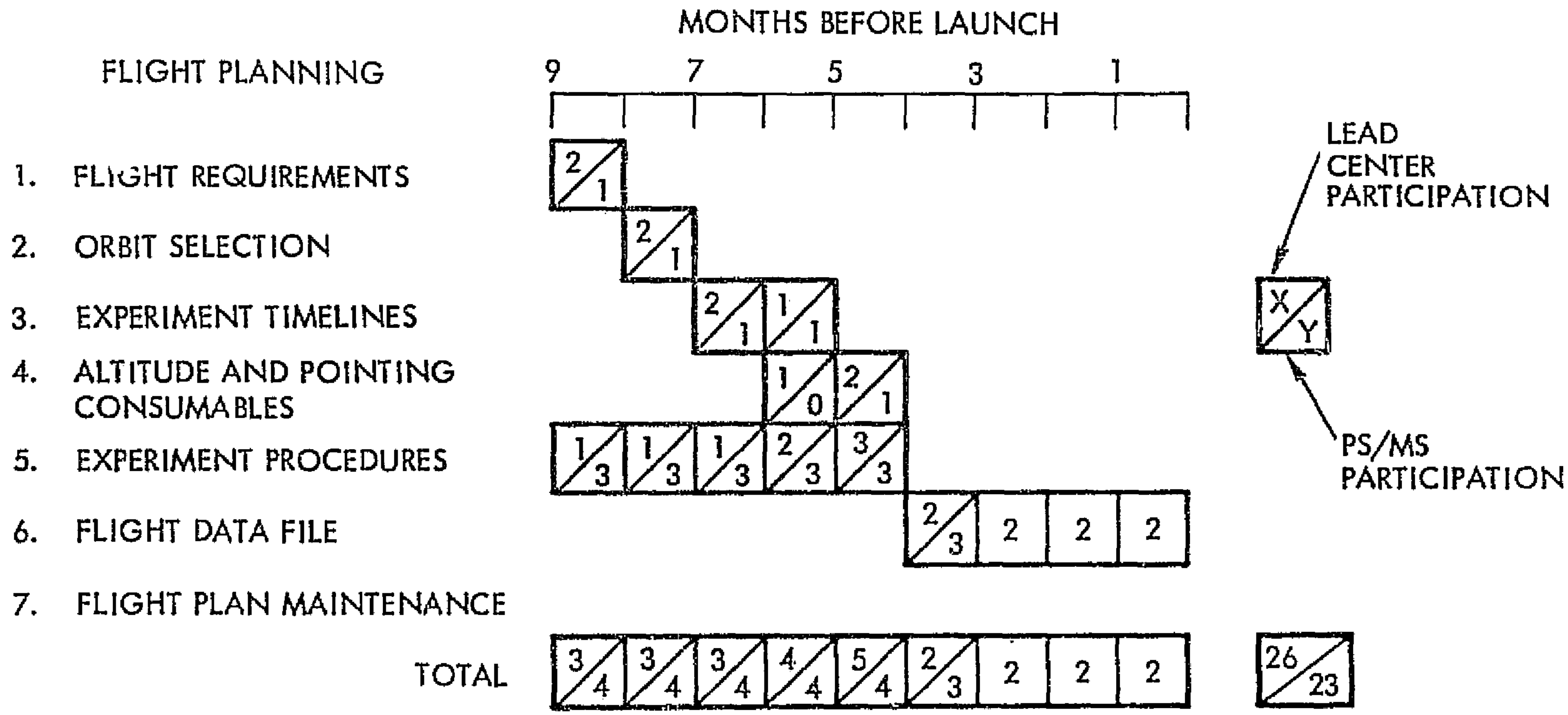


THE PAYLOAD FLIGHT CREW CAN PARTICIPATE IN FLIGHT PLANNING

A typical crew training schedule is shown in the top section of the accompanying figure, and the flight planning activities for the payload are shown in the lower section of the figure. A camparison of the schedules and the activities being performed indicates that it is both possible and desirable to use payload and mission specialists to perform significant portions of the payload flight plan. For example, Block B (procedural training on experiments) and Block 5 (experiment procedures) occur in parallel and should really be performed together, i.e., experiment procedures must be written in order to do the procedural training, and their use in training will show what changes are needed to make them realistic. Also, orbit selection, experiment timelines, attitude and pointing, and consumables analyses can impact the procedures for operating the experiments and should be considered during procedural training on experiments; accordingly, Blocks 1, 2, 3, 4 are deemed logical activities for the payload and mission specialists during their training on experiment procedures.

Analysis of the training load for the payload and mission specialists indicates that time will be available for payload flight planning up to about 4 months prior to launch. The liklihood that backup crew members will be assigned and trained increases the amount of specialist's time that can be applied to the flight planning activity. Accordingly, it is recommended that the specialists be used to help develop the payload flight plan during their training on experiment procedures at the host center, the experiment contractor's facility, or at the Principal Investigator's laboratory.

MISSION AND PAYLOAD SPECIALIST CONTRIBUTION TO FLIGHT PLANNING



- MAJOR CONTRIBUTION IS IN EXPERIMENT PROCEDURES DEVELOPMENT
- FINAL THREE MONTHS BEFORE LAUNCH ARE LEFT FREE FOR INTEGRATED TRAINING AND SIMULATIONS
- CREW ASSUMED FOR THIS PAYLOAD: ONE MISSION SPECIALIST AND ONE BACKUP
  TWO PAYLOAD SPECIALISTS AND TWO BACKUPS
- APPROXIMATELY 30 PERCENT OF TOTAL TIME (OVER 12 MONTHS TRAINING PERIOD) CONTRIBUTES TO FLIGHT PLANNING

MISSION AND PAYLOAD SPECIALISTS CONTRIBUTION TO FLIGHT PLANNING

For an average payload (e.g., Multi-Applications), an analysis has been made of flight planning contributions by the Payload and Mission Specialists. The major portion of the Specialists' contribution to flight planning is in preparation of experiment timelines and procedures and the flight data file, with support from the Lead Center for documentation and management. The Specialists can also contribute to the selection of the final orbit, consumables analyses, pointing and attitude, since these are intimately related to experiment operations. The schedule, as shown, leaves the crew available for integrated crew training and final flight preparations during the last three months before launch. During this period, any updates resulting from experiment simulations or integrated crew training will be entered into the flight data file by Lead Center flight planners, after coordinating with the flight crew.

A total of 23 man-months of specialist manpower is estimated for average payloads, thereby reducing Lead Center workload by an equivalent amount.

POSSIBLE MANPOWER SAVINGS

- COMBINED PAYLOAD SPECIALIST EXPERIMENT TRAINING AND PROCEDURES DEVELOPMENT
- COMBINED MISSION SPECIALIST FLIGHT MANAGEMENT TRAINING AND FLIGHT PLANNING

FLIGHT PLANNING PHASE	MANPOWER REQUIRED (MM)	FLIGHT CREW AVAILABILITY (MM)	REQUIRED ENGINEERING SUPPORT (MM)
PRELIMINARY	21	-	21
DETAILED	38	20	18
FINAL	11	3	8
SUSTAINING	13	-	13
TOTAL	83	23	60

POSSIBLE MANPOWER SAVINGS

Based on the three flight planning cycles recommended earlier, the contributions of Lead Center and assigned crew can be broken out for an average payload. No Specialist contribution is shown for the preliminary flight plan because this plan is prepared before the crew has been selected. The major Specialist contributions (20 man-months) are made in the detailed flight plan that is prepared between Level IV and Level III integration, while the Payload and Mission Specialists are being trained by the Principal Investigators and equipment designers.

ADDITIONAL ADVANTAGES IN USE OF SPECIALISTS FOR FLIGHT PLANNING

- ELIMINATES COST OF EDUCATING A SPECIALIZED GROUP OF PEOPLE ON EQUIPMENT CHARACTERISTICS, SCIENTIFIC OBJECTIVES AND EXPERIMENT PROCEDURES

- GREATLY REDUCES THE COST OF TRAVEL FROM THE LEAD CENTER TO PI'S FACILITY OR TO THE EQUIPMENT CONTRACTORS' LOCATIONS.

- REMOVES AN EXPENSIVE INTERFACE BETWEEN THE PI'S AND THE PAYLOAD AND MISSION SPECIALISTS, I.E., ELIMINATES A GROUP OF PEOPLE WHO TRANSLATE PI'S EXPERIMENT PROCEDURES INTO A FLIGHT PLAN AND SUBSEQUENTLY EDUCATE THE SPECIALISTS ON THE PLAN

- TRADES THE COST OF APPOINTING BACKUP SPECIALISTS TO HELP IN FLIGHT PLANNING AND POC DUTY VERSUS THE COST OF TRAINING DEDICATED FLIGHT PLANNERS FOR THESE FUNCTIONS

ADDITIONAL ADVANTAGES IN THE USE OF SPECIALISTS FOR FLIGHT PLANNING

If specialized flight planners were to be assigned to this function, they would have to become familiar with all details of equipment and objectives in order to do the flight planning. Also, their flight plan would later have to be studied and understood by the flight crew. Both of these costs can be reduced having the specialists participate in the flight planning as they do their training, with support from the Lead Center for formatting and documentation.

Backup specialists enhance the capability of the crew to do flight planning and to support the payload from POC consoles. Both these functions have to be performed and it appears economically and operationally desirable to assign and use backup specialists in this mode.

Since the specialists must visit PI's and equipment contractors for the training activity, no extra travel costs are incurred for their portion of payload flight planning.

PAYLOAD AND MISSION SPECIALISTS FOR FLIGHT PLANNING

SUMMARY

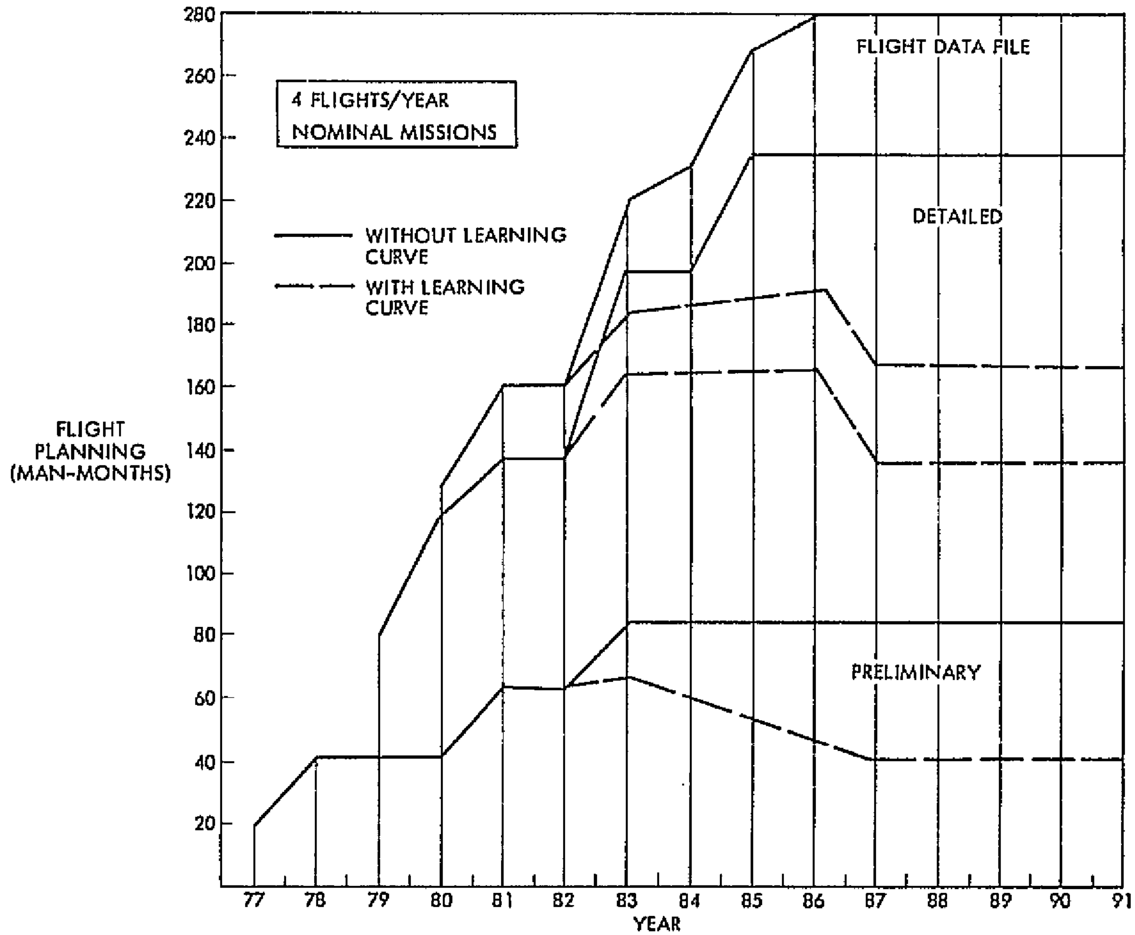
- COMBINED TRAINING AND PLANNING ACTIVITIES
  - PAYLOAD SPECIALIST DOES EXPERIMENT PROCEDURES
  - MISSION SPECIALIST DOES IN-FLIGHT REPLANNING/COORDINATION PROCEDURES
- CONTINUITY OF PERSONNEL
  - BACK-UP FLIGHT CREW BECOMES POC TEAM
  - LEAD CENTER PROJECT TEAM PROVIDES DETAILED SUPPORT
- FEATURES
  - MINIMIZES MANLOADING
  - AVOIDS FORMAL TRAINING OF EXPERIMENT PAYLOAD SPECIALISTS ON PROCEDURES DEVELOPED BY OTHER PEOPLE
  - REDUCES NEED FOR A "TRAINING TEAM", WHICH WOULD HAVE TO BE TAUGHT EXPERIMENT OPERATIONS IN ORDER TO WRITE AN EXPERIMENT FLIGHT PLAN

PAYLOAD AND MISSION SPECIALISTS FOR FLIGHT PLANNING

SUMMARY

The major characteristics of Payload and Mission Specialists participation in payload flight planning are summarized on the facing page. By combining the training and planning activities, as shown, the flight plan benefits from the Specialists' scientific background, their intimate contacts with Principal Investigators and equipment designers, and their thorough understanding of the flight plan. For operation of the POC, the backup crew will be supporting a payload flight plan that they have helped prepare, with a significant improvement in understanding of timelines, procedures, and consumables plan. Manpower requirements are minimized, not only in preparation of the flight plan but also in the transfer of information that would be required if the flight plan were prepared by other people.

FLIGHT PLANNING MAN-MONTHS USING PAYLOAD AND MISSION SPECIALISTS



	77	78	79	80	81	82	83	84	85	86	87	88	89	90
SPACELAB PAYLOAD FLIGHT/YEAR				1	2	2	2	3	3	4	4	4	4	4
FP MAN-MONTHS	21	42	80	129	161	161	220	231	269	280	280	280	280	280
EQUIVALENT PERMANENT EMPLOYEES	2	4	7	11	13	13	19	20	23	24	24	24	24	24
EQUIVALENT EMPLOYEES USING LEARNING CURVE					13	13	16	16	16	16	14	14	14	14
MANMONTHS WITH LEARNING CURVE						160	185	185	190	190	165	165	165	165
EQUIVALENT EMPLOYEES WITH LEARNING CURVE						13	16	16	16	16	14	14	14	14
EQUIVALENT EMPLOYEES WITH LEARNING CURVE USING PS&MS						5	8	8	8	8	6	6	6	6

FLIGHT PLANNING MAN-MONTHS USING PAYLOAD AND MISSION SPECIALISTS

Manpower requirements for payload flight planning have been estimated for a Lead Center supporting up to four average-payload flights/year with participation by Payload and Mission Specialists. The estimates have been made with and without consideration of a learning curve. At the rate of four flights per year, it has been estimated that, for average payloads, a total of 92 man-months year can be provided by the assigned Payload and Mission Specialists, i.e., 23 man-months per individual crew. The 92 man-months equate to eight full-time flight planners, thus reducing the required equivalent permanent employees as shown on the chart.

OPERATIONS CONCEPTS THAT REDUCE MANPOWER

RESULTS

- MOST CONTINGENCIES ARE RESOLVED IN REAL TIME
- LIMITING FLIGHT PLANNING ITERATIONS REDUCES MANPOWER AND COMPUTER USAGE
- MANPOWER REQUIREMENT FOR PLANNING VARIES SIGNIFICANTLY WITH PAYLOAD DISCIPLINE
- THE NASA COMPUTATIONAL CAPABILITY FOR FLIGHT PLANNING IS GENERALLY SUFFICIENT FOR EARLY YEARS
- SIGNIFICANT MANPOWER SAVINGS ARE POSSIBLE BY COMBINING CREW TRAINING AND FLIGHT PLANNING ACTIVITIES

RECOMMENDATIONS

- ADOPT DECENTRALIZED FLIGHT PLANNING AT EACH LEAD CENTER
- CONSIDER THE COMBINATION OF SOMF ASPECTS OF FLIGHT PLANNING AND FLIGHT CREW TRAINING

RECOMMENDED ADDITIONAL NASA ACTIVITIES

NEED TO LOOK AT EQUIPMENT REQUIREMENTS OF TOTAL TRAINING PROGRAM

- STS
- SPACELAB
- PAYLOAD
- GROUND CREWS

NEED TO PERFORM DETAILED POC REQUIREMENTS STUDY

- MCC CAPABILITY
- PAYLOAD DATA HANDLING
- CREW AUTONOMY

NEED TO LOOK AT TOTAL CAPABILITY OF NASA TO SUPPORT FLIGHT PLANNING

- SOFTWARE
- COMPUTERS
- TOTAL WORK LOAD

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