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Summary Report

GUIDELINES FOR MISSION INTEGRATION

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SUMMARY REPORT
SP79-MSFC-2392

GUIDELINES FOR MISSION INTEGRATION

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GEORGE C. MARSHALL SPACE FLIGHT CENTER

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PREPARED BY

SPACE SYSTEMS DEPARTMENT
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FOREWORD

This guidelines document was prepared by Teledyne Brown Engineering for NASA's George C. Marshall Space Flight Center under Contract NAS8-32711. The project was conducted under the direction of Mr. Richard E. Valentine, COR, JA61, MSFC. The information contained in this document will be updated as required. Any specific questions regarding this material should be directed to Mr. Valentine, telephone (205) 453-3423.

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GLOSSARY

Cargo	The total complement of payloads (one or more) on any one flight. It includes everything contained in the Orbiter cargo bay plus other equipment, hardware, and consumables located elsewhere in the Orbiter that are user-unique and are not carried as part of the basic Orbiter payload support.
Cargo Integration Review	Part of STS planning process that results in a cargo manifest, cost per flight, and billing schedule.
Certificate of Compliance	Documentation prepared by the user confirming that a payload has successfully completed interface verification.
European Space Agency	An International organization acting on behalf of its member states (Belgium, Denmark, France, Federal Republic of Germany, Italy, the Netherlands, Spain, Sweden, Switzerland, and the United Kingdom. The ESA directs a European industrial team responsible for the development and manufacture of Spacelab.
Experiment	The actual science investigation that may use available data, or use an instrument facility, or a combination of the above to obtain scientific data.
Experimenter	A user of the Space Transportation System who ordinarily will be an individual whose experiment is a small part of the total payload.
Facility	Hardware designed for performance of multiple experiments and reflight. Performance of the experiments may require additional experiment instrument hardware or may be accomplished by operation of the basic facility in a prescribed operation or sequence to meet a given experiment's objectives. A facility will often be provided by the government for the performance of several Principal Investigator (PI) experiments.
Instrument	Hardware designed to accomplish a limited number of experiments or investigations. The instrument is usually furnished by a principal investigator. He may have other PI's or co-PI's share the instrument to obtain experiment data.
Integration	A combination of activities and processes to assemble payload and STS components, subsystems, and system elements into a desired configuration, and to verify compatibility among them.

GLOSSARY (Concluded)

Mission	The performance of a coherent set of investigations or operations in space to achieve program goals. A single mission might require more than one flight, or more than one mission might be accomplished on a single flight.
Mission Specialist	This crewmember is responsible for coordination of overall payload/STS interaction and, during the payload operations phase, directs the allocation of the STS and crew resources to the accomplishment of the combined payload objectives. The mission specialist will have prime responsibility for experiments to which no payload specialist is assigned, and/or will assist the payload specialist when appropriate.
Payload	The total complement of specific instruments, space equipment, support hardware, and consumables carried in the Orbiter (but not included as part of the basic Orbiter payload support) to accomplish a discrete activity in space.
Payload Specialist	This crewmember, who may or may not be a career astronaut, is responsible for the operation and management of the experiments or other payload elements that are assigned to him or her, and for the achievement of their objectives. The payload specialist will be an expert in experiment design and operation.
Principal Investigator	Research scientist who is in charge of the conduct of an experiment carried by any STS element.
Program	An activity involving manpower, material, funding, and scheduling necessary to achieve desired goals.
Space Transportation System	An integrated system consisting of the Space Shuttle (Orbiter, external tank, solid rocket booster, and flight kits), upper stages, Spacelab, and any associated flight hardware and software.
User	An organization or individual requiring the services of the Space Transportation System.

DEFINITION OF ACRONYMS

AFD	Aft Flight Deck
AI	Analog Input
ASPS	Annular Suspension "Pointing" System
ATP	Authority To Proceed
CAMAC	Computer Automated Measurement and Control
CBP	Connector Bracket Panel
CCT	Computer Compatible Tapes
CDMS	Command and Data Management Subsystem
CDR	Critical Design Review
CPSS	Cold Plate Support Structure
DDS	Data Display System
DEP	Dedicated Experiment Processor
ECAS	Experiment Computer Application System
ECE	Experiment Checkout Equipment
ECOS	Experiment Computer Operating System
ECS	Environmental Control System
EGSE	Electrical Ground Support Equipment
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EPBD	Experiment Power Branching Distributor
EPP	Experiment Preparation Program
EPSP	Electrical Power Switching Panel
ERD	Experiment Requirements Document
ESA	European Space Agency
EVP	Equipment Verification Plan
FDOR	Final Design and Operations Review
FMDM	Flexible Multiplexer/Demultiplexer
FOR	Flight Operations Review
FOV	Field Of View
FRR	Flight Readiness Review
FS	Factor Of Safety
FSE	Flight Support Equipment

DEFINITION OF ACRONYMS (Continued)

GCLT	Ground Computer Log Tape
GIRD	Ground Integration Requirements Document
GMT	Greenwich Mean Time
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
HDLT	High Data Log Tape
IPLIDE	Integrated Payload Initial Design Evaluation
HIU	Hardware Interface Unit
HRM	High Rate Multiplexer
IH/SR	Integrated Hardware/Software Review
IIA	Instrument Interface Agreement
IMU	Inertial Measurement Unit
I/O	Input/Output
IPLRR	Integrated Payload Requirements Review
IPRD	Integrated Payload Requirements Document
IPS	Instrument Pointing System
IRDP	Integration Readiness Data Package
IWG	Investigators' Working Group
JSC	Johnson Space Center
MDE	Mission Dependent Equipment
MET	Mission Elapsed Time
MGSE	Mechanical Ground Support Equipment
MIA	Mission Implementation Agreement
MPE	Mission Peculiar Equipment
MROSIE	Mission Requirements On Spacelab Instruments/ Experiments
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
PCM	Pulse Code Modulation
PCU	Payload Checkout Unit
PDR	Preliminary Design Review
PI	Principal Investigator
PMIC	Payload Mission Integration Contractor

DIFINITION OF ACRONYMS (Concluded)

POCC	Payload Operations Control Center
RAU	Remote Acquisition Unit
RCS	Reaction Control System
RR	Requirements Review
SPAH	Spacelab Payload Accommodations Handbook
SP&R	Safety Policy and Requirements
SSME	Space Shuttle Main Engine
STS	Space Transportation System
TP	Twisted Pair
TSP	Twisted Shielded Pair
TV	Television
VS	Video Switch

1. INTRODUCTION

The purpose of this document is to provide guidelines for instrument/experiment developers concerning hardware design, flight verification, and operations and mission implementation requirements that must be satisfied after a mission is assigned. The approach in preparing these guidelines is to discuss the documentation where the user can find detailed information, to clarify or supplement data from these references, and to discuss and show pertinent examples of the payload integration work performed to date for Spacelab Missions 1, 2, and 3. Appendix A of this document contains a complete list of the referenced documents, the NASA Center where the documents originate, and the address of the organization that can provide the documents.

Section 2 lists the documentation where instrument/experiment developers can find Space Transportation System (STS) accommodations information. Interface requirements between the STS and instruments/experiments are defined. Interface constraints and design guidelines are presented along with integrated payload requirements for Spacelab Missions 1, 2, and 3. In some cases, interim data are suggested for use during hardware development until more detailed information is developed when a complete mission and an integrated payload system are defined. Separate subsections are developed to define safety requirements, flight verification requirements, and operations procedures.

Mission implementation requirements that an instrument/experiment developer must satisfy after he is assigned a mission are outlined in Section 3. General mission requirements are discussed for Spacelab instruments/experiments. Information flow between the Payload Mission Manager and the developer is discussed for two mission implementation scenarios: (1) instrument/experiment development in phase with the mission schedule and (2) instrument/experiment development underway or completed before a mission is assigned.

2.0 INSTRUMENT/EXPERIMENT DESIGN, VERIFICATION, AND OPERATIONS GUIDELINES

The purpose of this section is to aid the investigator in developing his hardware and operational aspects of his experiment. The main thrust of the topics in this section will be to discuss the documentation where the user can find basic accommodations inforation; secondly, to clarify or supplement data from these references; and thirdly, to discuss and show pertinent examples of the payload integration work performed to date for Spacelab Missions 1, 2, and 3.

2.1 INSTRUMENT/EXPERIMENT REQUIREMENTS

The development of instrument/experiment requirements starts with an instrument/experiment concept; and the refinement and detailed development of these requirements carry through the conceptual design, preliminary design, and final design phases. The next two subsections will deal with the STS accommodations available for users and a mechanism for specifying instrument/experiment requirements.

2.1.1 Accommodations Available

Table 2-1 lists documentation that presents accommodation information. Other supplemental documentation is referenced throughout this section. A complete list of the referenced documents, including the NASA Center where the documents originate and the address of the organization that can provide the documents, is contained in Appendix A.

2.1.2 Specifying Requirements

The Marshall Space Flight Center (MSFC) has developed a format (MSFC Form 3591) to guide the user in stating the requirements that must be considered in meeting the total mission goals. The format, which is basically a checklist type approach, has as its major headings:

- Experiment Operation and Configuration
- Flight Operations and Environments
- Electrical Requirements

TABLE 2-1. STS PAYLOAD ACCOMMODATIONS DOCUMENTATION

	DOCUMENT TITLE	DOCUMENT NO.
1.	Space Shuttle System Payload Accommodataions, Volume XIV	JSC 07700
2.	Shuttle Orbiter/Cargo Standard Interfaces, JSC 07700, Vol. XIV, Attachment 1	ICD 2-19001
3.	Shuttle Vehicle/Spacelab Structural/Mechanical Interfaces	ICD 2-05101C
4.	Spacelab Payload Accommodations Handbook (SPAH)	ESA SLP/2104
	SPAH Avionics Interface Definition	Appendix A
	SPAH Structural Interface Definition - Module	Appendix B
	SPAH Structural Interface Definition - Pallet	Appendix B-1
	SPAH Thermal Interface Definition	Appendix C (To be published)
5.	POCC Capabilities Document	JSC-14433
6.	Payload Operations Control Center Format Standards	JA-053
7.	Spacelab Payload Mission Operations	JA-063
8.	Spacelab Program Software Users Guide	MDC G6854B
9.	Experiment Computer Operating System (ECOS) Design Specification	ECO-8945A
10.	ECOS Requirements Definition Document	MDC G6862C
11.	Spacelab High Rate Multiplexer (HRM) Format Standards	MSFC-STD-630
12.	Spacelab Experiment Computer Application Software (ECAS) Display Design and Command Usage Guidelines	MSFC-PROC-711
13.	KSC Launch Site Accommodations Handbook for STS Payloads	KSC K-STSM-14.1 K-STSM-09, Vol. VI
14.	Experiment Checkout Equipment (ECE) to be Utilized at Kennedy Space Center (KSC), May 31, 1979	Memo MSFC-JA31 (79-125)

- Thermal Control Requirements
- Command, Data Management, and Software
- Ground Processing Operations.

As a guideline in determining and specifying equipment properties and requirements, estimates (e.g., mass, power required, heat dissipation) should be given that reflect the best judgment at the time and also consider possible growth as the design matures. For example, in the conceptual stage, flight equipment mass properties might be listed as 100 kg + 20 kg. This takes into account a growth contingency based on the stage of development and allows for a more realistic allocation of resources. In addition to the information specifically requested by the MSFC form, any additional information such as schematics, drawings, and results of analyses should also be included in the package.

2.2 INTERFACE COMPATIBILITY REQUIREMENTS

The major emphasis of this section will be to clarify and define more explicitly the interfaces that will exist between the STS and instruments/experiments. Interfaces as discussed here will include physical (e.g., mechanical mounting, electrical connections), environmental (e.g., contamination, electromagnetic interference), and operational (e.g., flight operations, ground operations). The Instrument Interface Agreement (discussed in 3.1.4) which is developed jointly between the Payload Mission Manager and the Investigator is the mechanism that controls the interface definition and ensures compatibility and adequate resources for proper operation of the instrument/experiment.

2.2.1 Flight Support Equipment (FSE)

Figures 2-1 and 2-2 schematically show typical rack-mounted and pallet-mounted instrument interfaces. These figures indicate that a typical instrument usually requires interfacing with a substantial amount of FSE. FSE is defined as consisting of Mission Dependent Equipment (MDE) or Mission Peculiar Equipment (MPE). MDE is provided from a Spacelab inventory. MPE is special purpose hardware developed for matching instruments to integrated payload interfaces. MPE required for interfacing components with basic Spacelab or Orbiter systems will be provided by the Payload Integrator. The experimenter

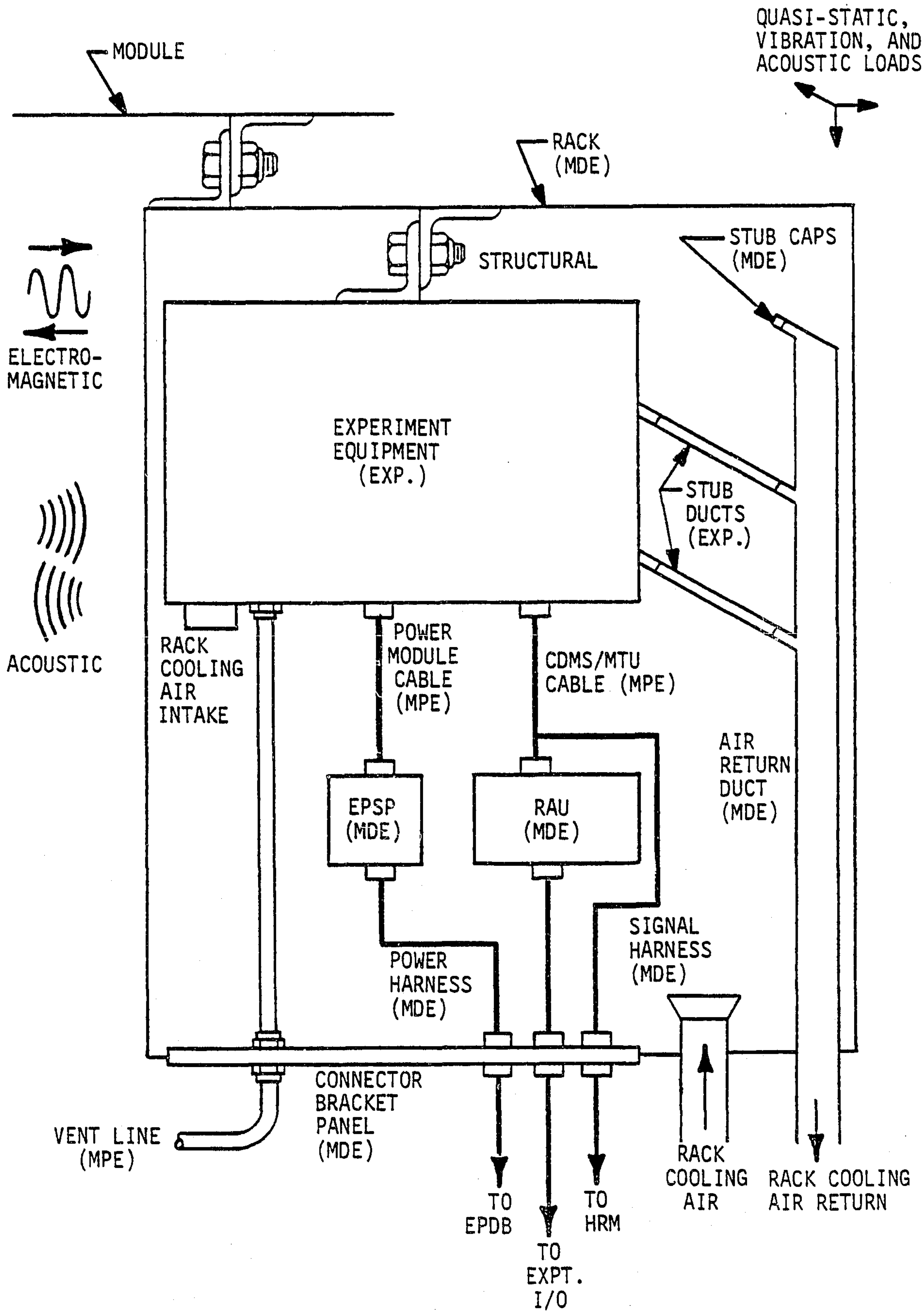


FIGURE 2-1. TYPICAL RACK-MOUNTED EXPERIMENT INTERFACES

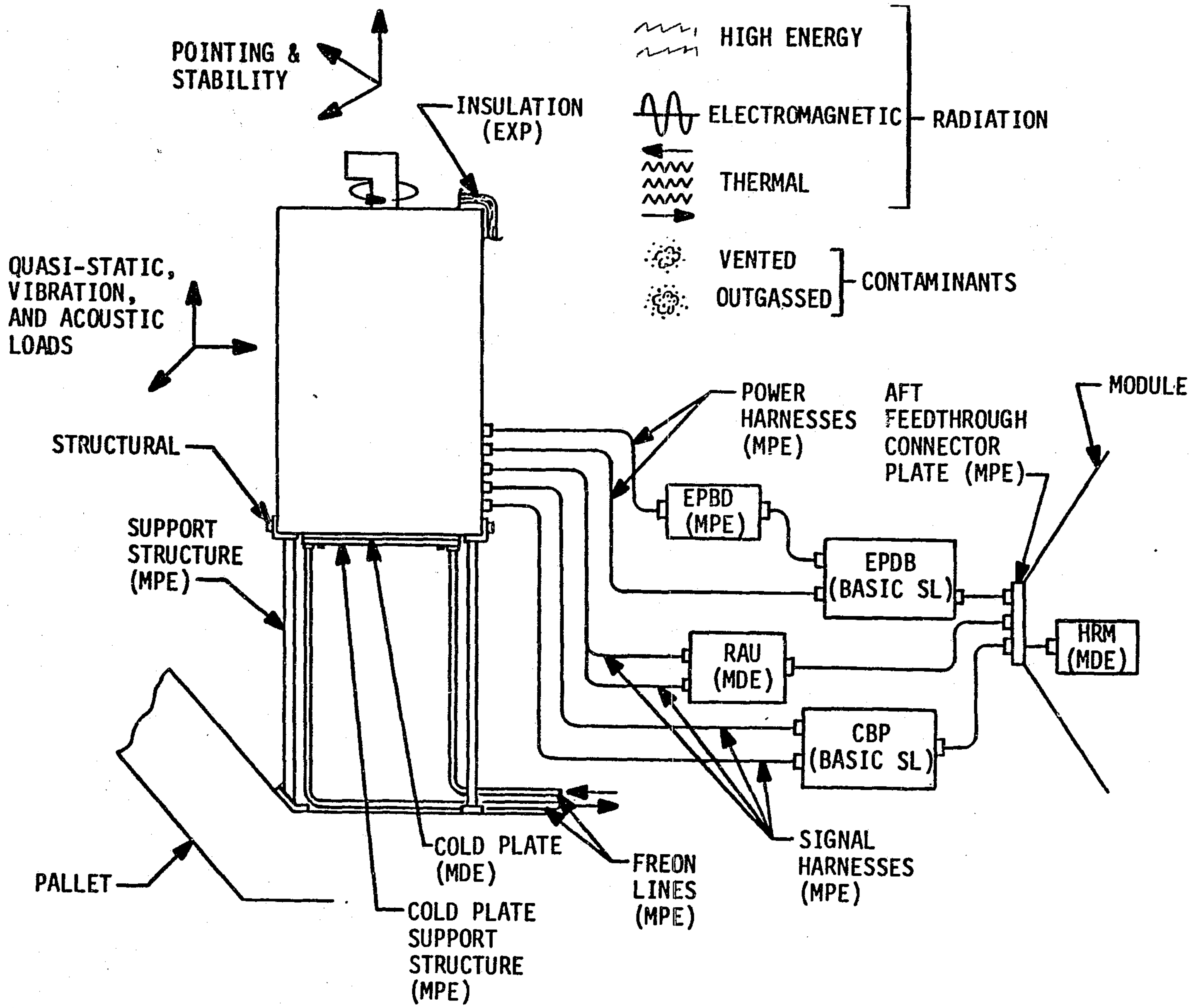


FIGURE 2-2. TYPICAL PALLET-MOUNTED EXPERIMENT INTERFACES

has the responsibility for interfacing one experiment component with another component of the same experiment.

The Integrated Payload Requirements Document (IPRD) defines and lists the MDE and MPE for a totally integrated payload. This information for the first three Spacelab missions can be found in the following documents:

Mission	IPRD No.
Spacelab Mission 1	MSFC JA-010
Spacelab Mission 2	MSFC NR-JA-017
Spacelab Mission 3	MSFC NR-JA-019

2.2.1.1 Mission Dependent Equipment (MDE) - Table 3-4 of the SPAH lists the MDE which can be flown according to the requirements of a particular mission. The interface details of the MDE are provided in the relevant subsystem sections of the SPAH and its Appendices.

2.2.1.2 Mission Peculiar Equipment (MPE) - Much of the MPE developed for Spacelab Missions 1, 2, and 3 will be applicable for future missions. Brief descriptions of some of the major items of MPE developed for Spacelab Mission 1 are included here.

Primary Platform (Orthogrid) - The primary platform (orthogrid) consists of a mounting surface for experiments and supporting struts for attaching it to the pallet. Its primary purpose is to raise experiment instruments off the pallet floor to provide them with a better field of view over the pallet sides. The mounting surface has a 70 mm hole grid pattern with cutouts between the mounting holes to save weight and to provide cable and piping feed-through capability.

Secondary Platforms - Secondary platforms are required to support certain instruments and equipment at a higher elevation than that provided by the primary platform to afford them the required field of view. The multi-experiment platform has an instrument mounting surface hole pattern that matches the cold plate hole pattern (70 mm grid).

Horizon Sensor - The horizon sensor is required to provide an indication of the orientation of the experiment equipment in the Orbiter payload bay with respect to the Earth's horizon. The information will be utilized in conjunction with the Orbiter provided attitude information to determine the payload orientation during flight. The performance requirements for the horizon sensor can be found in MSFC-SPEC-594.

Experiment Power Branching Distributor (EPBD) - The EPBD is a 28 Vdc (nominal) power branching distributor designed for mounting on a Spacelab pallet cold plate to provide remotely switched power to instruments. The EPBD is capable of accepting power through two inputs from a standard Spacelab Electrical Power Distribution Box. Each input power is fed through protective devices to six output connectors, or (as an option) one power input may feed all 12 output connectors. More information on the EPBD can be found in section 2.2.4.3. Specific requirements are contained in the EPBD specification. MSFC-SPEC-614.

Video Switch - The video switch (VS) is designed for Spacelab module rack-mounting and pallet-mounting configurations. Figure 2-3 shows the VS to Spacelab interface for power and signal.

More information on the design, performance, and interface requirements for MPE can be obtained from the MPE Requirements Document.

Mission	MPE Requirements Document
Spacelab Mission 1	MSFC JA-049
Spacelab Mission 2	TBD
Spacelab Mission 3	TBD

2.2.2 Structural/Mechanical

2.2.2.1 Structural/Mechanical Constraints - The design of instruments/facilities must stay within the limits of available accommodations with respect to envelope size, mass distribution, natural frequency, mechanical interfaces, and interface design loads. Structures must also have the capability to survive the design loading life spectrum.

2.2.2.1.1 Payload Envelopes - Experiment envelopes for single and double sized racks are presented in Figure 3.2-5 of the SPAH, Appendix B. The racks are designed to accommodate standard 19-in. panels. The rack/payload instrument interface mounting pattern is in accordance with MIL-STD-189. Figure 3.6-1 of the SPAH, Appendix B shows the experiment envelope for payloads located in the airlock while Section 3.6.2 of the same reference describes the viewport assembly.

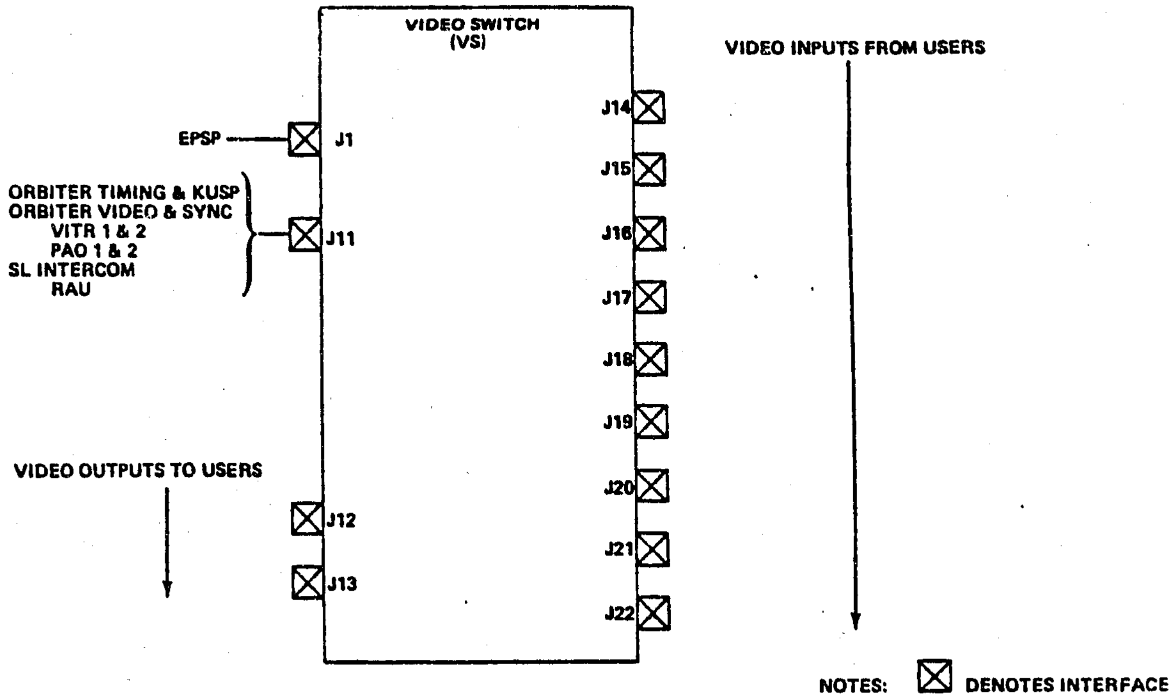


FIGURE 2-3. VIDEO SWITCH TO SPACELAB INTERFACES

The payload envelope for pallet-mounted equipment is shown in Figure 4.1-11 of the SPAH. Approximately 33 m^3 of volume are available above the floor of a single pallet.

2.2.2.1.2 Mass Distribution - The maximum rack payload mass capability is discussed in Section 3.2.6 of the SPAH, Appendix B. It should be noted that the maximum mass allowable in the upper part of the rack is 25 percent of maximum equipment mass.

The overall load carrying capabilities of a single pallet or pallet trains are discussed in Section 4.1.6 of the SPAH, Appendix B-1. There are 24 inner panels on each pallet with threaded inserts (arranged in a 140 x 140 mm grid) for the mounting of experiment equipment. The ultimate local load of 100 N per insert (Section 4.2.3.4, SPAH, Appendix B-1) is being revised upward. This change in load carrying capability will also increase for the cold plate support structure (CPSS) inserts (Section 4.2.4.3 of SPAH-B1).

2.2.2.1.3 Frequency Constraints - Hardware mounted to the pallet and module primary structure (e.g., fully loaded rack) should have a minimum natural frequency greater than 25 Hz. Hardware mounted to the module secondary structure (such as racks), orthogrid support structure, Instrument Pointing System (IPS) cruciform, aft and mid flight decks, Spacelab transfer tunnel, and airlock experiment table should have a minimum natural frequency greater than 35 Hz.

2.2.2.1.4 Mechanical Interfaces - The cold plate-experiment interface requirements are discussed in Section 4.3.1.3 of the SPAH, Appendix B-1. An example bolting pattern is shown in Figure 2-4 (example from SPAH) that complies with the standard bolting pattern for mounting equipment to a cold plate.

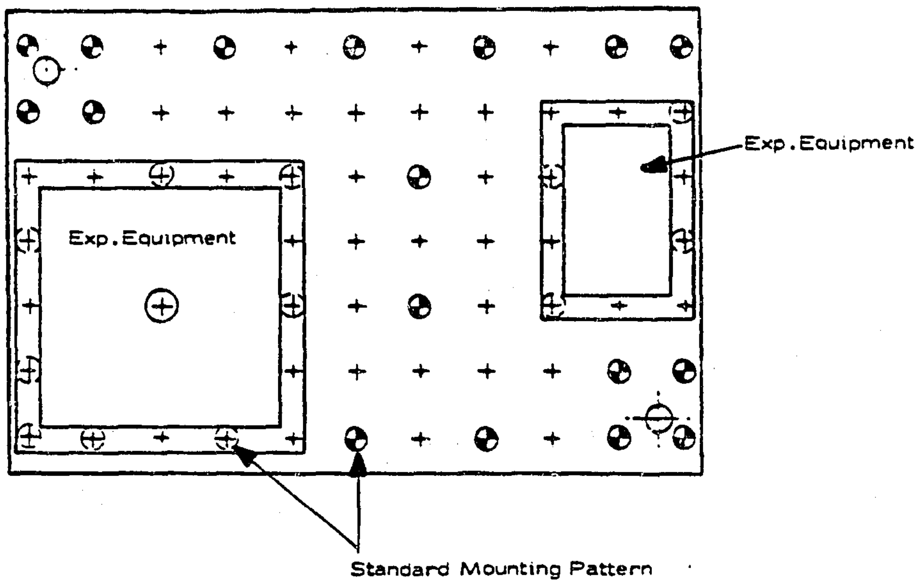


FIGURE 2-4. EXAMPLE - DIRECTLY MOUNTED EQUIPMENT (STANDARD BOLT PATTERN)

The instrument developer, in this case, is constrained to use the standard mounting holes in mounting his equipment or to make provisions for cold plate mounting hardware. The clearance requirement for cold plate hardware is a cylinder 10 mm high and 19 mm in diameter centered over the mounting hole and extending above the cold plate surface.

strain amplitude and N_{f_i} is the cycles to failure at the same amplitude (Miner's Rule).

TABLE 2-2. SAFETY FACTORS FOR EQUIPMENT HARDWARE AND MPE DESIGN

EXPERIMENT HARDWARE	YIELD	ULTIMATE	PROOF
<u>Structural Materials</u>			
Safety Critical Structures			
• Verified by Analysis Only			
- Quasi-Static Loads	1.25	2.0	
- Random Vibration Loads		1.4	
• Verified by Analysis and Static Test*			
- Quasi-Static Loads	1.1	1.4	
- Random Vibration Loads		1.0	
Non-Safety Critical Structures			
• No Test Required			
- Quasi-Static Loads	1.1	1.4	
- Random Vibration Loads		1.0	
Pressurized Lines and Fittings		4.0	2.0
Pressure Tanks, Actuating Cylinders, Valves, Filters, and Switches		2.0	1.5

*Test levels shall not exceed plastic deformation point when testing proto flight hardware.

MISSION PECULIAR EQUIPMENT	YIELD	ULTIMATE
• Structures Verified by Analysis Only		
- Quasi-Static Loads	1.25	2.0
- Random Vibration Loads		1.4
• Structures Verified by Analysis and Test*		
- Quasi-Static Loads	1.1	1.4
- Random Vibration Loads		1.0

*Test levels shall not exceed plastic deformation point when testing proto flight hardware.

2.2.2.1.5 <u>Interface Design Loads</u> - Interface design loads are expressed in terms of quasi-static (steady-state and/or low frequency dynamic) loads and random vibration (high frequency dynamic) loads. The combinations of these loads with the application of appropriate safety factors are used to:

- Design experiments
- Size experiment/bracket interfaces
- Size brackets
- Size bracket/pedestal interfaces
- Size pedestals
- Size pedestal/large support structure interfaces.

Safety factors for equipment hardware and MPE designs are presented in Table 2-2. The methodology for the determination of the preliminary design loads is presented in Section 2.2.2.2. Final experiment design loads are based on a coupled Shuttle/Spacelab/Payload dynamic analysis.

2.2.2.1.6 <u>Fatigue Design Criteria</u> - Fatigue analyses shall be performed which verify the capability of the structure to survive the design loading life spectrum.

All concurrently occurring loadings shall be considered and rationally combined to represent a conservative appraisal of the loading during each successive design loading event. Analysis shall include the combined effects of static loading, low cycle loading, and high cycle loading. Low cycle loads are loads which are applied 10^4 times or less, and high cycle loads are applied greater than 10^4 times, during the design life.

The following life factors shall be used to take into consideration the interaction of high- and low-cycle fatigue:

$$4\phi_{LF} + \phi_R \leq 1.0$$

where

ϕ_{LF} = low frequency fatigue damage

ϕ_R = random fatigue damage.

Fatigue damage shall be evaluated by a linear damage accumulation, $\phi_f = \Sigma \frac{n_i}{N_{f_i}}$, where n_i is the actual number of cycles at a particular stress or strain amplitude, and N_{f_i} is the cycle to failure at the same amplitude (Miner's Rule).

For the purpose of fatigue evaluation, the duration of the high-cycle loadings shall be 50 sec plus 20 sec per mission and shall be assumed to begin at lift-off. Durations for low-cycle loadings are given in Table 2-3. Fatigue design considerations are discussed in more detail in Section 2.2.2.2.2.

TABLE 2-3. FLIGHT DURATION TIME PER MISSION FOR LOW CYCLE FATIGUE ASSESSMENT

CONDITION	TIME (sec)
Lift-off	9
High Q Boost	35
Max. Boost	35
Orbiter Max. Load	100
Entry and Descent Maneuvers	
± Pitch	120
± Yaw	120
± Roll	120
Landing	10

2.2.2.2 Structural Analysis Guidelines - The principal concern addressed here is to promote the design of a safe structure for use in the Orbiter payload bay. Thus the suggested techniques are directed toward each "experiment package" and its supporting structure which mounts the experiment to the Spacelab (e.g., pallet or module rack). This procedure is not intended to cover the functional integrity but to ensure that structural failure does not jeopardize crew or Orbiter safety.

Steady-state and low frequency vehicle dynamic loads are treated as quasi-static loads since their rate of variation is low enough to have minimal fatigue effect on the structure. However, quasi-static loads, when applied in combination with high frequency alternating loads, may have an important fatigue effect (this will be discussed in the Fatigue Section). Quasi-static loads are generally produced by Shuttle maneuvers, thrust loads, or structural responses to externally applied loads, such as wind shears, reentry drag, landing impact, etc. Other sources of static loading are pressure and thermally induced loads. Random vibration loads in an experiment structure result from the structural response to high frequency excitational environments such as acoustic or mechanical excitation. Examples are rocket engine acoustically and mechanically induced vibrations during launch.

2.2.2.2.1 Design Loads - Design loads and the application of factors of safety (FS) are defined as follows:

Ultimate Load = FS_1 (Quasi-Static Load) + FS_2 (Random Vibration Load)

Yield Load = FS_3 (Quasi-Static Load + Random Vibration Load).

Determination of quasi-static and random vibration loads follows:

2.2.2.2.1.1 Quasi-Static Loads (P_s) - The corresponding quasi-static load may be determined for each axis by multiplying the total mass of each separately supported component by the appropriate load factor. Load factor data are presented in the SPAH, Tables 5-9 through 5-12, for module-mounted and pallet-mounted equipment. Table 4.2.1.1.1-1 of ICD 2-19001 gives load factor data for equipment mounted in the aft flight deck region. Figure 2-5 indicates the sign convention.

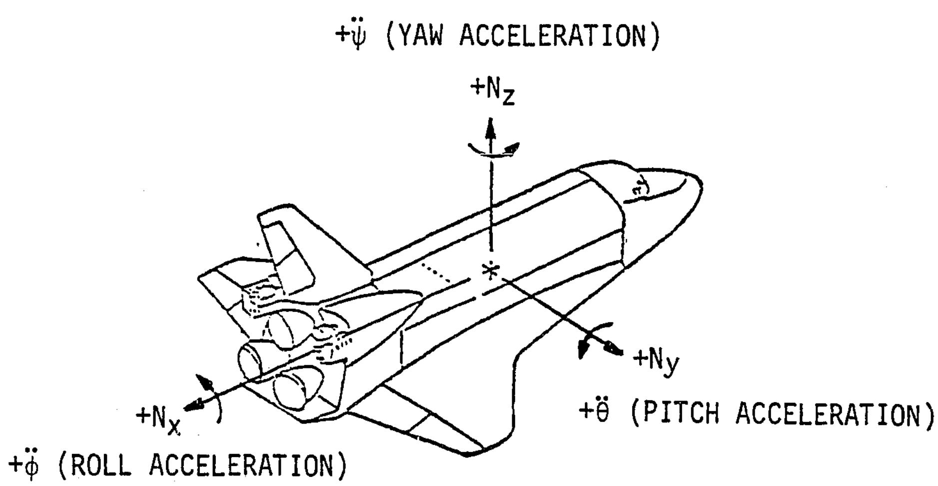


FIGURE 2-5. STRUCTURE COORDINATE SYSTEM AXIS CONVENTION

2.2.2.2.1.2 Random Vibration Loads (P_V) - Random vibration loads can be determined by multiplying the total mass by the appropriate random load factor determined for each axis. Random load factors can be calculated as follows:

Using Miles relationship: (f_n < 1200 Hz)

$$\text{Random load factor} = 3\sqrt{\frac{\pi}{2} Q f_n \, PSD}$$

Q = Magnification factor (determined from test data or estimated, usually 5 to 10)

f_n = First resonant frequency in each flight axis (Hz)

PSD = Power spectral density (g^2/Hz) at f_n.

For the cases where $f_n \geq 1200$ Hz:

Random load factor = 3 x G_{rms}

G_{rms} = composite load factor.

PSD and composite load factor data can be obtained from the SPAH, Tables 5-2, 5-3, and 5-4.

2.2.2.2.1.3 Experiment Preliminary Design Loads When Experiment is Mounted Directly to Pallet or Module - Total limit load factor curves (quasi-static load factor plus random load factor) are presented in various sections of the SPAH, Appendix B for specific application. These data can be used for experiment preliminary design if the experiment is to be mounted directly to the structure for which the load factors were developed.

The total limit load factor must first be separated into quasi-static and random load factors so that the appropriate safety factors can be applied. The combined load factors should be considered as absolute values. Therefore, the maximum quasi-static load factors from Tables 5-9 through 5-12 in the SPAH and Table 4.2.1.1.1-1 of ICD 2-19001 should also be considered as absolute values. These load factors should be subtracted from the combined load factors to determine the random load factors. The quasi-static and random load factors are then amplified by the appropriate safety factor and recombined to be used in calculating design loads.

The appropriate safety factors are presented in Table 2-2. The total load factors (with the appropriate safety factors) are used for design/assessment of each Spacelab experiment, the experiment support brackets, connections between the brackets and experiment and between the brackets and Spacelab primary or secondary structure, and for assessment of the local primary or secondary structure where the bracketry attaches (footprint loads).

The approach in performing a design/assessment analysis of the most critical loading cases should consist of the following points:

- Applying the static (P_S) and vibration (P_V) loads at the center of gravity (c.g.) of the total mass of the structure to be analyzed, being careful to apply the safety factors as stated above.

- Load components shall be applied to the X, Y, and Z directions simultaneously
- Every possible loading combination should be compared noting that many load factors have both positive and negative values.

- Using the most critical loading case (or cases), calculate the most critical margins of safety of the experiment structure.

Margin of safety is defined as:

$$\text{Margin of safety} = \frac{\text{Allowable Load}}{\text{Design Load}} - 1 > 0.$$

It should be noted that final load factors can only be determined by a coupled Shuttle/Spacelab/Payload dynamic analysis.

Additional test criteria and supplemental design data on vibration, acoustics, and shock design are presented in NASA Memorandum EE41-67-78 and attachments EL 32 (78-78) and ED23-78-116.

2.2.2.2.2 Fatigue Analysis - When alternating loads are to be experienced by the experiment and its mounting, the structure must be shown to possess sufficient fatigue life. If the static strength analysis shows that the magnitude of the combined limit stresses is less than the endurance limit of the material, the fatigue analysis may be omitted since infinite fatigue life is ensured. An acceptable method of evaluating Spacelab experiments is described below.

All concurrently occurring loadings must be considered and rationally combined to represent a conservative appraisal of the loading during each successive design loading event. Analysis must include the combined effects of static loading, low frequency loading, and random vibration loading.

The following life factors must be used to take into consideration the interaction of low frequency and random vibration fatigue.

$$4\phi_{LF} + \phi_R \leq 1.0$$

where

ϕ_{LF} = low frequency fatigue damage

ϕ_R = random fatigue damage.

Fatigue damage, ϕ_f, may be evaluated by a linear damage accumulation, $\phi_f = \Sigma\frac{n_i}{N_{f_i}}$, where n_i is the actual number of cycles at a particular stress amplitude and N_{f_i} is the cycles to failure at the same amplitude (Miner's Rule).

The maximum stress, either at the surface or internal, should be used in all fatigue analyses. The two categories of stress to be considered in a fatigue analysis are:

- Alternating Stress - Any stress which changes as a function of time or flight event. Typical examples are stress results from low frequency and random loads as described above.
- Mean Stress - Any constantly applied stress.

The fatigue analysis of components that are life-limited must demonstrate a calculated life for random vibration of 70 sec for the first mission plus 20 sec for each additional mission, beginning at Space Shuttle Main Engine (SSME) ignition, and for low frequency loadings, the event times specified in Table 2-3 of Section 2.2.2.1.6. Both the alternating and mean stresses should include the effects of fatigue concentration factors.

Combined Mean and Alternating Stress - Constant life fatigue data may be used when available. When not available, the modified Goodman rule may be used, as represented by the formula:

$$\sigma_{EQUIV} = \frac{\sigma\ ALT}{1 - \frac{\sigma_{MEAN}}{F_{TU}}}$$

where

σ_{EQUIV} = the pure alternating stress which is equivalent to the combination of alternating and mean stresses

σ_{ALT} = alternating stress (1/2 total amplitude)

σ_{MEAN} = mean stress

F_{TU} = ultimate tensile strength of the material.

The Goodman rule may be used in calculating life when both alternating stress and mean stress are present.

Using the equivalent alternating stress, σ_{EQUIV}, the fatigue life of the structural element may be determined from a fatigue life, Stress vs Number of Cycles (S-N) curve, for the material being analyzed. The fatigue life thus determined is the N_{f_i}, or "cycles of failure," which was described earlier in the linear damage equation for ϕ_f.

Flow charts, Figures 2-6 and 2-7, show a step-by-step procedure which may be used to evaluate the fatigue life of an experiment considering random vibration fatigue damage and low frequency fatigue damage, respectively. As noted above, fatigue analysis is only necessary where the total limit stresses exceed the fatigue endurance limit of the material.

2.2.3 Thermal Control

The comments in this section will point out some subsystem and system constraints that should be considered by the user in developing experiment requirements. Reference will also be made to the degree of total payload integration difficulty as a function of user requirements. In addition, thermal design guidelines are offered with respect to rack- and pallet-mounted equipment.

2.2.3.1 Thermal Constraints - The following sections outline some of the thermal constraints that pertain to the environmental control subsystems.

2.2.3.1.1 Environmental Control and Life Support - Cabin air temperature extremes of 5 °C to 50 °C for the launch/ascent and reentry phases of a mission will impose some restrictions on Life Sciences experiments. Limited available power during these mission phases also limit the performance of supplemental Environmental Control System (ECS) MPE that can be utilized to offset these possible temperature extremes.

2.2.3.1.2 Experiment Thermal Control - Cabin Air - The primary purpose of the cabin air loop is to provide conditioned air within established comfort criteria for the crew in the module. Cabin air can also be used for cooling equipment in the module center aisle, high quality window/viewport, and airlock. However, large amounts of cabin air (25% of cabin flow) diverted for experiment cooling can produce severe verification problems of the cabin air flow.

2.2.3.1.3 Experiment Thermal Control - Avionics Air Loop - From an integrated payload standpoint, the most favorable air flow distribution in the racks is that resulting in the lowest pressure drops through the distribution ducts. This distribution results from an equal allocation of the total flow between the right and left sides of the module (Figure 2-8) and when the racks requiring air flow are near the forward end of the module. Approximately

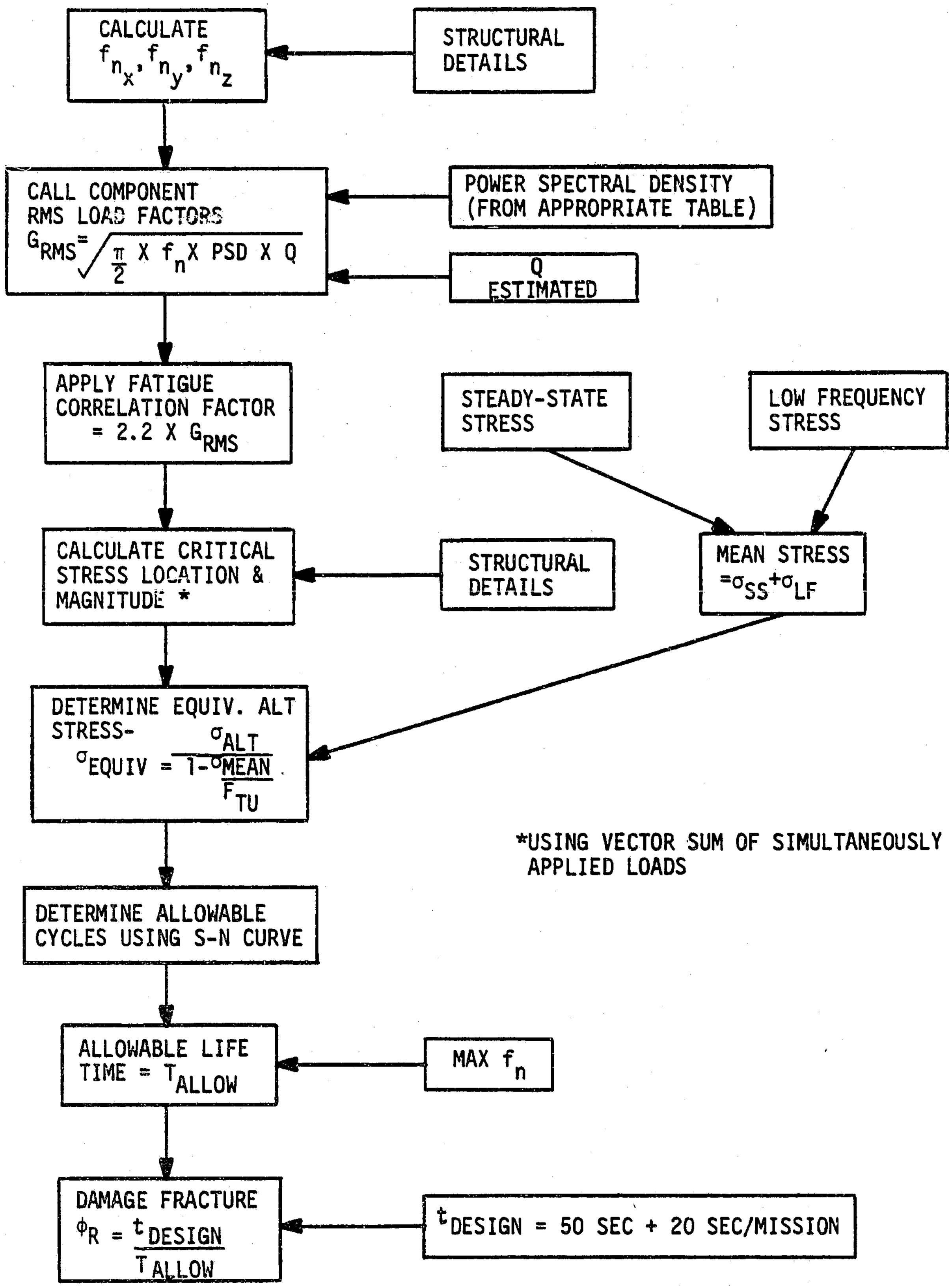


FIGURE 2-6. PROCEDURE TO EVALUATE RANDOM VIBRATION FATIGUE DAMAGE

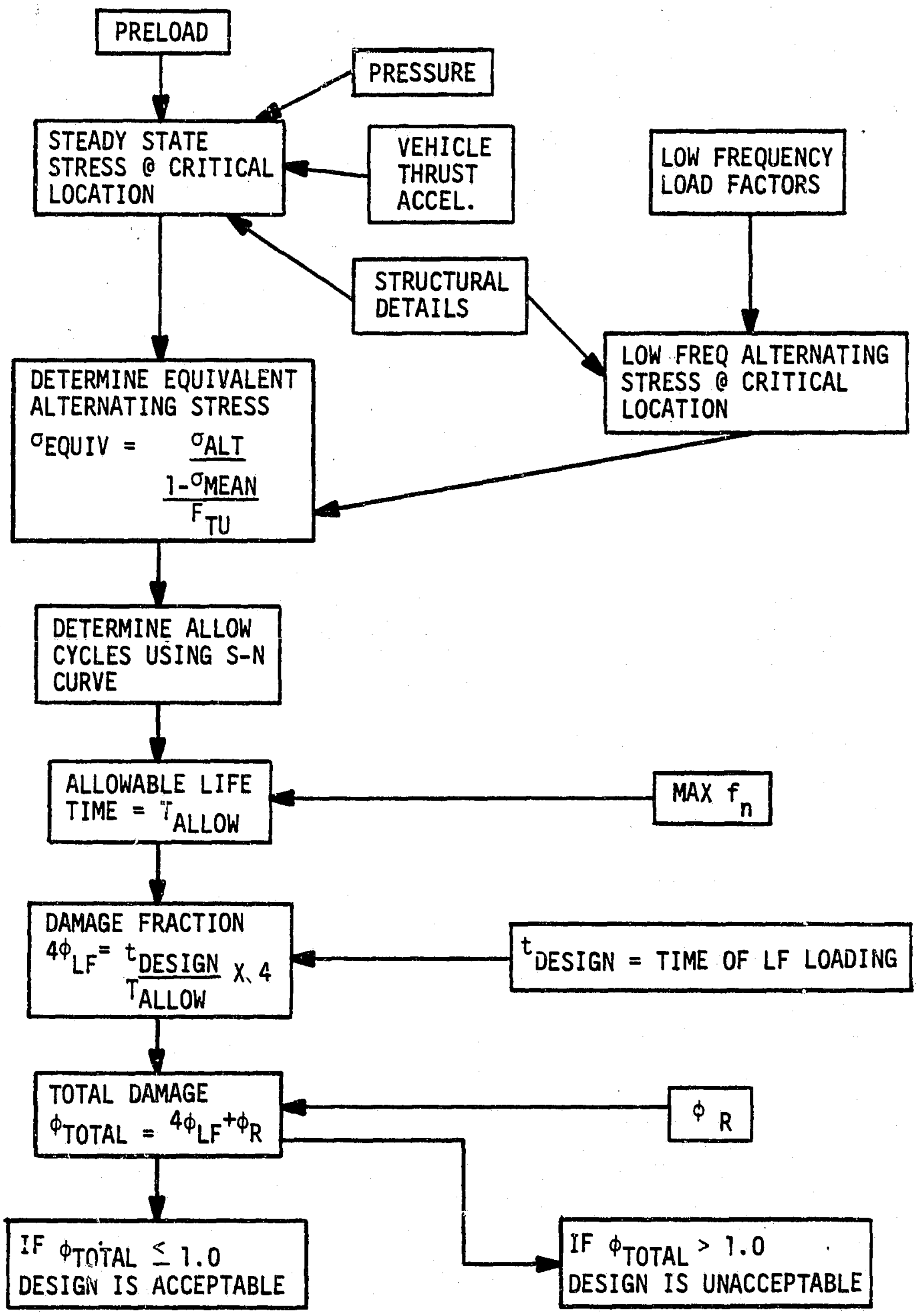


FIGURE 2-7. PROCEDURE TO EVALUATE LOW FREQUENCY FATIGUE DAMAGE

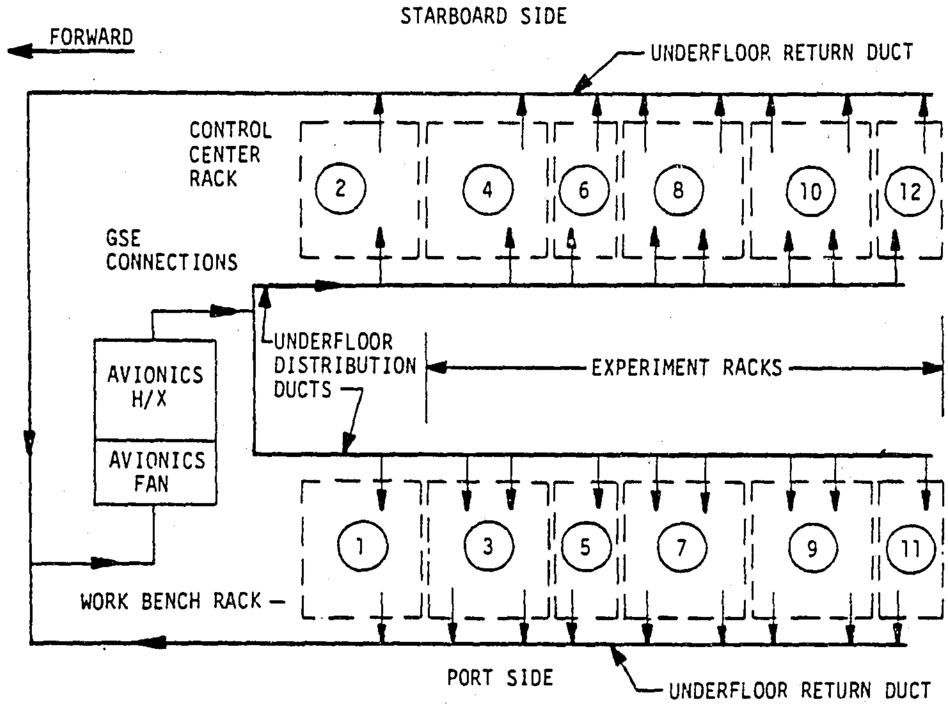


FIGURE 2-8. AVIONICS AIR COOLING

2.5 to 3.1 kW of cooling for experiments (300 W average per rack) remain after accounting for the cooling of basic subsystem equipment in racks 1 and 2. Timelining of equipment operations is necessary if the total waste heat removal requirement is greater than this range. Instruments that can tolerate a power-off mode offer an added advantage over those that, as a minimum, require a standby (powered down) mode.

As a frame of reference, the following table shows what would be considered a low, moderate, or high heat load per rack.

HEAT LOAD (W)	PER RACK
Low	0-150
Moderate	100-400
High	300-1000

The avionics air inlet temperature will vary over a range of from 10 to 35 °C for on-orbit operation. This air temperature is not controllable to a set value.

2.2.3.1.4 Experiment Thermal Control - Rack 4 - An experiment heat exchanger and cold plate are available for use in Rack 4 only. The heat exchanger uses water only (with additives) as a secondary loop working fluid. Material compatibility must be considered when using the cooling loop.

2.2.3.1.5 Experiment Thermal Control - Freon Loop With Cold Plates - The Freon loop with cold plates can be utilized as a heat sink or source. Freon temperatures between the first and last cold plates can range from 10 to 41 °C. There is no fluid temperature control or set point capability.

The method of mechanical attachment of experiment equipment to the cold plate surface is critical if the optimum transfer of heat from the equipment to the Freon is to be realized. Some of the factors affecting this interface include bolting pattern, number of bolts used, bolt torque, type and thickness of interface filler material (e.g., thermal grease, silicone foil), and roughness/flatness of mating surfaces. The SPAH currently lists the value of heat conductance from the experiment heat transfer area to cold plate coolant as 0.08 W/°C-cm^2 with filler. Through a joint effort within NASA and ESA, CHO-THERM 1661 has been selected as the interface filler material for the first Spacelab missions. Considering the factors mentioned above, the conductance values shown in Table 2-4 should be used by equipment developers.

TABLE 2-4. HEAT CONDUCTANCE* FROM EXPERIMENT HEAT TRANSFER AREA TO COLD PLATE COOLANT AS A FUNCTION OF BOLTING PATTERN FOR CHO-THERM 1661 FILLER**

BOLTING ATTACHMENT CONFIGURATION	TORQUE (N/m)	CONDUCTANCE (W/°C-cm^2)
70 x 70 mm Pattern	3.2	0.070
Perimeter Bolting	3.2	0.043

*Data must be appropriately reduced if an equipment adapter is utilized.
**0.5 mm material thickness.

2.2.3.1.6 Experiment Thermal Control - Passive Means - Passive thermal control is accomplished by means of insulation, thermal isolation mounting, surface optical properties, etc. to control the radiation and/or conduction of heat from/to the equipment.

Two conceptual designs for thermal isolators proposed for use with facilities for Spacelab Mission 3 are discussed briefly in Section 2.2.3.2.2.

2.2.3.1.7 Experiment Vent System - The total vent system must be analyzed to define vent flow rates. Maintaining the desired pumping speed will be a strong function of the facility pressure (flow regime ranging from continuum to free molecular). The following table gives an indication of venting accommodations for different facility pressures.

ACCOMMODATION DIFFICULTY	FACILITY PRESSURE (m BARS)
Unconstrained	>50
Moderate	0.1 to 200
Difficult	$<10^{-2}$

The determination of pumping speed for low facility pressures which would be associated with free molecular (rarefied gas) flow has to consider tube wall outgassing flow effects as well. Accommodation of desired pumping speed will be more difficult in this flow regime.

2.2.3.2 Thermal Design Guidelines

2.2.3.2.1 Pallet-Mounted Instruments - The integration contractor, under normal circumstances, will establish thermal environments and boundary conditions for the experimenter to use in the detailed thermal design and analysis of experiment equipment. The approach normally is for the integration contractor to provide both hot and cold recommended design conditions for a given mission as well as a nominal environment. In addition, extreme hot and cold environments, the most hostile environments possible for a Spacelab design condition based on a given mission configuration, are also assessed. Realistic thermal environments can only be provided if the total configuration is analyzed to account for reflections from all surfaces in the cargo bay.

The total integrated payload configuration effects cannot be assessed when the hardware developer proceeds ahead with his design before mission assignment. It is recommended that the Spacelab hot and cold design environments be used for this situation in assessing the thermal design. Figure 2-9 shows the Orbiter attitude for the hot and cold design environments.

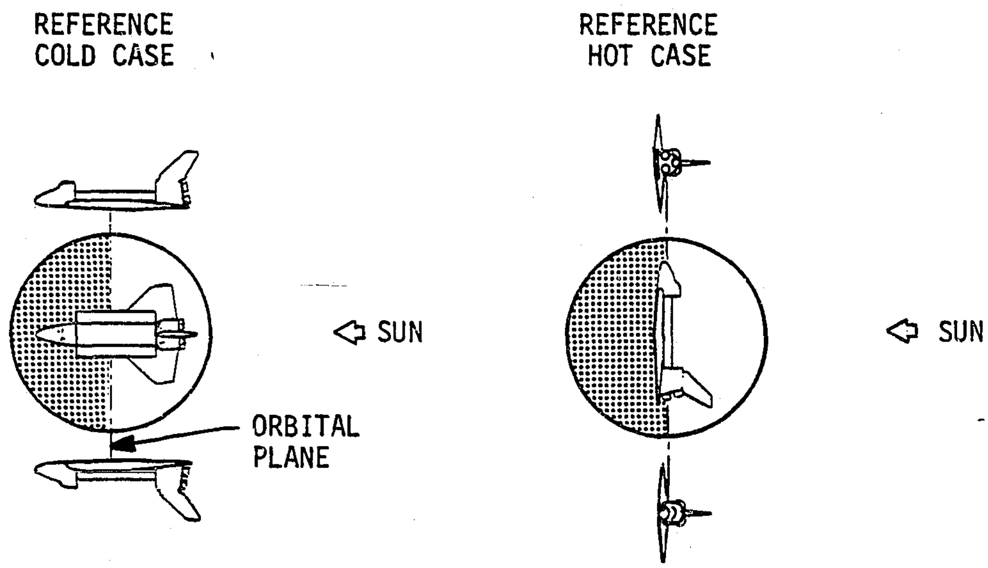


FIGURE 2-9. ORBITER/SPACELAB ATTITUDE FOR HOT AND COLD DESIGN ENVIRONMENTS (β = 90°)

These orbital parameters, which will provide a more hostile environment than the actual mission flown, will allow thermal reflight capability with little or no redesign. Positioning of the experiment hardware on a pallet will be somewhat arbitrary, however, and pointing requirements (Instrument Pointing System with Cruciform, pedestal, orthogrid structure) will dictate somewhat the location along the Z axis. Clearance and c.g. constraints will be about the only factors that can be considered for the X and Y axis locations. One of the key factors of the thermal design at this point is to make the experiment hardware insensitive to location in the cargo bay. Extreme boundary temperature conditions of the pallet and cargo bay as presented in Section 5.2 of the SPAH should be used in any thermal study as well as the space thermal environment data of Table 5-19 and the thermal-optical properties of the pallet and Orbiter, Tables 5-20 and 5-21 of the SPAH.

The detailed thermal design and analysis of experiment hardware is the responsibility of the investigator. The investigator will establish heater power requirements, energy requirements, temperature gradient control techniques, and the details of the thermal design in order to meet the instrument requirements. The investigator will supply heaters, thermal-optical coatings, insulation, isolators, etc., to implement the instrument thermal design. Experiment equipment will not be inserted into the Spacelab coolant loops. The baseline loops will be modified as necessary to accommodate mission peculiar configurations (such as rerouting coolant lines to accommodate cold plates on the secondary structure).

As was previously stated, a thermal model of the total payload configuration will be developed by the integration contractor. The environmental data from this model and other analyses by the integration contractor will provide the following:

- External Radiation Thermal Coupling Factors
- Surrounding Instrument/Structural Sink Temperatures
- Absorbed Heating Rates for Max./Min. Environmental Heating Conditions (based on mission parameters)
- Freon Loop Cold Plate Sink Temperatures.

These data will be provided through the Instrument Interface Agreements. The form of the data for pallet-mounted experiments is shown in Figure 2-10. The signif[illegible] of having more refined thermal environment data can be illustrated by the situation where temperature gradients on a piece of equipment are critical to instrument performance. Designing to worst case maximum/minimum extremes alone may not produce the best thermal design.

As a design goal, instrument and insulation surfaces located external to the module (i.e., cargo bay) should use diffuse reflecting white coatings, with solar absorption (α_s) $\leq$ 0.3 and infrared emissivity (ε) $\geq$ 0.9. The investigator should attempt to limit external surface coating specularities in the solar wavelength (0.30 to 3.0 microns) to values less than 10 percent. This is a guideline rather than a rigorous requirement, so that coatings with specularities greater than 10 percent will be considered.

EXPERIMENT	SURFACE	EXTERNAL ABSORBED HEAT RATE (w)	RADIATION CONDUCTOR RADK (m^2)	SURROUNDING TEMP. ENVIRONMENT (°C)
	1 (Forward)	$\dot{Q}_1$	$R_{11} \cdots R_{1n}, R_{1\infty}$	$T_{11} \cdots T_{1n}, T_\infty$
	2 (Port)	$\dot{Q}_2$	$R_{21} \cdots R_{2n}, R_{2\infty}$	$T_{21} \cdots T_{2n}, T_\infty$
A	3 (Aft)	$\dot{Q}_3$	$R_{31} \cdots R_{3n}, R_{3\infty}$	$T_{31} \cdots T_{3n}, T_\infty$
	4 (Stbd)	$\dot{Q}_4$	$R_{41} \cdots R_{4n}, R_{4\infty}$	$T_{41} \cdots T_{4n}, T_\infty$
	5 (Top)	$\dot{Q}_5$	$R_{51} \cdots R_{5n}, R_{5\infty}$	$T_{51} \cdots T_{5n}, T_\infty$

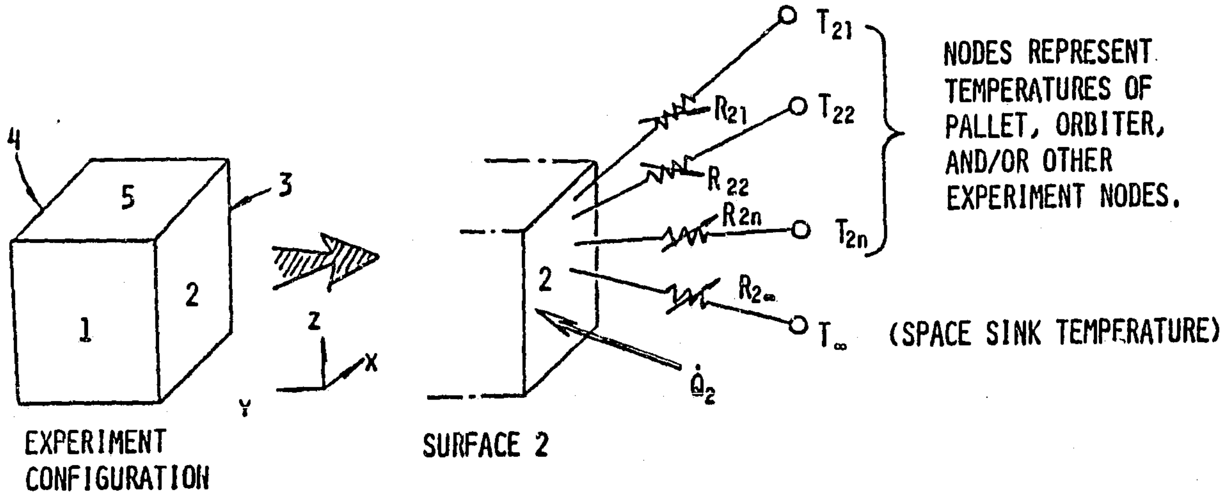
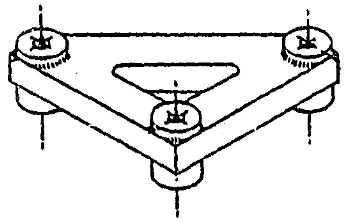


FIGURE 2-10. EXAMPLE OF DATA TO BE PROVIDED IN THE IIA'S FOR PALLET-MOUNTED EXPERIMENTS

2.2.3.2.2 Thermal Isolator Design - Two conceptual designs for thermal isolators are shown in Figure 2-11. Each design can achieve an overall thermal resistance of 20 ± 2 °C/W. The fiber glass material selected for the isolators (Type GEB per MIL-P-18177) is employed in the design because of its known applicability for such uses and the acceptability of its thermal and mechanical properties. Other alternate materials identified include nylon, teflon, and TREVARNO-type fiber glass. Some of the advantages and disadvantages are listed for each configuration.

The isolator concepts presented here are specific designs to provide a given thermal resistance and load carrying capability, however, the design principle can be utilized for thermally isolating any experiment hardware.

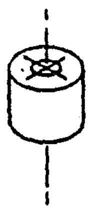
CONCEPT 1



(TYPICAL CORNER SPACER)

	ADVANTAGES	DISADVANTAGES
CONCEPT 1	- EASIER TO INSTALL - REDUCES BOLT BENDING STRESSES - REDUCES SPACER STRESSES	- SLIGHTLY HIGHER HEAT LEAK - INCREASED WEIGHT - HIGHER FABRICATION COST
CONCEPT 2	- MINIMUM THERMAL CONDUCTANCE AREA - MINIMUM WEIGHT - MINIMUM FABRICATION COST	- STRUCTURAL INSTABILITY - BOLT BENDING - HIGH COMPRESSIVE STRESSES IN SPACER

CONCEPT 2



(TYPICAL OF 3 SPACERS PER CORNER)

FIGURE 2-11. THERMAL ISOLATION CONCEPTS FOR EXPERIMENT HARDWARE

2.2.3.2.3 Rack-Mounted Instruments - The following thermal design guidelines are suggested for an experimenter who will develop a completely preintegrated rack. Rack-mounted experiments should be thermally designed using Aeronautical Radio Inc. (ARINC) Specification 404A, dated March 15, 1974. The following guidelines are offered with respect to pressure loss requirements, heat load requirements, and surface cooling of experiments.

2.2.3.2.3.1 Pressure Loss - The maximum unit pressure drop at the required unit air flow rate of 21.8 kg/hr per 100 W should not exceed 2.5 mbar (1 in. of water) when measured across the unit and the ducting from the unit to the stub of the rack return duct. The total pressure drop for an integrated rack should be less than 3.85 mbar at its design flow rate. When integrating a double experiment rack, both return ducts should be loaded as equally as possible to minimize total/rack pressure loss.

2.2.3.2.3.2 Heat Load Requirements - Each experiment rack return duct has eight intakes, or stubs (Figure 2-12). The equipment producing the highest heat load should be located in the bottom of the rack when it is feasible. Heat loads in any one stub of the bottom half of the rack should not exceed 400 W. No more than 400 W total should be distributed in the three stubs of the upper rack. Heat loads of 150 W or more should be put into any one of the lower five stubs. If possible the heat loads should be evenly distributed in the top or bottom stubs.

2.2.3.2.3.3 <u>Surface Cooling of Experiments</u> - Unless surface cooled equipment has low heat dissipation, it is better to use the suck-through method to ensure proper cooling. If suck-through cooled equipment can withstand higher inlet temperatures, place surface cooled equipment below suck-through equipment. This may be compensated for by increasing the flow through suck-through cooled equipment if possible. If surface cooled equipment is located above suck-through cooled equipment, the air flow for the surface cooled equipment should be sucked through the stub above the surface cooled equipment.

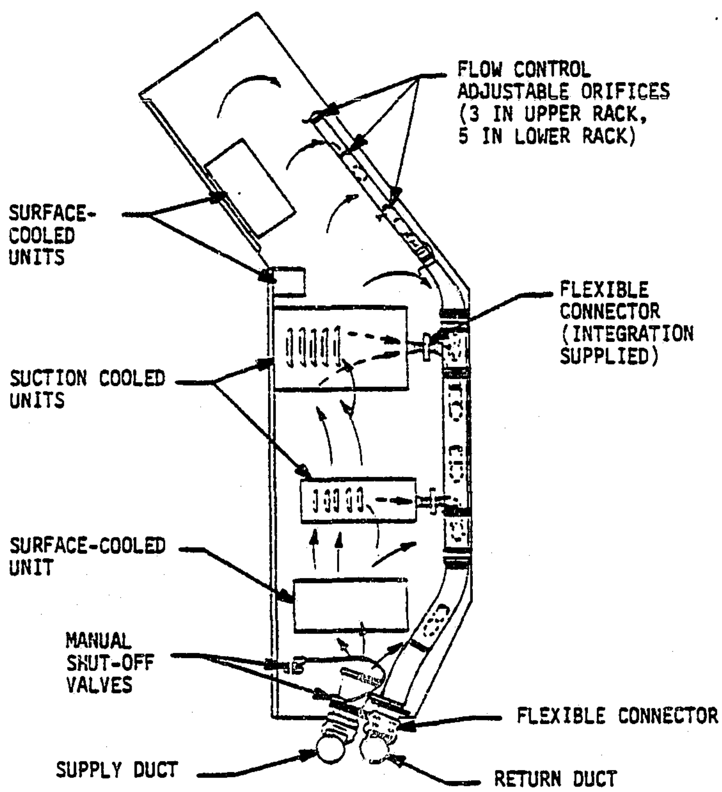


FIGURE 2-12. RACK COOLING CONCEPTS

2.2.4 Electrical

Constraints and interface design requirements with respect to electrical networks have been developed based on the STS accommodations. Interface design requirements will be discussed in this section considering the interfaces between experiment hardware and MDE/MPE/Spacelab subsystems as well as integrated electrical network requirements.

2.2.4.1 Electrical Constraints - The following constraints must be considered when developing experiment hardware.

Cabling - The experimenter will provide interconnecting cables between his own experiment hardware except for:

- Cables between the module and pallet
- Cables between two module racks if these racks are not adjacent.

The experimenter will terminate his Spacelab interfacing cabling at an experiment-provided connector group on the connector bracket panel (CBP) at the bottom of a rack. The exception will be rack 4, in which case, cables from the rack to the instrument electrical/electronic chassis will be MPE. All other cables are MPE (integrator provided) or MDE (Spacelab provided).

Power Control - Individual pallet mounted instruments are not guaranteed that power on/off control will be provided in their interfacing power circuit. The experiment hardware must in all cases provide this function even though on/off control is provided in the Module racks via the Experiment Power Switching Panels (EPSP). At each EPDB interface, an experiment shall provide power control, so that the experiment can be activated or deactivated by a CDMS command or manually on a front panel.

Voltage - The dc voltage level provided at the experiment hardware interface may, for worst case conditions, be as low as 22 V. A voltage drop analysis for each mission will be required.

Protection - In no case will the power circuits, provided to experiment hardware, be sized to protect the experiment. Instead, the system protection (circuit breakers, fuses, or current limiters) are sized to ensure that the wires feeding the power do not deteriorate and become a safety hazard due to fire. This usually means that the current design limit specified on a certain wire size may be exceeded by a factor of 3 before the protective device opens the circuit. The protective device should never open until the current design limit is exceeded by 10 or 20 percent.

Essential Power - This service will be extremely limited. It will only be made available when fail-safe (no hazard to crew or Orbiter) design is not possible with loss of main power (for Caution and Warning and Experiment Safing). Essential power is available during the ascent/descent portion of the mission.

Signal Harness - Only AWG #22 size wire and a TBD coax size will be utilized in the MPE harnesses. The cables will be either twisted pairs (TP's) or twisted shielded pairs (TSP's) as appropriate.

Power Lines - All power lines will be TP's for dc and for single phase ac power.

2.2.4.2 Instrument Interface Design Requirements - A series of interface design requirements are offered to aid in the development of the electrical interfaces between experiment hardware, Spacelab subsystems, MDE, and MPE.

Power Demand - Every effort should be made, by the instrument developer, to minimize the power required by equipment. This should include careful design and selection of components, and the elimination of nonessential power demand whenever feasible.

Connection Selection - Connectors which interface with STS hardware, MDE, MPE, or other experiment hardware can be selected from the connector list presented in MSFC document 15M00002. All flight equipment should be designed to allow any testing required after payload integration to be accomplished without disturbing interface connectors.

Connector Location - Pallet connectors should be located on a plane perpendicular to the box or plate mounting surface no higher than 20 cm (7.9 in.) above the mounting surface. No two connectors should be closer than 5 cm (2 in.) as measured from tangent (shell) to tangent. Rack connectors should be located on a plane parallel to the back of the rack no more than

20 cm (7.9 in.) from the back of the rack cable supports. Relative positioning should be the same as for pallet. These requirements enable the MPE cabling to be installed with no support dependence on the experiment equipment except for the connector to which it is attached.

Essential Power Connections - This service will require a separate (dedicated) connector.

Reference Designators - MPE harnesses will utilize a consistent system of identifying where connectors are to be mated. Instrument external interfaces should be designated as follows:

Power: (Typical Example) Instrument XX/J1, J2, J3, etc.
Data: (Typical Example) Instrument XX/J11, J12, J13, etc.

Wire Size - Wire for power lines shall be selected from wire sizes listed in Table 7-3 of the SPAH.

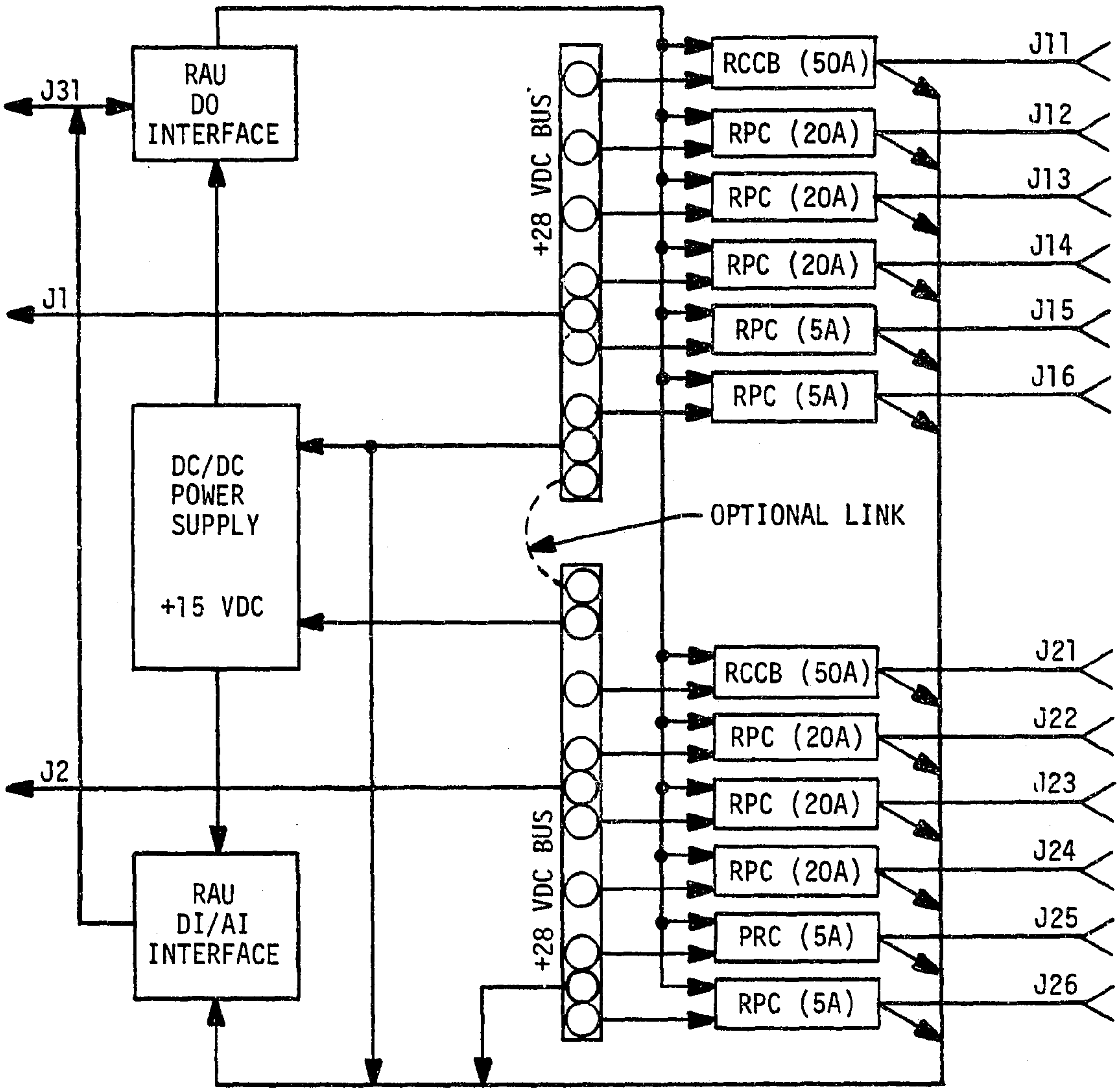
2.2.4.3 Integrated Electrical Requirements - For an integrated system, the main dc and ac power is supplied by four Experiment Power Distribution Boxes (EPDB), one in the core segment, two in the experiment segment, and one on the pallet. These EPDB's supply the Experiment Power Switching Panels (EPSP) which in turn provide power to the experiments in the module. On the pallet, dc power is furnished to the experiments via Experiment Power Branching Distributors (EPBD) and ac power is supplied directly from the EPDB.

The EPBD (see Section 2.2.1.2), designated as mission peculiar equipment (MPE), functions as a direct current (dc) electrical power branching distributor using Remote Power Controllers (RPC) and Remote Control Circuit Breakers (RCCB). The EPBD is controlled and monitored from a dedicated interface connector. The EPBD provides short circuit/overload protection for 12 output loads. The EPBD function is shown in Figure 2-13.

2.2.5 Command and Data Management System (CDMS) and Software

2.2.5.1 CDMS

2.2.5.1.1 CDMS Capability - Figure 2-14 is a functional diagram of the experiment portion of the Spacelab CDMS. The Experiment Computer with its Input/Output Unit (IOU) controls most CDMS activity. The only direct interface an experiment instrumentation has with the experiment computer



Legend:

RPC - Remote Power Controllers
RCCB - Remote Control Circuit Breakers
DI - Digital In
DO - Digital Out
AI - Analog In

FIGURE 2-13. EXPERIMENT POWER BRANCHING DISTRIBUTOR BLOCK DIAGRAM

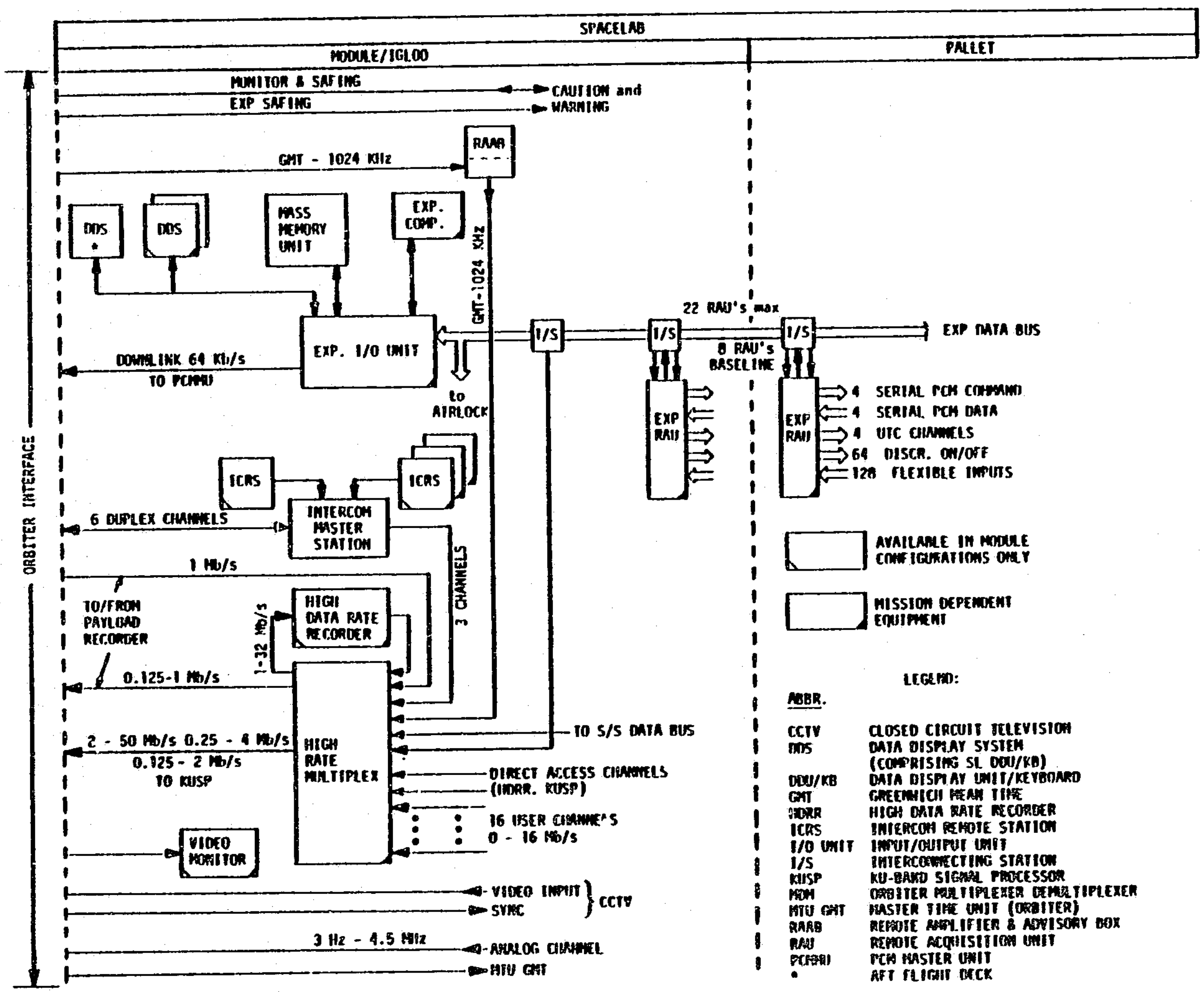


FIGURE 2-14. COMMAND AND DATA MANAGEMENT SYSTEM BLOCK DIAGRAM

is via a Remote Acquisition Unit (RAU). An experiment instrument may interface directly with three other CDMS components: Analog/Video Switch (AVS), Master Timing Unit (MTU) buffer, and High Rate Multiplexer (HRM). The characteristics of all CDMS interfaces are defined in the SPAH.

The MTU buffer provides a 100 PPS timing signal to the experiment instruments. The signal is a coded signal that provides a 10 ms timing resolution.

The HRM is the main component in the experiment telemetry system. There are 16 multiplexed inputs and two direct inputs. The input to any one of the 16 multiplexed inputs cannot exceed 16 mbs and the composite output cannot exceed 50 Mbps. When video or analog is being downlinked; the HRM composite data rate is limited to 2 mbs.

The analog/video switch is used for routing one of eight possible analog/video signals from experiments to the Ku-band Signal Processor (KuSP). One analog or video data stream can be downlinked at a time. The analog/video switch allows switching between instruments for downlinking. Two recorders are supplied for recording and playback of the analog/video data. Experiment instruments share the direct downlink (one at a time) when that channel is not constrained by high-rate data or RF occultation.

The Spacelab High Rate Multiplexer Format Standards document (MSFC-STD-630) defines the constraints placed on the signal input to the HRM.

The experiment computer links the experiment instruments to CDMS functions via the RAU. The RAU supports analog inputs, discrete inputs, serial inputs, discrete outputs, and serial outputs. The RAU's are connected to a common data bus which is controlled by the experiment computer. The one megabit capability of this data bus is shared among all RAU's and provides a means of transferring commands and data between experiments and the experiment computer/onboard display and the status monitoring system. Status information can also be transmitted to the ground from the experiment computer via the experiment computer bus through an HRM port capable of a combined data rate of 25.6 or 51.2 kbps. The portion of this data bus allocable to each experiment is dependent upon mission configuration and will vary with specific mission requirements. Maximum allocation to a single RAU serial data channel on the heavily loaded Spacelab 1 mission was 5 kbps.

2.2.5.1.2 Experiment Control - The experiment computer software provides a convenient method of issuing commands to experiments, and its use is encouraged when commands can be predefined. It is also possible to control experiments through the onboard payload operator.

One alternative technique of issuing commands is through the POCC command uplink. A combined command rate of 20 bits per second is available for sharing between experimenters. It has been estimated that command uplink communications can be maintained during half of the on-orbit mission time.

2.2.5.1.3 Available Hardware for CDMS Interfacing - The Spacelab Payload Standard Modular Electronics (SPSME) consists of modular electronics conforming to Computer Automated Measurement and Control (CAMAC) standards. Essential components include the controller and RAU interface modules which interface all other electronics to an RAU serial data and command channel. Other modules include the HRM Interface and Time Interface modules. A user wire wrap module is also available for Special user applications. Additional modules under development or planned for development are as follows:

Analog to Digital Converter/Multiplexer
Digital Input Register
Digital Output Register
Digital to Analog Converter
Motor Controller
Scanning Analog to Digital Converter
Serial Input Register (Scaler)
Serial Input/Output Register
Relay Contact Output Register
Isolated Input Gate
Peak-Sensing Analog to Digital Converter.

The crate and power supply is sized to hold 32 (305 mm x 183 mm) boards and is consequently capable of controlling quite large and complex experiments.

2.2.5.2 Software

2.2.5.2.1 Software Overview - Experiment software requirements can be met by Experiment Computer Operating System (ECOS) services, by Experiment Computer Applications Software (ECAS), by the experiments providing their own processor, or by a combination of these. The experiment-provided processor that interfaces with the experiment computer is called a Dedicated Experiment Processor (DEP).

The experiment computer software is composed of the ECOS and the ECAS. Figure 2-15 defines the ECOS services available to experiments. An ECAS can be developed to perform software functions required by the instrument that is not supported by the ECOS services.

The detailed definitions of the ECOS services available to an experiment are documented in the ECOS Requirements Definition Document (MDC G6862) and the ECOS Design Specification (ECO 8945). Following is a brief discussion of these services.

The ECOS supports both synchronous and asychronous operations on the RAU data bus. The General Measurement Loop (GML) is the synchronous data acquisition and distribution system. The acquired data may be downlinked via the HRM, displayed onboard, exception/event monitored, and made available to an ECAS. Configuration Data Tables (CDT) entries are required for parameters that are displayed, monitored, or commanded. The CDT's contain information to allow the display of parameters in engineering units and the display of limits for status monitoring. Time, state vector, attitude information, and pointing information (when a pointing system is part of the payload) are available to experiments via a serial output channel of the RAU. All synchronous outputs will be at 1 Hz rate. The time is correlated to the timing signals output from the RAU to provide timing resolution to less than 10 microseconds. Asynchronous operations are performed when requested by the other system functions. The ECOS supports either a 25.6 or 51.2 kbps HRM data rate containing all ECIO experiment data transmitted from Spacelab.

The ECOS supports the crew interface via the Data Display Unit (DDU). The DDU can be used for displaying parameter data and crew tutorials and for crew commanding via the keyboard.

Ground commands uplinked via the MDM link are supported by the ECOS. Reference Orbiter/Avionics Interface ICD (ICD-2-05301) for interface details.

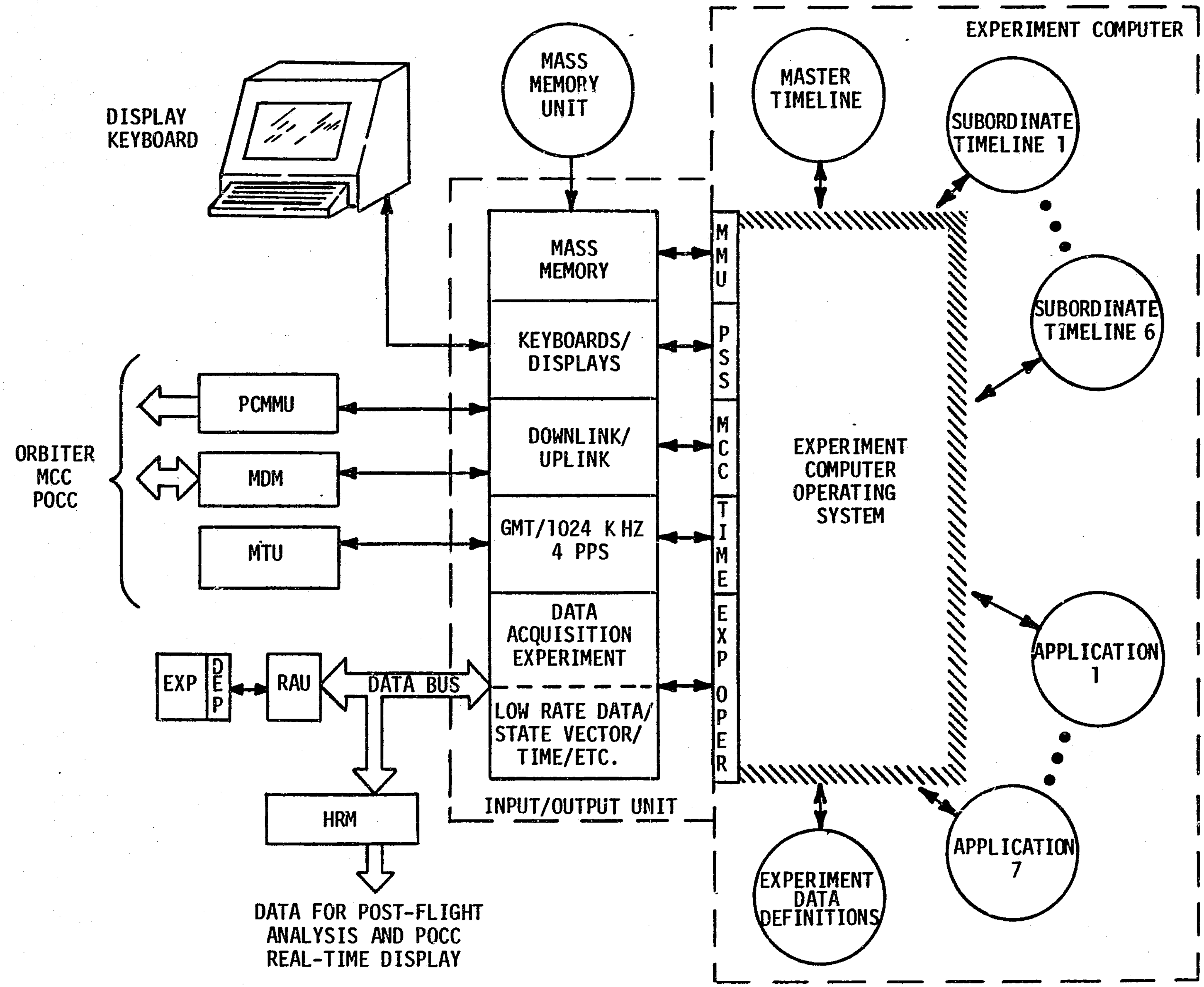


FIGURE 2-15. ECOS INTERFACES

The ECOS supports a master timeline, six subordinate timelines, and eight ECAS programs concurrently. The timelines provide commanding based on time. The time of execution for each command may be actual time or time since the previous command within that timeline. The ECAS functions are dependent upon the requirements of the particular experiment. With a normal complement of ECOS and ECAS tasks, it is difficult to ensure ECAS responses to experiments within less than 1 sec or execution time accuracy greater than 100 ms for predetermined actions. For these reasons, experiments requiring guaranteed fast reaction should consider the use of DEP's.

The ECOS has access to a MMU which is a large nonexecutable memory storage. The MMU may be used to store ECAS and timeline segments and to display skeletons and other data.

The ECOS provides special services to DEP. A DEP protocol is maintained that allows the DEP to initiate the transfer of all data and command transfers. The ECOS also provides the capability to load DEP's.

Like the CDMS resources, experiment computer software and capability are shared among individual experiments. Therefore, the resource available to any particular experiment will depend upon the payload configuration into which that experiment is to be integrated. ECAS development for experiments may be obtained by establishing requirements to the Payload Integrator.

2.2.6 Payload Operations Control Center (POCC)

2.2.6.1 <u>POCC Role</u> - All real-time and near real-time experiment data are obtained via the POCC data handling systems at Johnson Space Center. Capabilities of the POCC are defined in the POCC Capabilities Document JSC-14433 which is updated periodically to reflect current capabilities. It should be referred to for the latest configuration and interface information.

2.2.6.2 <u>POCC Facilities</u> - Each experimenter can expect to share one of seven user support areas, each having approximately 450 square feet of floor space. A conference room of approximately 500 square feet is located near the POCC for use by the Investigator's Working Group. Each user area typically consists of four bays with one to three CRT's, overhead TV display, CRT hardcopy, intelligent CRT terminal, communications panel, timing, and eight strip chart recorders.

2.2.6.3 POCC Capability - The POCC system is depicted in Figure 2-16. The system is capable of stripping out 2000 parameters per second and supplying these data to the central processor. The 2000 parameters per second are selected from up to three dedicated experiment channels and the Experiment Computer I/O channel from the Spacelab HRM. These data are available for real-time CRT display or near real-time recall in a CRT or hardcopy history format. The data system can additionally provide up to 500 parameters per second of Orbiter and Spacelab data from the Orbiter PCMMU for processing and display. A total of up to 80 parameters per second may be displayed on strip chart recorders. Up to 5 HRM channels of data at less than 2 Mbps each can be processed simultaneously on the POCC computer in addition to video, time, and Spacelab ancillary data. Spacelab ancillary data consist of pointing system, engine firing, and other support equipment status information. Each data display room may receive 3 POCC computer or direct data links simultaneously in addition to video, voice, and Spacelab ancillary data.

2.2.6.4 Standard Services - Standard POCC services consist of calibration/engineering unit conversion, limit checking, data display, real-time or near real-time playback and experiment command.

Engineering unit conversions may be obtained from calibration data in the form of either tabular or polynomial coefficient values. Fourth order polynomial fitting, corresponding to onboard usage, is most common. Tabular six point calibration curve fitting is also standard, and up to 21 point calibrations can be accommodated.

Limit checking can be performed to two different sets of limits. These limits may be independent of onboard values.

Data can be displayed on the CRT/hardcopy unit and strip chart recorders at the experimenter's console, and high speed printouts can be obtained from the POCC facility.

The real-time or the near real-time system may be accessed from the console terminal. To use the near real-time system, the operator may change systems, and request the desired data. Response may not be immediate due to the large volume of data held by the playback system and the effect of other user requests on that system.

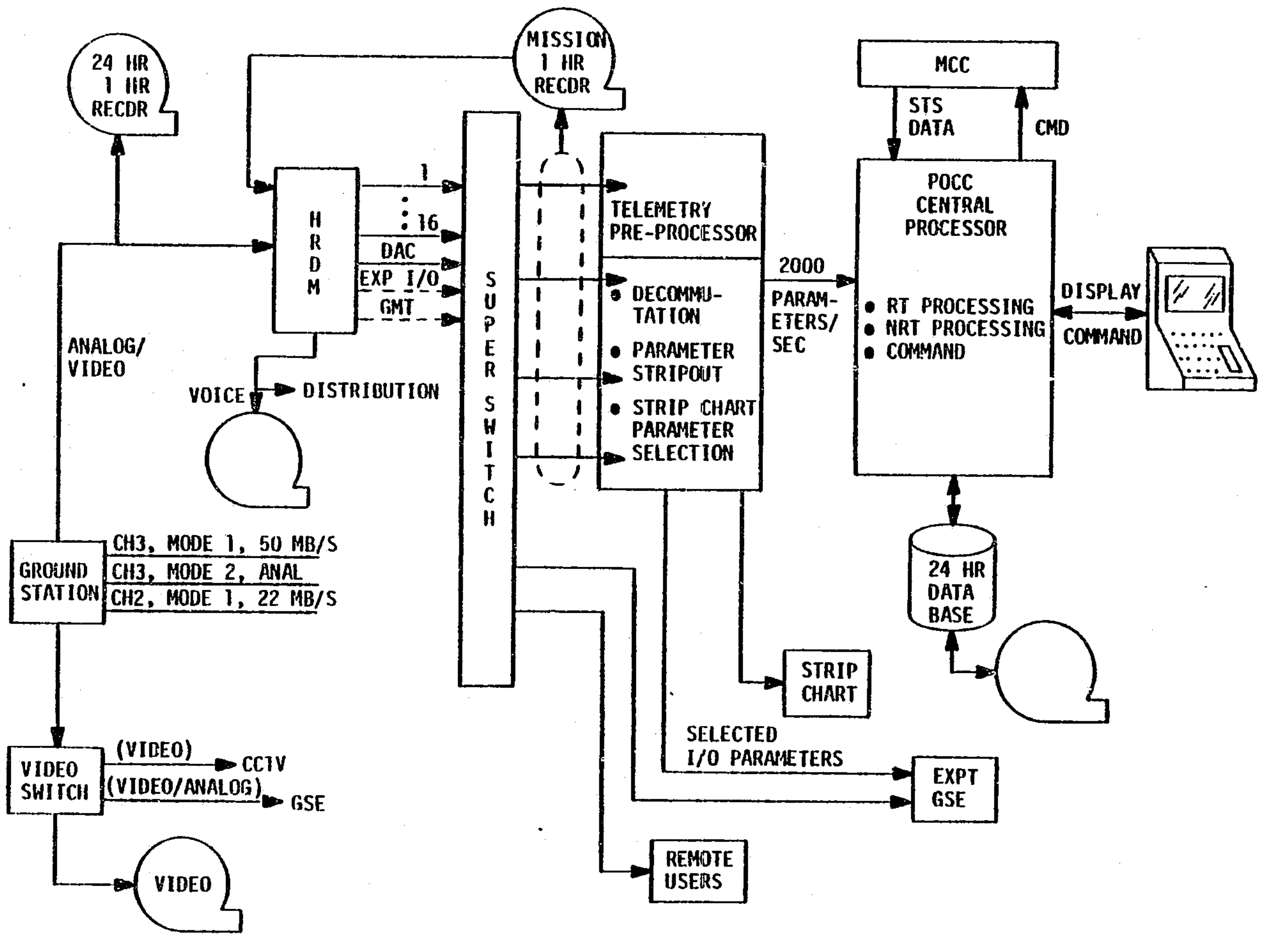


FIGURE 2-16. POCC SYSTEM

2.2.6.5 GSE Interconnection - Experimenters may use their own special processing equipment in addition to the above POCC provided services. Any HRM channel may be provided as raw data to experiment GSE and the 4.2 MHz analog downlink may also be provided to experiment GSE.

In general, an experimenter will require his own computer when off-line analysis is required. Although the POCC computer will accept user supplied FORTRAN for real-time analysis, users wishing to use this service must provide such code at least 6 months in advance without the inclusions of DO loops or GO TO statements.

Computer compatible digital tapes will not normally be available except by the use of GSE.

2.2.6.6 POCC Originated Commands - Experimenters may send their own commands to individual experiments except for those cases where interference with other activities is possible, e.g., simultaneously turning on experiments that require high power. Commands which may create compatibility problems will be restricted to the Command Controller, who coordinates system usage among the experimenters and the MCC. Commands may be generated on the provided keyboard/CRT terminal or on off-line devices compatible with POCC terminals. The command uplink rate reserved for experimenters is approximately 20 bits per second shared among all experimenters. Favorable conditions for uplink command transmission to satellites exist approximately half of the mission duration.

2.2.6.7 Special Requirements for Slow Rate Subcommutated Data at POCC - The POCC demultiplexer baseline format standards do not permit RAU Input/Output (I/O) sampling rates of less than 1.0 Hz without meeting additional guidelines. Each experiment sampling at less than 1.0 Hz must provide a subframe identifier (major frame counter) as the first data word in a submultiplexed channel. The major frame counted must be located in a single fixed (word and frame) location in each experiment I/O major frame, and each submultiplexed parameter must be unambiguously identified by the use of the subframe ID and the minor frame counter. All submultiplexed channels must be synchronized with the experiment computer I/O major frame and all submultiplexed formats shall be premission defined. The submultiplexed data cycle cannot exceed 60 experiment computer I/O channel major frames (1.0 min). No more than four submultiplexed formats may form a given experiment computer I/O format. Strip chart recording of submultiplexed data cannot be supplied in the POCC.

2.2.6.8 Documentation of POCC Requirements - Experiment operational procedures are defined in the Spacelab Payload Mission Operations Plan MSFC-JA-063. Specific requirements are contained in the POCC Format Standards MSFC-JA-053.

Experimenters should document POCC requirements well in advance beginning with submission of initial inputs through the ERD 38 months before launch. The requirements should contain a brief description of basic services required including non-standard services desired and types of GSE interfaces to be used. Detailed requirements are required 30 months before launch including special processing requirements and estimate of data base size required for commands and telemetry. Final requirements should be provided by 24 months before launch. Final data base requirements must be provided by 7 months before launch including calibration, limit sense, strip chart, real-/near real-time display formats and command processing formats. Code for standard services will be generated at the POCC beginning approximately six months before launch.

2.2.6.9 POCC Training - POCC training and familiarization are required so that experimenters may effectively use POCC resources and coordinate their activities with other POCC users. This training begins with a familiarization course conducted approximately one year before launch, progresses to hands-on familiarization beginning 3 to 6 months before launch, and concludes with simulated on-orbit operations in the final weeks before launch. Information on how tests and operations are to be conducted are contained in the Spacelab Payload Mission Operations Plan document MSFC-JA-063.

2.2.6.10 Data Delivery - Digital tapes suitable for input to other computer systems are provided by the Satellite Data Processing Facility at Goddard Space Flight Center (GSFC). The goal of this facility is to provide digital tapes within 30 days of each mission and merged error corrected digital data with minor frame fill and overlap within 60 days after the mission. Data users requiring quicker reduction response may do so by application of GSE at the POCC.

Other flight data are available directly from the POCC including specific experiment or general flight film and magnetic tapes. Payload crew logs and records documenting results or observations of experiment activity are available. The payload crew flight data file and other carry-on documentation will also be made available.

2.2.7 Pointing and Stabilization

Pointing and stabilization constraints and guidelines are discussed with respect to Orbiter attitude control, accelerations on orbit, alignment, and the Instrument Pointing System (IPS).

2.2.7.1 Pointing and Stabilization Constraints - This section discusses system constraints with respect to pointing and stabilization systems.

2.2.7.1.1 Orbiter Attitude Control - Orbiter attitude is controlled through the Inertial Measurement Unit (IMU) located in the nose of the Orbiter. There are two factors that contribute to degradation of the pointing accuracy for an experiment in the payload bay: (1) variable distortion of the Orbiter can produce up to 2 deg of misalignment between the IMU and an experiment in the bay so that the pointing accuracy becomes ±2.5 deg, and (2) IMU drift degrades the pointing accuracy by 0.1 deg/hr/axis between IMU updates. Stability and stability rate are not affected by these factors. Note that the SPAH defines stability rate as the envelope size of 1 sec of jitter, not as the time derivative of the attitude.

The IMU is normally updated about once per hour. Depending on the orbit and attitude, this may require interruption of attitude hold. Under certain conditions, the IMU can be continuously updated, eliminating the IMU drift.

If pointing accuracy or stability better than the Orbiter capability is required, the experiment must either include its own attitude reference sensor and pointing system or use a pointing mount such as the IPS discussed in Sections 2.2.7.1.5 and 2.2.7.2.4.

There are constraints on the length of time the Orbiter can maintain orientations. These are discussed in paragraphs 6.1.1.2.1 and 6.1.1.2.2 of ICD 2-19001.

2.2.7.1.2 Accelerations - Accelerations on orbit are mainly of interest to those experiments requiring a microgravity environment. They can arise from both rotational and translational motions of the Orbiter. Two types of accelerations need to be considered: steady state and impulsive. Steady state accelerations are primarily due to gravity gradient forces and aerodynamic drag. Figure 5-4 of the SPAH illustrates the steady state accelerations expected, which are usually $<10^{-6}$g. Impulsive accelerations are primarily due to the reaction control system (RCS) and crew motion. Accelerations due to vernier thruster firings and crew motion can each approach 10^{-3}g. The frequency of vernier thruster firing is a function of stability deadband, orbital altitude, and orbiter orientation. Gravity gradient orientation requires the least frequent thruster firings. Increasing deadband and/or altitude also decreases the frequency of thruster firing.

In the gravity gradient stabilized mode, the largest rotational rate is due to the rotation (≈0.07 deg/sec) required to maintain the gravity gradient attitude.

2.2.7.1.3 Navigational Accuracy - The Orbiter position and velocity are available to Spacelab to the accuracy specified in Table 2-6 of the SPAH. Pointing accuracy for earth or earth orbital targets interacts with the positional accuracy of the Orbiter, which limits the pointing accuracy achievable. However, the pointing error due to position error is much smaller than the orbiter pointing error.

2.2.7.1.4 Alignment - Pointing requirements imply alignment requirements to a reference system which ultimately must be aligned to the Orbiter navigation reference. The alignment reference may be the Orbiter navigation reference, the pallet, or the axes of the Spacelab IPS. If better alignment accuracy is required than is obtainable by simply fastening the instrument to the standard mounting holes, an optical reference cube, with its faces aligned to the reference system, is required on the experiment. Proper orientation of this cube with respect to the experiment axes is the experimenter's responsibility.

2.2.7.1.5 Instrument Pointing System (IPS) - Experiments requiring greater pointing accuracy or stability than is provided by the Orbiter may use the IPS. This is a three axis gimbal system with star or sun trackers. The pointing accuracy and stability are suitable for most astronomical observations. The experiment can provide a bias signal to the tracking subsystem to produce offset pointing or raster scans, but if more than one experiment is mounted on the IPS this requires coordination between experiments.

Pointing, stabilization, and scan capabilities are detailed in the SPAH. Note that horizon sensors are not included for earth pointing applications. If horizon sensors are used, the accuracy of the ground point location will not be as good as implied by the pointing accuracy due to Orbiter navigation uncertainties. The IPS is capable of tracking a fixed earth target from any altitude greater than 200 km, but for scan rates >3 arc min/sec the pointing accuracy is degraded to that available from the gyros. Torque available for tracking (20 Nm/axis) limits the maximum tracking rate.

2.2.7.2 Pointing and Stabilization Design Guidelines - In this section, some design guidelines relating to satisfying pointing and stabilization requirements of experiments are discussed.

2.2.7.2.1 Attitude Control - There are two situations which indicate the use of an experiment pointing system: (1) the experiment pointing and stabilization requirements are not met by the orbiter capabilities, (2) the experiment requires pointing to multiple targets. On some flights, payload attitude sensors may be used which will provide post flight pointing knowledge to greater accuracy than the orbiter pointing accuracy.

If an experiment pointing system is required, in general a small experiment will be less restricted in flight assignment and operating time if the pointing system is integral to the instrument.

Careful consideration should be given to the unobstructed volume requested. Unobstructed viewing directions or mechanical clearance requirements can severely restrict the placement of other instruments.

2.2.7.2.2 Accelerations - Spacelab Mission 3 can be considered typical of the acceleration levels to be expected during a gravity gradient mode, low g mission. For SL-3, the largest accelerations are due to vernier thruster firings and crew motion. For each source, the worst case acceleration is 6×10^{-4}g (assuming normal crew activity). The duration of thruster firings varies from

80 to 1000 milliseconds. The frequency of thruster firings depends on the stability deadband, varying from approximately 60 firings/orbit for 0.1 deg deadband to approximately 6 firings/orbit for 2.0 deg deadband. Crew motion accelerations decrease to 2×10^{-4}g during periods of quiescent crew activity.

2.2.7.2.3 Alignment - Spacelab Mission 1 has specified the requirements for alignment as an optical cube with at least 2 cm dimensions, flatness 1/4 wavelength of mercury light, and reflectivity $\geq$90 percent. The faces of the cube must be oriented to the reference system used and either be permanently and durably installed on the instrument, or removable/replaceable without adjustment.

2.2.7.2.4 Instrument Pointing System (IPS) - Although the IPS has both optical sensors and gyroscopes for attitude control, the full pointing accuracy can only be obtained under optical sensor control. Stability is the same under both optical sensor and gyro control.

Scans are programmable up to the size of the optical sensor field of view. Larger scans are possible but can only use gyro control. Pointing accuracy depends on the scan rate, degrading to 3 arc minutes accuracy at 3 arc min/sec scan rate. Faster scan rates can only use gyro control.

On orbit calibration of instrument/IPS alignment is possible. This may allow the instrument alignment requirements at integration to be relaxed.

2.2.8 Ground Operations

The following sections describe ground operations constraints that the experiment developer must consider as well as facilities and resources available at the Level IV complex.

2.2.8.1 Ground Operations Constraints - This section describes the constraints involved in ground operations that the experiment developer must consider during the development of his experiment. These constraints affect the design of the experiment, activities occurring during preparation of the instrument/experiment package for delivery to Level IV testing, and the operational aspects of the experiment throughout the payload integration effort. Any experiment related requirement that affects ground integration or flight operations must be specified in the ERD.

2.2.8.1.1 <u>Testing and Checkout</u> - Experiment performance will not be evaluated during payload integration operations except as required to verify interface compatibility. It is the responsibility of the experiment developer to assemble, service, and test his payload to the maximum extent possible prior to delivery to the Level IV site.

The experimenter will be responsible for experiment calibration. The National Aeronautics and Space Administration (NASA) will provide standard calibration laboratory facilities to calibrate and repair test instrumentation when required.

Experiment checkout equipment will not be carried to the launch site area unless it is required to service the instrument/experiment or perform mandatory calibration and/or alignment. This equipment will remain at the Level IV complex and will be made available to support contingency operations.

Integration at the launch site includes the following Spacelab tests in accordance with the Spacelab Ground Operations Implementation Plan:

- Spacelab to Payload Interface Verification
- Mission Sequence Test.

Note: Flight software will be used to the maximum extent practical while conducting these tests.

Instruments will be powered up only to the extent necessary to implement the above tests or mandatory alignments, calibrations, and functional verification of new interfaces.

2.2.8.1.2 <u>Instrument/Experiment Support Requirements</u> - All interconnecting cabling between two or more elements of a pallet-mounted instrument shall accompany the instrument to the Level IV site.

A single or double rack that is shipped to the Level IV site with the instruments installed is required to have all internal cabling and fluid lines installed and verified prior to shipment.

Where alignment of an instrument to a structure is required, the instrument side of the interface will contain an instrument axis reference.

Where a pallet secondary structure is required and it requires alignment to the pallet, a reference point and an adjustment mechanism shall be provided to enable this alignment to be accomplished.

The experimenter is responsible for spares support of his deliverable hardware. Spares should precede or accompany the delivery of experiment related items.

2.2.8.1.3 Experiment Unique Equipment and GSE - The experiment development is responsible for all experiment-unique test and servicing equipment and experiment unique GSE and for the calibration, operations, and maintenance of this equipment.

Experiment-unique GSE must be designed to interface with standardized interfaces.

A listing of the unique equipment must be supplied to the Mission Manager accompanied by a description sheet for each item specifying the required site interfaces, i.e., area, power, cooling, etc. which are required for use of the equipment. It will be the experimenter's responsibility to deliver this equipment to the applicable site in time to allow sufficient installation and checkout prior to its use with the payload.

2.2.8.1.4 Cleanliness Levels - Spacelab and Shuttle Orbiter payload bay requirements are based upon the need to maintain a Class 100K cleanliness level during all ground processing and mission phases. It is the responsibility of the experiment developer to make provisions for those instruments/experiments that require Class 10K environments.

2.2.8.1.5 Constraints on Experiment Access

2.2.8.1.5.1 Preflight - After Orbiter installation, access will be possible to the interior and to the exposed exterior of Spacelab. Spacelab and its GSE are designed to provide limited access for experiment servicing during ground operations in a vertical position.

Access to the interior of the Spacelab during pad operations is available on a contingency basis only and should not be planned. Any access permitted must be justified based on scientific needs.

Following Orbiter installation, power and monitoring capability will be provided consistent with the capabilities of the Orbiter and GSE during ground flow. Experiments must be able to withstand periods of no STS power and monitoring capability of up to 26 working hours during the flow.

2.2.8.1.5.2 Post-Flight - Access to payload hardware in the Orbiter payload bay may be no less than landing plus 30 hr in the Orbiter Processing Facility and landing plus 72 hr in the Operations and Checkout Building.

Payload time critical items located in the Orbiter mid-deck may be removed no earlier than landing plus 40 min.

2.2.8.1.6 Experiment Developer Integration Responsibilities - The major responsibility of the experiment developer in the ground processing flow is the successful operation of the experiment instruments. Accommodation of this responsibility is provided through the Level IV integration function. In the event a problem occurs with any experiment instrument, the experiment developer will be required to assist the Payload Project Ground Operations Team personnel in an active and/or advisory capacity in resolving the problem and ensuring that the instrument meets all requirements.

2.2.8.2 Ground Operations Facilities - The information presented in this section will provide Ground Operations facility resources and equipment details. This information will aid the experiment developer in designing his experiment for compatibility with the integration equipment.

The Level IV complex consists of the necessary facilities and GSE to perform the integration and checkout of Spacelab payloads. The Level IV site has additional services and facilities available to the user; however, the user will have to make prior arrangements for their use, by request in the ERD. The Payload Mission Manager will integrate the requirements from all users and allocate space, time, and services which will be documented and agreed to in the IIA's for each experiment on each mission.

The requirements for GSE are still in the process of being fully established and will change slightly with subsequent missions.

2.2.8.2.1 Facility Layout and Description - The details of the Level IV complex capabilities and services that will be provided are described in the following subparagraphs.

2.2.8.2.1.1 Receiving Inspection and Storage - The receiving inspection will be performed in a designated building at the Level IV complex. After receiving inspection, those items of equipment to be used in the integration area within 2-3 days will remain in the storage area of the receiving inspection building. The equipment which will not be required within 2-3 days will be moved to the bonded storage area assigned for this equipment.

2.2.8.2.1.2 Level IV Processing Area - A 100K clean area is allocated to pallet processing, rack and floor assembly processing, and integrated payload checkout and verification. This area will contain a bridge crane and sufficient area to perform the tasks required in this room. Covered trenches will be in the floor for accommodating fluid and electrical services. Access to the area by the payload will be through a preplanned route from the rack/experiment buildup area for assembled racks. Allocation of space for ECE to be used during on-line processing shall be determined on a mission by mission basis based on integrated ERD requirements.

2.2.8.2.1.3 Level IV Computer Control Room - The Level IV Computer Control Room will be equipped with an elevated floor to accommodate interconnecting cables and to serve as an air conditioning plenum. It will also have sufficient ceiling clearance to accommodate the computer equipment. This room contains the necessary Level IV consoles, displays, and computers to operate the complex. The Experiment Checkout Equipment (ECE) contained in the room will be allocated based on the integrated requirements from all ERD's.

2.2.8.2.1.4 Rack/Experiment Buildup and Assembly Area - The rack assembly and buildup area will be in a convenient location to the Level IV Computer Control Room and the processing area. The mission peculiar and experiment hardware are to be installed into the racks in this area. Handling will be accomplished by a portable crane. It is not intended that ECE be located in this area; however, if a firm requirement exists, limited space may be allocated based on the integrated requirements of all ERD's.

2.2.8.2.1.5 Experiment Off-Line Service Area - Space will be provided in the facility where users and other Level IV personnel may perform maintenance and off-line testing to resolve anomalies occurring during the Level IV integration. The space available will be used for servicing experiments as required prior to entering the integration process. The space to be allocated to each user will be based on the integrated requirements of all ERD's. Any experiment-unique test and checkout equipment will be provided by the user.

2.2.8.2.1.6 10K Clean Area - Within the processing area will be a 10K clean room which is available for experiment work or rack/pallet checkout. The clean room area will contain a seismic pad. The seismic pad will be utilized to accomplish alignment of instruments and experiments on a pointing system when applicable. Alignment of instruments will be accomplished with optic and/or laser alignment equipment, using gravity as a primary base to align to within 10 arcsec. The space available for ECE is TBD and will be allocated based on the integrated requirements of all ERD's.

2.2.8.2.1.7 Office Space - Office space to support the Level IV operation will be made available in the near proximity of the processing area. Space allocation will be based on the integrated requirements of all ERD's.

2.2.8.2.1.8 Tool Crib - A tool crib will be located adjacent to the experiment off-line service area. The crib will contain such items as oscilloscopes and volt-ohm meters which the user can check out and use in the off-line service area. Availability of equipment from the tool crib will be based on total ERD requirements.

2.2.8.2.1.9 Storage Area - There will be two storage areas. The bonded area will provide a controlled environment for experiments and experiment support equipment.

The uncontrolled storage area will be a part of the receiving inspection building. Both areas will be controlled to the extent that free access will not be allowed. Storage in either area will be based on the integrated requirements of all ERD's.

2.2.8.2.1.10 Space Allocation - There will be a limited amount of space available to the experimenter in the off-line area, rack buildup area, processing area, and the control room. The Mission Manager will allocate space to the user based on the integrated requirements on all the ERD's.

2.2.8.2.2 Facility Resources - The Level IV Integration Complex will furnish the resources identified in the paragraphs of this section. Resources other than those identified will be supplied by the user or prior arrangements will have to be made to obtain the unique resources at the Level IV site. Allocation of the resources will be determined on a mission-by-mission basis.

2.2.8.2.2.1 Fluids and Gases - Standard fluids and gases will be provided by the facility. Drawings will be prepared and furnished to the experimenter that show the details where the fluid and gas outlets are located.

2.2.8.2.2.2 Electrical Power System - A standard power system will be provided by the facility. A drawing showing the services supplied to the various areas will be prepared and furnished to the experimenter along with drawings that show the details where power outlets are located.

2.2.8.2.2.3 Environment - The worst case environmental conditions for the various integration areas are as follows:

Temperature: +18 °C to +25 °C
Humidity: 30% - 60% R.H.

2.2.8.2.3 Ground Support Equipment (GSE) - The GSE that will be provided at the Level IV complex is that which will be used over a wide range of payloads. All GSE that is unique to an experiment must be provided by the experiment developer. Table 2-5 provides a listing of the Level IV GSE. The following paragraphs give more detail on the GSE in order to more clearly define the interfaces that the experiment developer must consider in designing his equipment for payload integration.

2.2.8.2.3.1 Mechanical Ground Support Equipment (MGSE) - The MGSE provides the mechanical services to the flight experiments normally provided by the Spacelab subsystems and/or Orbiter. Also, other equipment that may be peculiar to Level IV integration operations will be provided. Among these services are handling, transportation, servicing, access, and checkout of experiment equipment with the individual mounting elements (e.g., racks and pallet segments). This includes physical and functional interfaces required for cooling and purging of experiments and physical interfaces for support of the experiment mounting elements during Level IV integration operations. The MGSE is listed and discussed below.

Vacuum System - The facility will supply a vacuum system for use by the experiments during integration operations. The unit will be capable of TBD torr. The unit will provide for connecting to each experiment vent assembly interface by means of ducts, hoses, fittings, and adapters.

TABLE 2-5. LEVEL IV GSE (Sheet 1 of 2)

MECHANICAL GSE

Access Equipment

Rack Pallet Interior Access Kit
Pallet Segment Floor Covers
IPS/ASPS Alignment Access and Support Stand
Integration Stand Access Platforms
Integration Stand Walkway and Interior Access Kit
Rack Lower Access Platform
Rack Upper Access Platform
Integration Stand (Installed by others)

Servicing Equipment

Freon Leak Detector
Helium Leak Detector
Rack Conditioning Unit
Freon Services
Vacuum Pumping Unit
Water Servicing Unit
GN_2/GHe Panel

Spares

Handling Equipment

Handling Sling Kit
Utility Support
Subsystem Positioning Aids
Rack Handling Kit
IPS/ASPS Payload Handling Kit
Trunnion Handling Fitting Kit

Transportation Equipment

Rack Transport Dolly

Simulators

Spacelab Floor Simulator
Vacuum Vent/Manifold Vent Adapter

Miscellaneous

Optical Alignment Kit
IPS/ASPS Payload Seismic Pad Adapter
Rack Stabilization Struts
Aft Flight Deck Work Station
Control Center Rack/Work Bench Rack
Work Bench Rack

ELECTRICAL GSE

Power Supplies and Distribution

Rack/Pallet AFD Power
- 28 Vdc, 500 Amp Supply
- Switching Module
- Bus Distributor
- Receptable Distributor

Control Room Power
- 28 Vdc, 50 Amp Supply
- Switching Module
- Bus Distributor
- Receptable Distributor

Power Supplies and Distribution

Integration Area GSE Power
- 28 Vdc, 100 Amp Supply
- Switching Module
- Bus Distributor
- Receptable Distributor

5 Vdc Measuring Supply

TABLE 2-5. LEVEL IV GSE (Sheet 2 of 2)

ELECTRICAL GSE (Cont.)

Experiment Power Distribution

Aft Flight Deck Power Distribution Box

Timing Equipment

Count Clock
Control Panel
Remote Displays

Manual Control & Display

Initiation & Safing Panel
C&W Control Room
C&W AFD Station
R7 Panel Substitute

Network Distribution

Control Room Distributor
Integration Area Distributor

Cables

Signal Conditioning

Fuse Panels

Payload TV Monitor

Ground Equipment Test Set ESE

Spares

PAYLOAD CHECKOUT UNIT (PCU)

CDMS Equipment

125S Computer
I/O Unit
Data Display System
RAU
Computer Terminal
Interconnect Station
Data Bus Coupler
Cables

Interface Equipment

Hardware Interface Unit
Computer Interface Device

Software Programs

PCU Operating System
- Operating System
- CDMS/ORB Simulation

Level IV Systems Software
- High Rate System Postprocessing
- Interface Self-Test Program
- System Test Postprocessing
- PCM Postprocessing

Test Software
- CDMS Test Software
- Ground Computer Test Software

Ground Computer Equipment

Computer
Main Memory
Mag Tape Unit
Disc Memory
Line Printer
Card Reader
Computer Terminal
Operator's Console
Hard Copy Equipment
- CRT Page Printers
- Power Supplies
- Buffer Memory

HRM Simulator

Ground Recorder
HRM I/F Simulator
PCM Decommutator/Ground Computer Interface Box

Water Chiller - Chilled water will be supplied to the experiment heat exchanger for heat rejection. This chilled water interface, equivalent to the flight interface, shall provide equivalent temperature and flow rate conditions. The temperature at the interface will be 44.6 °F (7 °C). The unit will provide supply/return lines that will interface with the supply/return lines on the integration stand. Flow can be directed to either stand; however, it is not intended to be done simultaneously.

Pneumatic Purge Unit - A pneumatic purge unit will provide gaseous nitrogen (GN_2) and 1K clean air for purging experiments. The regulated pressure is TBD. The lines will interface with each integration stand. It is not intended to supply both stands simultaneously.

Rack Conditioning Unit - The rack conditioning unit will provide air cooling to rack mounted equipment. The rack interface, equivalent to the flight interface, shall provide equivalent temperature and flow rate conditions. The temperature at the interface with the Spacelab floor is 71.6 °F (22 °C). The maximum heat load is 4.5 kW.

2.2.8.2.3.2 Electrical Ground Support Equipment (EGSE). The EGSE provides the electrical services to the flight experiments normally provided by the Spacelab subsystems and/or Orbiter. Among the services are power, power distribution, cabling, signal conditionings, and controlling and monitoring of the electrical/electronic interfaces of equipment, including those associated with MGSE performing functions such as cooling, purging, and environmental conditioning. The EGSE is listed and discussed below.

Television (TV) - TV monitors will be provided in the control room to monitor the integration stands. The monitors will be switchable to either stand.

Timing - The facility will provide Greenwich Mean Time (GMT) and Mission Elapsed Time (MET) which are referenced to WWV and a 1024 kHz timing signal. The timing can be preset to a specified MET by the Payload Checkout Unit (PCU) through the Hardware Interface Unit (HIU) interface. The system will include displays throughout the complex for both GMT and MET. The display will be in days/hours/minutes/seconds. This simulates the flight timing system.

Electrical Power Distribution - The facility will provide for the distribution and control of various power interfaces to racks/pallets, Aft Flight Deck (AFD) work station and GSE. Twenty-eight volt direct current power distribution to experiments will consist of a bus system supplied by a common source.

2.2.8.2.3.3 Payload Checkout Unit and Standard Data Products - The PCU is a portion of the Level IV complex which provides the simulation of the Spacelab/Orbiter command and data systems and computer control for test and checkout of Spacelab payloads. The PCU is comprised of two major subassemblies, a Spacelab Level IV experiment CDMS and a ground computer system with accompanying peripheral devices. The Spacelab Level IV experiment CDMS (MITRA 125S) will provide for the simulation of the Spacelab avionics equipment used for command and data interfacing with the flight experiments. The computer will be a ground version of the flight computer with peripherals needed for the validataion of ECAS, such as the performance of a Mission Sequence Test. The ground computer will provide for control of the PCU/payload testing and operations. There will be only one PCU within the Level IV complex, but may be used with either integration stand on a serial basis.

The HRM interface simulator will interface with the payload with up to 16 experiment input channels, 2 direct channels, and up to 18 channels available to the ECE. The capability will be to provide for the recording of all data and evaluate in real time one channel for signal compatibility. A block diagram of the PCU is shown in Figure 2-17.

Figure 2-18 outlines the standard data products that are available for off-line processing of science and test data that were recorded during Level IV activities. As shown, two data tapes are recorded during testing. One, the Ground Computer Log Tape (GCLT), contains all Pulse Code Modulation (PCM), RAU, and mixed (system, operator input, etc.) data for post processing. The second, the High Data Log Tape (HDLT), contains the experiment data as input to the HRM interface simulator shown in Figure 2-18.

Outputs from the post processors shown are in the form of displays, line printer hard copy, and Computer Compatible Tapes (CCT's).

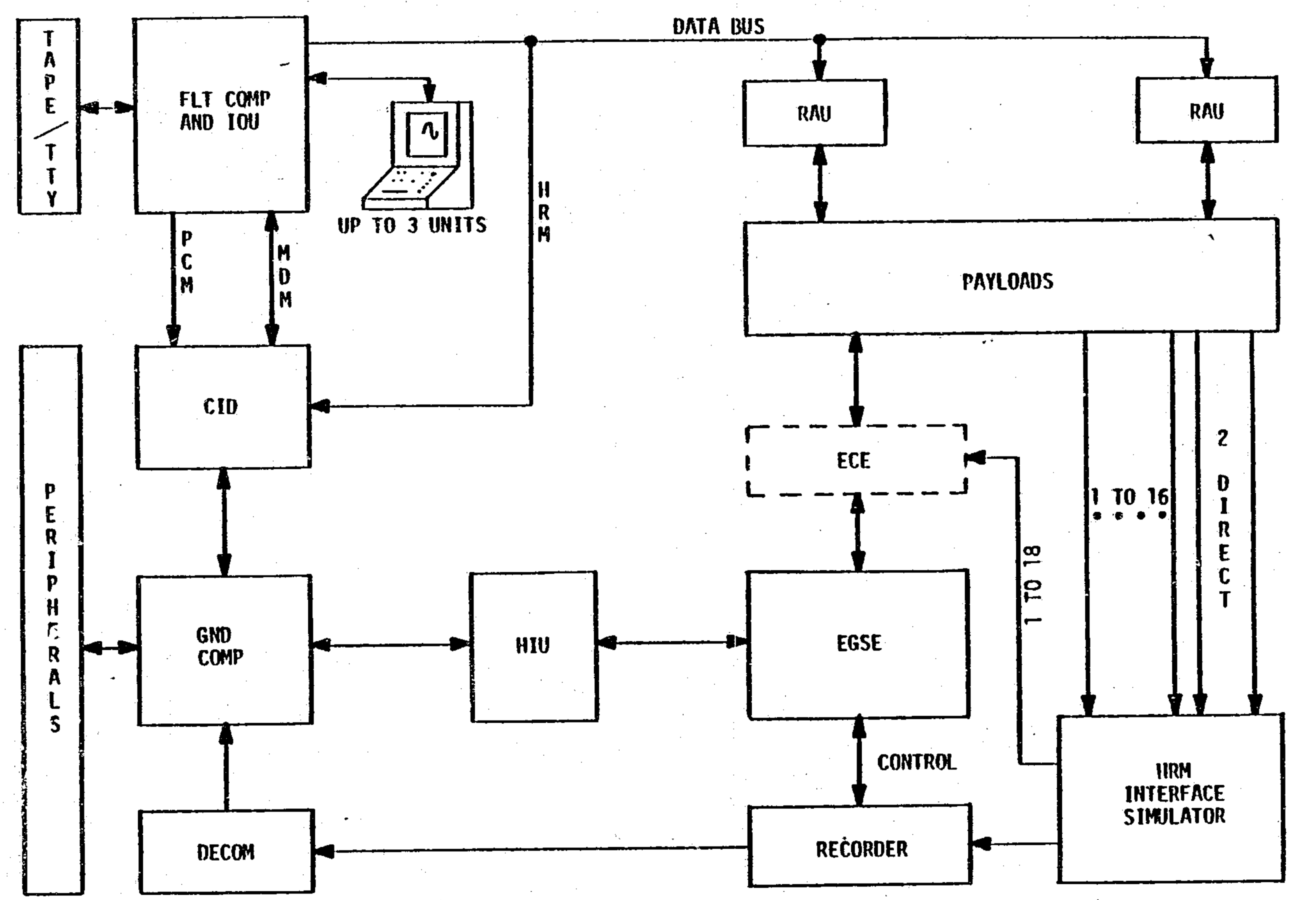


FIGURE 2-17. LEVEL IV PCU

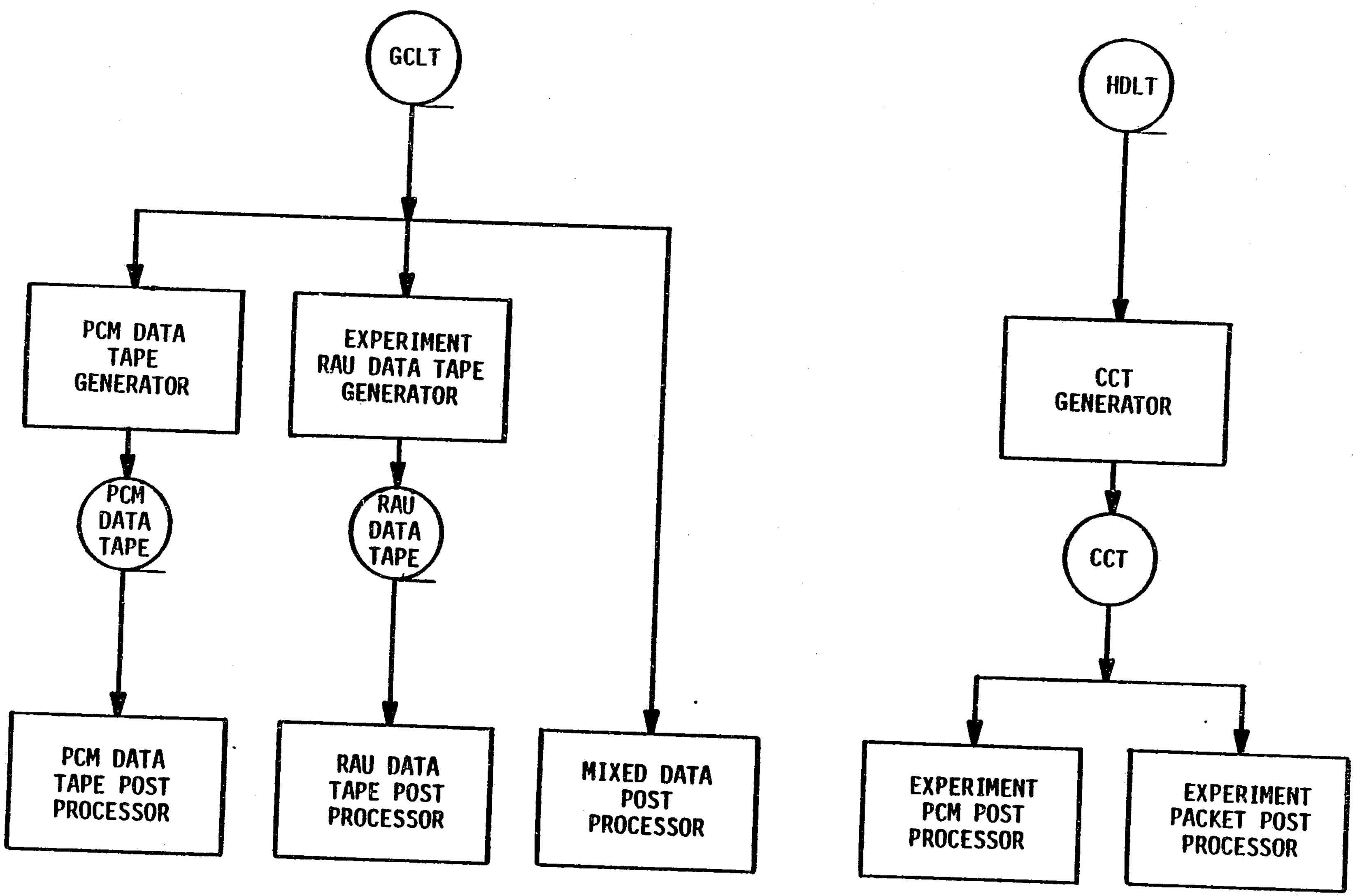


FIGURE 2-18. SPACELAB LEVEL IV INTEGRATION POST PROCESSING DATA PRODUCTS

2.2.8.2.3.4 AFD Work Station - The AFD work station will be an elevated structure that can be positioned by the bridge crane at the front end of either of the integration stands. The work station shall consist of personnel and structural rack accommodations for those panels of the three work stations; namely, the "mission station," the "on-orbit station," and the "payload station," and for a Data Display System (DDS). Connector bracketry will be provided which can accommodate flight cabling associated with the experiment-supplied hardware. The main working surface will be at the relative height difference that exists between the Spacelab flight deck and the module floor/pallet floor.

The side nearest the integration stand will contain a bulkhead to simulate the Orbiter forward bulkhead, station X_O 576.

Accommodation shall be made on the bulkhead for two payload J-boxes. Each box shall contain the required payload electrical signal and control interfaces. The work station structure will contain provisions for routing cables (raceways, clamps, etc.) for satisfying the ac, dc, and power bus arrangements.

Two fans are located on each side of the bulkhead which will satisfy the AFD cooling requirement by circulating 133 lb/hr (60.3 kg/hr) of cool conditioned facility air into the equipment enclosure.

The work station controls and displays and mounting provisions will duplicate the operational concept for the Spacelab. The layout of the AFD displays will be a U-shaped arrangement, namely, the mission station, on-orbit station, and the payload station.

2.2.8.2.3.5 Miscellaneous Support Equipment - This category contains various pieces of equipment--a Freon and helium leak detector to check for leaks, drying oven to dry and condition silica gel cartridges in small dessicant canisters, and optical alignment kit for alignment of pallet-mounted experiments requiring less stringent accuracies (1/10 of a degree or greater). Experiments requiring alignment accuracies on the order of arcseconds will be aligned on the seismic pad. There will be other general purpose laboratory test equipment, such as oscilloscopes and volt-ohmmeters.

2.2.8.2.3.6 Facility Support Equipment - This equipment consists of items such as the overhead cranes located in the receiving/inspection area, fork lifts, and transportation dollies, lift-a-lofts, handling slings, and road transporter. This equipment will be operated by Level IV personnel.

2.2.8.2.4 Support Capabilities - Interspersed within the Level IV Complex are several supporting laboratories and shops which will not normally be supplied to the user, but will be made available on a negotiated basis. Experimenters requiring the use of these capabilities must state the requirements in the ERD and contact the Ground Operations Manager to make arrangements for their use. Laboratories and shops included in this additional support capacity are listed below:

- Computer Services
- Optical Fabrication Shop and Electro/Optical Laboratories
- Precision Cleaning Facility
- Calibration Laboratory
- Cable Fabrication
- Tubing Shop
- Machine Shop.

2.2.8.2.5 Level IV Cabling and Tubing Installation - Instrument unique cabling between a rack-mounted instrument element and its pallet-mounted element(s) or to another pallet-mounted instrument shall be supplied by the NASA mission integrator and will be used in Level IV testing.

Mission peculiar cabling between an experiment rack-mounted instrument and its elements in the optical window will be supplied by the NASA mission integrator and will be used in Level IV testing.

MPE cabling connecting the instrument to a pallet interface and/or to the experiment aft bulkhead fitting on the Spacelab module shall be supplied by the NASA mission integrator.

Where NASA pallet-mounted instruments require insulation, the insulation will be installed after the instrument has been installed on the pallet and servicing is complete.

Non-standard mounted pallet cold plates and support structure cold plates with associated cold plate tubing for NASA instruments will be installed at Level IV.

2.2.8.2.6 <u>Unique GSE Requirements</u> - Unique experiment GSE required for support of ground testing, monitoring, and servicing of experiments will be minimized by making maximum use of the Spacelab and experiment flight systems to support these functions. Instrumentation system capabilities and sensors required to support ground test activities must be included in the flight experiment wherever practical in order to minimize the requirements for ground support equipment.

2.2.8.2.7 <u>Processing Activities</u> - Caution and warning indications required for experiments which have hazardous conditions will be displayed by GSE during active subsystems testing or operation.

The installation of Spacelab in the Shuttle Orbiter will take place with the Shuttle Orbiter in a horizontal position. Spacelab vertical installation is not planned.

2.2.8.2.8 <u>Technical Support Services</u> - Listed below are the administrative and technical support services available to the experiment developer at the launch site. Complete details as to capability, types, etc. of each service are provided in Section 5.0 of the Launch Site Accommodations Handbook for STS Payloads.

<u>Administrative Support</u>

- Housekeeping
- Communications
- Security
- Safety
- Transportation
- Medical
- Food Services
- Reproduction
- Mail Services

<u>Technical Support</u>

- Clean Rooms
- Cranes
- Operational Communications
- Instrumentation
- Propellants, Liquids, and Gases
- Ordnance
- Chemical Sampling and Analysis
- Non-Destructive Evaluation
- Technical Shops
- Laboratories
- Photography

2.2.9 Flight Operations

Section 2 of the SPAH discusses, among other things, the Orbiter/Spacelab performance capability and constraints with respect to orbital maneuvering, achievable orbits, crew tasks, and crew size. The following additional constraints and guidelines are offered with respect to flight operations.

2.2.9.1 Flight Characteristics - Mission planning requirements should be based on nominal operations and not contingency operations. Experiment deactivation procedures may be planned to occur within the last 12 hr prior to deorbit if they are compatible with STS deactivation requirements and procedures.

2.2.9.2 Orbiter Attitude Constraints - During on-orbit operations, the amount of time the Orbiter can hold a vehicle attitude is dependent on a combination of the following factors:

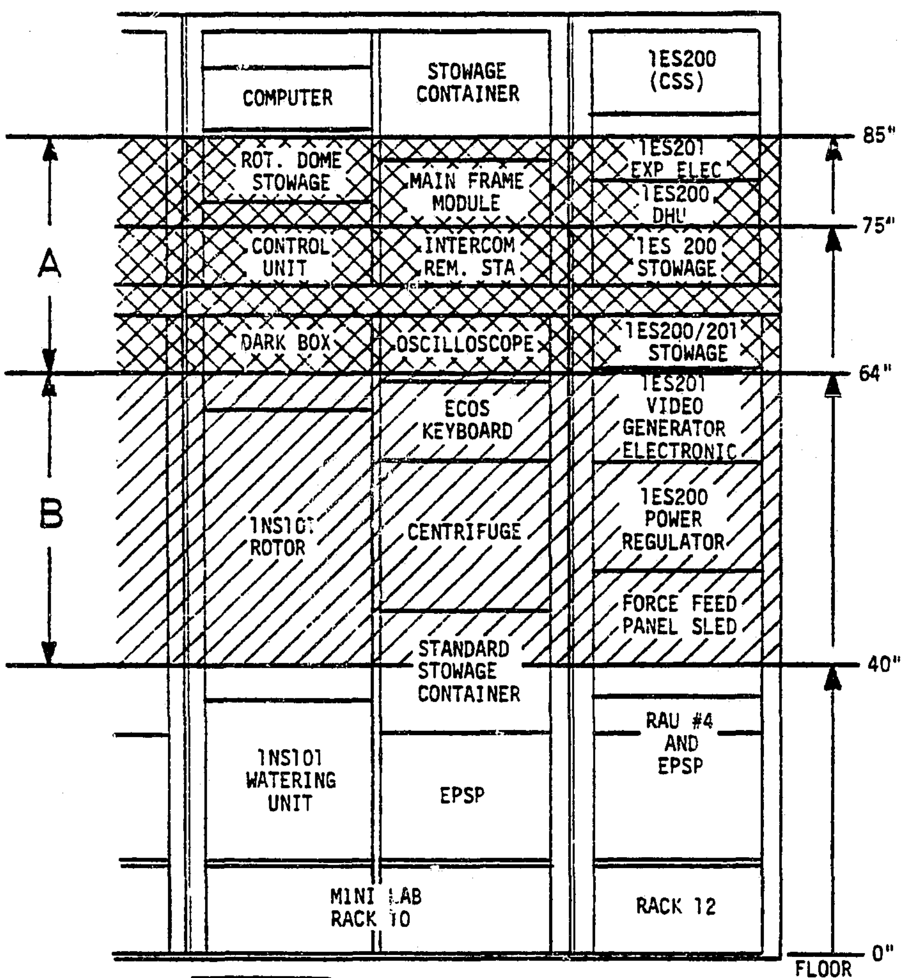
- Solar incidence angle (beta angle)
- Orbiter attitude
- Orbiter and payload heat-rejection load profile
- Addition of radiator kit
- Preentry thermal conditioning
- Stored water available for Orbiter heat rejection
- Orbiter attitude
- Crew size.

These items which are discussed in paragraphs 6.1.1.2.1 and 6.1.1.2.2 of ICD 2-19001 are for beta angles less than 60 deg and beta angles greater than 60 deg, respectively. Attitude-hold durations longer than the smaller number will impose mission constraints, such as vehicle orientation, orbital parameters, etc. Before the attitude-hold time durations can be repeated, the Orbiter must be placed in a preferred attitude to allow fuel cell generated water accumulation and/or thermal conditioning.

2.2.9.3 Uplink Data Transmission Rates - Uplink (ground to Spacelab) data transmission rates to the experiment computer, e.g., updates to computer memory, mass memory unit data loads, or new timelines for mission operations are relatively low. While the crew can enter a certain amount of data by hand, any major change cannot be uplinked within a 7-day mission.

2.2.9.4 Man-Machine Interface - In addition to crew-interface guidelines presented in Section 7.2.5 of the SPAH, two areas will be discussed: (1) location of control panels, and (2) crew efficiency for a 7-day mission.

2.2.9.4.1 Control Panel Location - The investigator who is developing equipment for a preintegrated rack should locate control panels within the optimum control envelope where possible. Figure 2-19 shows this envelope superimposed on the front panels of racks 10 and 12 for Spacelab Mission 1.



A MAXIMUM UPPER REACH ZONE

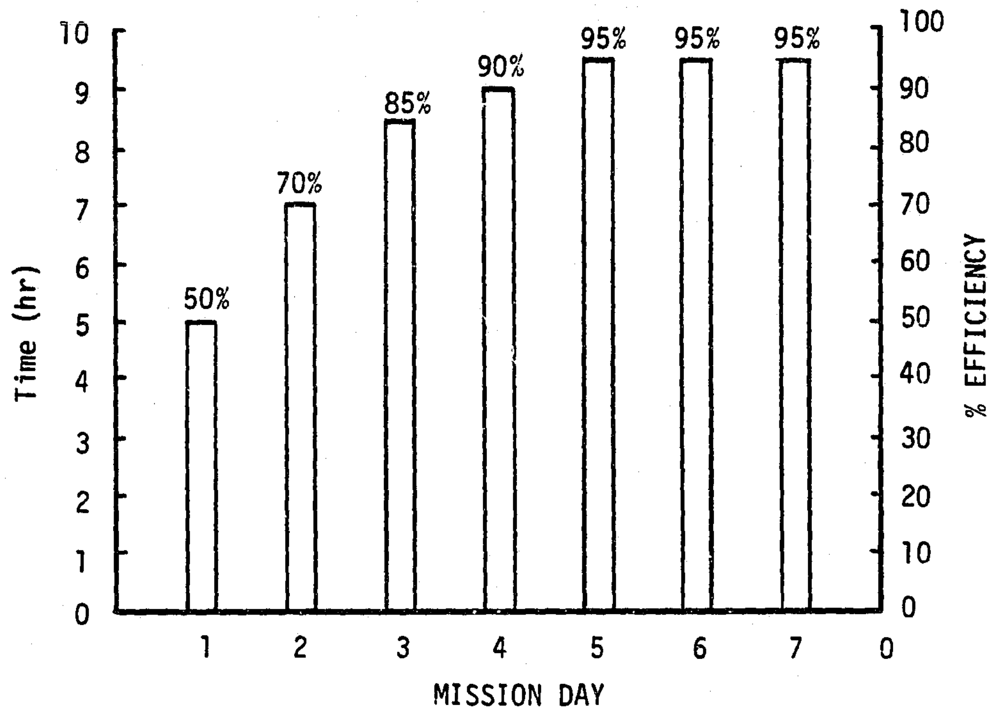
B OPTIMUM CONTROL ENVELOPE

40" MINIMUM OPTIMUM CONTROL AREA (95th PERCENTILE MALE)
64" MAXIMUM OPTIMUM CONTROL AREA (5th PERCENTILE MALE)
75" MAXIMUM FUNCTIONAL REACH (5th PERCENTILE MALE)
85" MAXIMUM FUNCTIONAL REACH (95th PERCENTILE MALE)

FIGURE 2-19. OPTIMUM CONTROL ENVELOPE FOR CONTROL PANEL LOCATION

The optimum control envelope is based on a 0-g neutral body position and lies between 40-64 in. from the floor. The upper limit is constrainted by a 5th percentile male. All crew interfaces requiring precise reading of displays and precise operation of controls should be located in this envelope. Controls and displays located outside of the envelope will create crew fatigue and contribute to performance errors. Foot restraints and handrails are provided and can be used to gain access to areas above the optimum envelope, however, crewmen will be limited to one-handed operations.

2.2.9.4.2 Crew Efficiency - Crew efficiency should be considered by the experimenter in planning the inflight operation of his equipment. Based on Skylab results, crew efficiency has been found to vary according to the data presented in Figure 2-20. The pre- and post-launch awake period adds up to a 23-hr workday for the crew. This extended workday coupled with crew circadian rhythm and 0-g environment adjustment accounts for the reduced efficiency during the early part of mission.



NOTE: Data are based on SL-1/STS compatibility assessment, JSC, October 1977.

FIGURE 2-20. CREW EFFICIENCY DATA

2.2.10 Environmental

Environmental constraints and guidelines with respect to contamination and electromagnetic compatibility are discussed in this section.

2.2.10.1 Environmental Constraints - Section 5 of the SPAH describes the natural and induced environments that the Spacelab payload may be exposed to for both module- and pallet-mounted equipment. Two areas, contamination and electromagnetic compatibility (EMC), will be discussed here in more detail.

2.2.10.1.1 Contamination - The experimenter must determine if the contamination levels produced from the integrated payload and Spacelab configuration exceed his requirements and request reductions, if necessary. These data will be available in the IPRD. Column density predictions (+Z axis) of different species are predicted from sources such as:

- Material outgassing
- Early desorption
- Leakage
- Vernier Control System
- Evaporation
- Coolant leakage
- Experiments.

Additional sources to consider occur when there are periodic fuel cell purges (gaseous O_2 and H_2) and periodic liquid H_2O vents (potable water, urine, and H_2O generated by the fuel cells). These vents are directed along the Y axis. The lack of structural elements in this direction causes no additional contribution to the column density along the +Z axis. However, a maneuver placing the vehicle Z axis or experiment Field of View (FOV) axis in a direction formerly aligned with the +Y or -Y axis (if performed rapidly enough) could cause the gaseous cloud or ice particles to appear in the FOV of the instrument.

2.2.10.1.2 Electromagnetic Compatibility - The basic EMC requirement is that all subsystems shall be able to operate compatibly during a mission. Payload equipment should not generate levels of interference which would degrade the performance of or cause a malfunction in the Orbiter, Spacelab, or other payload subsystems. Also, equipment should not malfunction due to susceptibility to system emission.

2.2.10.2 Environmental Guidelines - Guidelines pertaining to the control of outgassing of pallet experiment materials and the electromagnetic compatibility of subsystems are presented in this section.

2.2.10.2.1 Contamination Guidelines - Controlling the outgassing of experiment material is one way to minimize the induced environment around experiments mounted on the pallets. This can be accomplished by the careful selection of experiment materials. The following documents should be used as guidelines for the selection of materials:

(1) JSC-SP-R-0022A, Vacuum Stability Requirements of Polymeric Materials for Spacecraft Application, September 9, 1974.

(2) ESA Specification PSS 09/QRM-02T, Screening Test Methods Employing a Thermal Vacuum for the Selection of Materials to be Used in Space.

(3) JSC-02681, Nonmetallic Materials Design Guidelines and Test Data Handbook.

(4) MSFC-HDBK-527, Revision A, Materials Selection Guide for MSFC Spacelab Payloads.

2.2.10.2.2 Electromagnetic Compatibility - Each experimenter, by designing his equipment to meet the EMC specificarion MSFC-SPEC-521 and the electromagnetic environments and design requiremetns of the SPAH and ICD 2-05301, will establish the minimum susceptibility and maximum emission limits of his equipment. Teledyne Brown Engineering Document specification number B1-0-0004-TBE-A groups individual requirements from the above reports and puts them into a system concept of grounding and isolation applicable to all Spacelab missions. In meeting EMC requirements, the experimenter must consider these interfaces:

(1) Experiment/Spacelab, Orbiter

(2) Experiment/Experiment

(3) Experiment/MPE.

2.2.10.2.2.1 Experiment/Spacelab, Orbiter - Compliance with MSFC-SPEC-521 reasonably ensures each experimenter that his equipment will be compatible with the SYS generated electromagnetic environment. Analysis of the subsystem test data generated in accordance with MSFC-SPEC-521 will determine if an experiment will generate electromagnetic energy that will interfere with the STS.

The problem will be solved at the system level if interference with the STS occurs after demonstrated compliance with MSFC-SPEC-521. The same test data in conjunction with analysis are to determine that each experiment of a payload complement will be compatible with all other experiments in that complement.

2.2.10.2.2.2 Experiment/Experiment Interfaces - EMC between experiments will be determined by analysis and tests utilizing MSFC-SPEC-521 requirements, technical data provided in the IIA's, and experimenter provided documentation. This analysis and test planning will be performed by the integration contractor.

EMC testing will be conducted on the payload complement during Level IV integration. The integration contractor will provide the planning and detailed requirements necessary to ensure that experiment/experiment EMC is adequately demonstrated.

2.2.10.2.2.3 Experiment/MPE Interface - MPE is designed to functionally interface the experiments to each other and with the Spacelab/Orbiter. The baseline design of all MPE will comply with the requirements of MSFC-SPEC-521. The MPE cable harness design will comply with the circuit EMC classification shown in Table 2 of MSFC-SPEC-521. Cable shielding and shield ground requirements will be determined by analysis and will consider the experiment/MPE input/output circuits and the STS-generated electromagnetic environment.

2.2.10.2.2.4 Bonding - Each separate piece of electrically active experiment equipment will have a stud or tapped hole to serve as a point for the box to be electrically bonded to primary structure. Reference is made to MIL-B-5087B and SPAH paragraphs 5.4.1.3 and 7.7.2.2.1.

2.2.10.2.2.5 Shielding - Sufficient connector pins will be designated to carry cable shields through for proper grounding (as applicable) within the box. In order to safeguard against potential EMC problems, experiments should not require MPE cabling to transfer data with normal operational voltages of less than 5 V.

2.3 SAFETY REQUIREMENTS

For the mutual benefit of all organizations participating in Spacelab missions, it will be necessary that all experiment equipment, flight and ground operations, and ground support equipment meet certain requirements to ensure safety of operation.

The basic safety requirements applicable to Spacelab instruments/ experiments are specified in five documents:

- Safety Policy and Requirements (SP&R) for Payloads Using the Space Transportation System (NHB 1700.7)
- Kennedy Management Instruction (KMI 1710.1), Kennedy Space Center Safety Program
- Safety and Environmental Health Standards (MMI 1700.4B), MSFC
- Space Transportation System Payload Safety Guidelines Handbook (JSC-11123), JSC
- Spacelab Payload Accommodation Handbook (SPAH, SLP/2104), ESA.

The SP&R is the Level I (top) safety document that defines safety policy and basic safety requirements applicable to Spacelab payload missions, and takes precedence over all other applicable documents.

2.3.1 Safety Implementation Guidelines

The NASA Headquarters document "Safety Policy and Requirements (SP&R) for Payloads Using the Space Transportation System (NHB 1700.7) establishes the official set of basic safety requirements for all payloads using the STS. The thrust of the SP&R is to minimize STS involvement in the payload design process while maintaining the assurance of a safe operation. The SP&R provides overall safety policies and requirements that must be complied with while allowing flexibility in the implementation approach.

MSFC document Spacelab Payload Safety Implementation Approach (JA-012) provides guidelines and instructions for the implementation of the requirements contained in the SP&R. This document presents the minimum requirements for safety data submittal. JA-012 outlines an approach that implements the SP&R in five steps. These steps are keyed to scheduled hardware program reviews as well as integrated payload reviews. Hazards will be identified including hazardous conditions, possible effects, existing safety provisions, applicable requirements, and recommended additional safety provisions. Hazard control verification requirements, methods, and safety related compliance data will be established (Section 2.4).

The five steps outlined in JA-012 are as follows:

Step 1: Hazard Identification

a. Complete a Payload Safety Matrix (Figure 2-21) for experimental hardware. Hazards groups and subsystems are defined and described in JSC 11123, STS Payload Safety Guidelines Handbook dated July 1976.

b. Complete a Hazard List (Figure 2-22) for each subsystem checked on the Payload Safety Matrix giving hazard group, hazard title, and applicable safety requirement per SP&R.

*c. Submit the Payload Safety Matrix and Hazard Lists when completed or two weeks prior to the Requirements Review (RR).

Step 2: Establish Requirements Implementation and Verification Approach

a. Refine and update the Payload Safety Matrix and Hazard Lists.

b. Assess design/operational/procedural provisions for hazard elimination, reduction, and/or control.

c. Postulate hazard consequences (possible causes/effects, existing or additional safety provisions).

d. Establish verification approach; i.e., analysis, test, inspection, etc.

e. Complete Payload Hazard Report (Figure 2-23) for each hazard title by subsystems. Give each report a unique number and revision letter for tracking purposes; i.e., 1, 1A, 1B; review phase, date, etc.

f. Prepare block diagrams, schematics, and other supporting data to describe identified hazards.

g. Prepare a list of:
   (1) Nonmetallic materials
   (2) Radioactive materials
   (3) Equipment generating hazardous ion.

h. Prepare potential waiver requests to igure 2-24).

*Data submitted to Mission Manager when mission ass

PAYLOAD SAFETY MATRIX

PAYLOAD	PAYLOAD ORGANIZATION	DATE	PAGE

HAZARD GROUP / SUBSYSTEM	COLLISION	CONTAMINATION (TOXICITY, ETC)	CORROSION	ELECTRICAL SHOCK	EXPLOSION	FIRE	INJURY AND ILLNESS	LOSS OF ENTRY CAPABILITY	RADIATION	TEMPERATURE EXTREMES								
Biomedical																		
Hazard Detection and Safing*																		
Cryogenics																		
Electrical																		
Environmental Control																		
Human Factors																		
Hydraulics																		
Materials																		
Mechanical																		
Optical																		
Pressure Systems																		
Propulsion																		
Pyrotechnics																		
Radiation																		
Structures																		

NOTE: Hazard groups and subsystems are defined and described in JSC 11123, STS Payload Safety Guidelines Handbook. The subsystems list may be expanded or modified for specific payloads/GSE. The intent of this form is to assist the Payload Organization in identifying hazards associated with the payload/GSE.

INSTRUCTIONS:

1. For a single element type payload prepare two matrixes, one for the payload and another for GSE/ground operations. For experiment payloads prepare matrixes for the following:
   a. one for each experiment
   b. one for interface hazards
   c. the carrier structure (if applicable)
   d. GSE/ground operations
2. Complete blocks for payload/GSE/experiment title, payload organization, date, and page.
3. Determine safety subsystem elements.
4. For each identified safety subsystem element, check the hazard group(s) that could apply. This will be based on the particular hardware, design, and operation of the subsystem. JSC 11123 may be used as a guide to determine if a hazard group applies.

JSC Form 542 (Feb 78) *Reference "Caution and Warning" in JSC 11123. NASA-JSC

FIGURE 2-21. PAYLOAD SAFETY MATRIX

HAZARD LIST

PAYLOAD	SUBSYSTEM	DATE

HAZARD GROUP	HAZARD TITLE	APPLICABLE SAFETY REQUIREMENT

PAYLOAD: Enter title of payload, or payload GSE. (For experiment payloads enter payload or experiment title as applicable.)

SUBSYSTEM: Enter subsystem checked on Safety Matrix.

DATE: Enter date form is completed or revised.

HAZARD GROUP: Enter hazard group (checked on Safety Matrix) that corresponds to the subsystem above.

HAZARD TITLE: Enter hazard title(s) which identify the safety concern for each hazard group listed. Hazards are identified from safety analysis.

APPLICABLE SAFETY REQUIREMENTS: Enter the SP&R paragraph numbers for the technical requirements that are related to each identified hazard.

Complete the Hazard List for each subsystem checked on the Payload Safety Matrix. Hazard lists for more than one subsystem may be included on one hazard list form.

A separate hazard list should be prepared for GSE and ground operations.

JSC Form 542A (Feb 78) NASA-JSC

FIGURE 2-22. HAZARD LIST

PAYLOAD HAZARD REPORT		NO. (Unique No.)
PAYLOAD (Enter payload, GSE or experiment title from Hazard list) NOTE: Separate hazard reports are required for GSE and ground ops.		PHASE (Safety Review Phase)
SUBSYSTEM (Title of subsystem from Hazard List)		DATE (Date completed or revised)
HAZARD TITLE (Title of hazard from Hazard List)		

APPLICABLE SAFETY REQUIREMENTS:

(SP&R paragraphs from Hazard List)

DESCRIPTION OF HAZARD:

Describe the hazard and its effects on the Orbiter, other payload, the crew, and/or ground operations. Define the mission phase(s) when hazard could occur (i.e., ground operations, boost, etc.).

HAZARD CAUSES:

Itemize each possible hazard cause.

HAZARD CONTROLS:

For each hazard cause, define the controls designed into the system to preclude or minimize the occurrence of the hazard. Preliminary information may be provided for phase I and more details provided at phases II and III.

SAFETY VERIFICATION METHODS:

For phase I, identify the verification approach (i.e., test, analysis, inspection, etc.). For phase II, identify the test plan that verifies the effectiveness of the hazard control. For phase III, provide the results of the test, analysis, inspection, etc.

STATUS:

Hazard Report is open until all verification is satisfactorily completed. At phase I, provide a tentative schedule for completion of the verification task.

CONCURRENCE	PHASE I (PDR or IDE)	PHASE II (CDR or FDOR)
Payload Organization		
STS Operator		

APPROVAL	PHASE III (Delivery)
Payload Organization	STS Operator

JSC Form 542B (Feb 78) NASA-JSC

FIGURE 2-23. PAYLOAD HAZARD REPORT

PAYLOAD SAFETY REQUIREMENTS WAIVER	WAIVER NO.	DATE
PAYLOAD NAME *(Include model(s) or serial(s))*		
SUBSYSTEM AND SPECIFIC COMPONENT AFFECTED:		
REQUIREMENT BEING WAIVED:		
HAZARD OR HAZARD CAUSE *(Include reference to Payload Hazard Report.)*		
REASON REQUIREMENT CANNOT BE FULFILLED:		
RATIONALE FOR ACCEPTANCE: *(Attach applicable data as required to support rationale; i.e., drawings, test data, photographs, etc.)*		
PAYLOAD ORGANIZATION MANAGER		DATE
NASA STS OPERATOR		DATE

JSC Form 542C (Feb 78) NASA-JSC

FIGURE 2-24. PAYLOAD SAFETY REQUIREMENTS WAIVER *i. Submit Payload Safety Matrix, Hazard Lists, Payload Hazard Reports, proposed waivers and supporting data (f and g above) when completed or two weeks prior to the Preliminary Design Review (PDR).

Step 3: Assess Requirements Implementation and Verification by Analysis

a. Update the Payload Safety Matrix, Hazard Lists, Payload Hazard Reports, and requested waivers, as required.

b. Provide engineering drawings of safety critical subsystems when specifically requested.

c. If required, update list of:
   (1) Nonmetallic materials
   (2) Radioactive materials
   (3) Equipment generating hazardous radiation.

d. Prepare a list of safety related failures or accidents.

e. Prepare an assessment of verification by previous use, analysis, and similarity.

f. Finalize verification test and/or inspection provisions.

*g. Submit a, b, c, d, e, and f above when completed or two weeks prior to the Critical Design Review (CDR) for concurrence.

Step 4: Pre-Level IV Data Compliance Review

a. Finalize the Payload Safety Matrix, Hazard Lists, Payload Hazard Reports, and requested waivers, as required.

b. Provide engineering drawings of safety critical subsystems when specifically requested.

c. If required, update list of:
   (1) Nonmetallic materials
   (2) Radioactive materials
   (3) Equipment generating hazardous radiation
   (4) Safety related failures or accidents.

d. Prepare summary assessment of results of safety verification by previous use, analysis, similarity, and test for each Hazard Report.

e. Assess requirements, including changes versus verification provisions.

f. Review disposition of safety related waivers, deviations, and failures.

g. Finalize hazardous procedures including training requirements.

*Data submitted to Payload Mission Manager when mission assigned.

h. Prepare safety compliance data required by paragraph 305 of the SP&R including the safety assessment report and the Certificate of Safety Compliance (Figure 2-25).

i. Submit a, b, c, d, e, f, g, and h above when completed or two weeks prior to delivery of experiment/equipment/ facility to level IV for approval.

Step 5: Integrated Payload Safety Analysis and Assessment

a. Experimental hardware developers will resolve any safety issues that may be detected during level IV integration and tests related to his responsibility.

b. The integrated payload will be analyzed by the Mission Manager for hazards and SP&R will be implemented as applicable in much the same manner as for the experimental hardware.

c. The Mission Manager will conduct a Flight Readiness Review (FRR). During this review all experimental hardware for that mission and the integrated payload will be assessed for flight worthiness. Residual safety concerns will be addressed and dispositioned.

d. At the conclusion of this FRR and subject to the resolution of action items, the Mission Manager will sign his Certificate of Safety Compliance.

e. Prior to the STS Flight Readiness Review the STS operator will endorse the payload Mission Manager's Certificate of Safety Compliance signifying his agreement with the integrated payload assessment.

The SP&R is equally applicable to "off-the-shelf" hardware as it is to specifically designed hardware for use in the STS. Every responsible effort will be made to minimize safety analysis, verification, and data required for "off-the-shelf" hardware. However, the basic objectives and requirements of the SP&R must be achieved. Basically, the approach should be to evaluate "as built" hardware to identify potential hazards and determine compliance to the SP&R as outlined previously.

2.3.2 Safety Compliance

Steps 1 through 3 may be completed without an assigned mission. When a mission is assigned the Payload Mission Manager will conduct a Project Review (see Section 3.3) at which time concurrence or a request for further action will be given.

MISSION ______________

DATE ______________

Page _____ of _____

CERTIFICATE OF SAFETY COMPLIANCE

THE ______________________________ EXPERIMENTAL HARDWARE COMPLIES WITH APPLICABLE REQUIREMENTS OF THE "SAFETY POLICY AND REQUIREMENTS (SP&R) FOR PAYLOADS USING THE SPACE TRANSPORTATION SYSTEM (STS)" DATED MAY 1979. IDENTIFIED HAZARDS HAVE BEEN ASSESSED AND ARE CONSIDERED ACCEPTABLE RISKS TO THE STS.

SUBMITTED: ______________________________
EXPERIMENTAL HARDWARE DEVELOPER

APPROVED: ______________________________
SPPO, MISSION MANAGER

APPROVED: ______________________________
PAYLOAD ORGANIZATION

APPROVED: ______________________________
STS OPERATOR

EXCEPTIONS NOTED:

FIGURE 2-25. CERTIFICATE OF SAFETY COMPLIANCE

2.4 VERIFICATION FOR FLIGHT

Spacelab Payload Mission Manager Verification Requirements for Instruments, Facilities, MPE, and ECE Document (MSFC JA-061) establishes the verification requirements to be met by the payload hardware developers. These requirements are imposed by the Payload Mission Manager but do not include the requirements to verify equipment performance. This responsibility is left up to the facility/instrument Project Manager. A certification process, including both formal documentation and project reviews, is defined in this section to determine compliance with these requirements.

2.4.1 Spacelab Payload Mission Manager Verification Requirements for Instruments, Facilities, and ECE

Equipment will be verified to the design requirements contained in the following documents:

Document	Number
Safety Policy and Requirements for Payloads Using the Space Transportation System	NHB 1700.7
Spacelab Payload Accommodations Handbook (SPAH) Appendix A - Avionics Interface Definition Appendix B - Structures Interface Definition, Module Appendix B-1 - Structure Interface Definition, Pallet	SLP/2104
Shuttle Orbiter/Cargo Standard Interfaces	ICD 2-19001
Integrated Payload Requirements Document (IPRD for specific mission)	JA-(Varies with mission)
Instrument Interface Agreements (IIA's for specific equipment/mission)	JA-(Varies with mission)
ECOS Design Specification	ECO-8945A
HRM Format Standards	MSFC-SPEC-630
Experiment Checkout Equipment (ECE) to be Utilized at KSC, May 31, 1979	MEMO JA31(79-125)
MPE Requirements Document	JA-(Varies with Mission)
MPE Specifications	(Varies with equipment)

Methods of verification and specific requirements are discussed in the next sections. These same methods and requirements will also pertain to the verification of equipment performance.

2.4.1.1 <u>Verification Methods</u> - Equipment interfaces will be verified by test, analysis, or inspection; a combination of these methods (e.g., test individual items, analyze integrated assemblies); or an option of methods (e.g., analysis or test). These methods are defined as follows:

2.4.1.1.1 <u>Test</u> - Test is the actual operation of equipment under simulated conditions or the subjection of equipment to a specified environment to measure responses.

2.4.1.1.2 <u>Analysis</u> - Analysis is a technical evaluation that predicts the response of the actual design and operating characteristics so that comparisons can be made to the design requirements and specifications. Analysis can be used to verify requirements, provided established techniques are used which are adequate to yield acceptable accuracies, or where testing is impractical. There are many types of acceptable computer codes that are currently available for use in performing analyses (e.g., stress, thermal, dynamic). These codes, both of a general and specific nature, can be obtained through the following organization:

Computer Software Management and Information Center (COSMIC)
112 Barrow Hall
University of Georgia
Athens, Georgia 30602
(404) 542-3265

COSMIC is a software dissemination center operated under contract to NASA by the Information Services Division of the University of Georgia Computer Center. Its mission is to facilitate the dissemination of computer software which has been developed by NASA and NASA contractors.

Included in this category is analysis by similarity to items previously verified. An example would be the reflight of previously verified payload hardware. Analyses would be required to verify that fatigue life criteria and new flight operational parameters could be met. These analyses along with the inspection of the physical condition of the hardware and some testing (e.g., verify optical properties of external surfaces) would requalify hardware for flight.

2.4.1.1.3 Inspection - Inspection is a physical evaluation of equipment and associated documentation. Inspection may be used to verify construction features, drawing compliance, workmanship, and physical condition. It includes determination of physical dimensions.

2.4.1.2 Verification Requirements - It is the responsibility of each equipment developer to determine those requirements from document MSFC JA-061 that are appropriate to his design and develop his verification program accordingly. Each verification requirement is defined by an identification number, description of requirement, verification method, and source of design requirement. The identification numbering system shall be used in his verification plan and subsequent documentation (discussed in 2.4.3). When more than one verification method is specified, the developer shall select the most appropriate method or combination. Documentation listed as sources of design requirements contain the specific requirements to be verified.

2.4.2 Spacelab Payload Mission Manager Verification Requirements for Operational Procedures

Equipment operating procedures will be verified to the inflight operating procedures developed by the experimenter.

2.4.2.1 Verification Method - Crew training activities which the facility developer/investigator is required to conduct will verify the written procedures required for inflight operations.

2.4.2.2 Verification Requirements - Written procedures and requirements for inflight onboard crew operations (example shown in Figure 2-26) will be developed by the facility developer/investigator.

2.4.3 Certification Process

Procedures for reviews and documentation requirements have been established to certify the verification process.

2.4.3.1 Reviews - Reviews include both project and integrated payload reviews.

2.4.3.1.1 Project Reviews - Project reviews are normally held to determine facility/instrument/experiment design progress and compliance with mission requirements. The Payload Mission Manager will normally participate

LOCATION OR PANEL	ID	TASK	TRAINING NOTES
		A. Procedure for 49-minute (before sleep) experiment (MS2-OBS, PS2-SUB)	
	MS2	1. Remove targets, sticky tapes, blindfold and notebook from stowage in TBD.	
		2. Unstow TV camera from TBD and set up at TBD location.	
	PS2	3. Get into berth.	
		4. Place restraining straps on body and adjust so loose fit.	
	MS2	5. Arrange 6 targets in convenient position about subject's body. 4 in front of subject (3, 6, 9 & 12 o'clock positions) 1 on subject's x-axis 1 behind him (if possible)	
	PS2	6. Memorize targets and locations. (Will be allowed approximately 3 min) Do not point at or touch the targets	
	MS2	7. Review, for the subject, what he will do without being asked when the observer signals by a whistle. a. Without moving describe posture, knowledge of location of his hands and feet, angle of bending at elbows and knees, orientation of his spine relative to spacecraft coordinates and degree of certainty concerning his description. b. Touch left ear ballistically with right hand.	

FIGURE 2-26. EXAMPLE FOR PREPARING INFLIGHT ONBOARD CREW OPERATIONS PROCEDURES

in these reviews to verify or establish interfaces and to review compliance with the mission's requirements. Table 2-6 outlines the review process.

2.4.3.1.2 Integrated Payload Reviews - The Payload Mission Manager will conduct integrated payload reviews during the definition and development phases to fulfill his responsibility for verifying that all facilities/instruments/experiments meet safety and compatibility requirements, and that each facility developer's/investigator's requirements have been met in the integrated payload.

2.4.3.1.3 Flight Readiness Review - Following completion of payload integration and final assembly preparations of Spacelab, and before its installation into the Orbiter, a Payload Flight Readiness Review will be held by the Payload Mission Manager. The Mission Manager will determine the readiness of the payload for commitment to flight. This will be accomplished by a review of the installed status of all facilities/instruments/experiments, and the results of all test and checkout operations, including interface verification tests, functional tests, and mission simulations. The review will also cover the status of open tasks in servicing and flight preparation of the payload, the readiness of ground support systems (POCC), flight operating procedures, flight software, flight operating plans and timelines, payload specialist readiness, and the readiness of all other elements of the flight. Facility developers/investigators will be requested to participate in this review to determine and verify the flight readiness of their facilities/instruments/experiments, certify payload specialist proficiency in the operation of their experiments, and certify safety compliance. The Payload Mission Manager will, in conjunction with the mission scientist and facility developer/investigator, decide on the appropriate action or disposition in the event any facility/instrument/experiment or portion thereof is not ready for flight.

2.4.3.2 Documentation - The following documentation is required to establish and certify the verification process.

2.4.3.2.1 Verification Plan - Each equipment developer will submit an Instrument/Facility/ECE Verification Plan in accordance with the data format shown in Figure 2-27. This plan will describe methods proposed to implement the verification requirements of document MSFC-JA-061 and include a schedule of each proposed analysis and test. The initial submission is required for review and approval. The final submittal shall incorporate agreed upon changes.

TABLE 2-6. FACILITY/INSTRUMENT/EXPERIMENT REVIEW PROCESS

REVIEW ITEM	REQUIREMENTS REVIEW (RR) DATA	PRELIMINARY DESIGN REVIEW (PDR) DATA	CRITICAL DESIGN REVIEW (CDR) DATA
1. Analyses a. Safety	Identification of all safety requirements applicable to design and operation of experiment equipment.	Preliminary safety analyses verifying safety, identifying hazards and the corrective action proposed, including safety critical items lists.	Final safety analysis and resolution of all potential hazards.
b. Interface	Identification of all interface areas, and requirements that are Spacelab Payload Accommodations Handbook (SPAH) applicable.	Identification of all environments generated by the instrument/experiment, limits of the environments to which the instrument/experiment is sensitive and proposed resolutions as applicable.	Final resolution of all areas of potential incompatibilities.
2. Interface Design	Review verification, and finalization of "Experiment Requirements" document, for all physical and functional interfaces.	Identification of each individual physical and functional interface with Spacelab for each piece of equipment, including each data signal or command, power circuits, fluid connection, structural attachment, etc., to extent possible.	Total interface design to extent possible.
3. Operations a. Ground b. Flight c. POCC		Preliminary operating procedures.	Updated operating procedures.
4. Decisions Made	Identification of all safety and interface requirements applicable to instrument/experiment design.	Resolution of safety, compatibility and interface problem areas, or action assignments, and schedule for resolution.	Final resolution of any outstanding problem areas for safety, compatibility and interface design.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

DATA REQUIREMENT (DR)

DATA PROCUREMENT DOC. 1. NO. 1 ISSUE

2. TITLE: Instrument/Facility/MPE/ECE Verification Plan

3. OPR:

4. DR NO. PAGE DATE REV.

SUBMITTAL REQUIREMENTS

5. TYPE:

6. FREQUENCY OF SUBMISSION:

Twice-Final 30 days prior to equipment Final Design Review (or Critical Design Review)

7. DISTRIBUTION:

8. INITIAL SUBMISSION:

30 days prior to equipment Initial Design Evaluation (or Preliminary Design Review)

9. AS OF DATE:

10. REMARKS:

DATA REQUIREMENT DESCRIPTION

11. STANDARD DRD TITLE: Equipment Verification Plan

12. STD DRD NO. REV PAGE DATE

13. USE:

14. INTERRELATIONSHIP:

15. REFERENCE:

16. PREPARATION INFORMATION:

Each Spacelab payload equipment developer shall prepare a verification plan for approval by the Payload Mission Manager. The plan shall contain the minimum elements defined in this DR, but may be in the developers format.

Verification Plan Contents

a. Baselined equipment to be verified. (Nomenclature, ID number, configuration, etc.)
b. List of requirements to be verified and corresponding identification numbers in JA-061.
c. Description of each test and analysis to be performed.
d. Schedule for each test and analysis to be conducted.

MSFC - Form 3461-5 (Rev August 1970)

FIGURE 2-27. EQUIPMENT VERIFICATION PLAN DATA FORMAT

2.4.3.2.2 Reporting and Verification Results - Results of each equipment verification by test or analysis will be documented and submitted in accordance with the data requirement format shown in Figure 2-28. Inspection verification will be performed and recorded, but data submittal to the Payload Mission Manager will be required only upon request. Detailed analysis and test data will be made available upon request. Data submittals specified herein do not relieve the developer from reports required to support program and design reviews.

2.4.3.2.3 Integration Readiness Documentation - The documentation required to accompany the instrument/experiment equipment when delivered to the integration site is outlined in Table 2-7. This documentation is known as the Integration Readiness Data Package (IRDP). All experiment interface compatibility and safety analyses and tests must be completed prior to delivery to the Level IV integration site.

While all experiment equipment, spares, tools, specimens, software, etc., remain at all times the property of the investigator/sponsoring agency, a complete detailed listing and numerical identification of all safety-critical items must be included as a requirement for accountability purposes.

2.5 DEVELOPMENT OF OPERATIONS PROCEDURES

In keeping with the philosophy that promotes investigator/experimenter responsibility for all aspects of instrument/experiment performance, it will be expected that each investigator will develop operating procedures to include payload integration and flight operations.

2.5.1 Payload Integration

The investigator will be expected to provide written procedures governing all necessary tests, checkout, calibration, etc. of his equipment. These ground operating procedures may be submitted with a wide variation in detail but must include all procedures required for operation of the equipment for interface verification, functional checkout, calibration, special testing, servicing, maintenance, handling, etc., to include both preflight and postflight phases.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

DATA REQUIREMENT (DR)

DATA PROCUREMENT DOC. 1. NO. 2 ISSUE

2. TITLE: Verification Test or Analysis Report

3. OPR:

4. DR NO. PAGE DATE REV.

SUBMITTAL REQUIREMENTS

5. TYPE:

6. FREQUENCY OF SUBMISSION:

Once each-30 days after completion of each analysis and test, but no later than 30 days prior to equipment acceptance or Integration Readiness Review.

7. DISTRIBUTION:

8. INITIAL SUBMISSION:

9. AS OF DATE:

10. REMARKS:

DATA REQUIREMENT DESCRIPTION

11. STANDARD DRD TITLE: Verification Report

12. STD DRD NO. REV PAGE DATE

13. USE:

14. INTERRELATIONSHIP:

15. REFERENCE:

16. PREPARATION INFORMATION:

All requirements which are verified in accordance with the equipment-developer's verification plan shall be documented in a report in a format of the payload equipment developer's choosing. The following minimum information must be contained for each interface to be verified.

(a) Objective of the test or analysis
(b) Description of analytical technique, including previous validations of models used in analysis
(c) Test method
(d) Test facility description
(e) Test article description
(f) Test failures or anomalies and corrective action
(g) Technical results
(h) Conclusions

MSFC - Form 3461-5 (Rev August 1970)

FIGURE 2-28. VERIFICATION TEST OR ANALYSIS REPORT DATA FORMAT

C-2

TABLE 2-7. INTEGRATION READINESS DATA PACKAGE (IRDP)

INTEGRATION READINESS DATA PACKAGE - To accompnay instrument/experiment equipment delivered to the Level IV integration site.

A. Index or Table of Contents - An index or inventory of the IRDP contents.

B. Drawings

(1) Top Assembly Drawing: One copy of the facility/equipment Top Assembly Drawing for each assembly that is handled as a unit.

(2) Installation Drawings and Schematics: One copy of the facility/instrument/experiment equipment Installation Drawings and Schematics that identify physical and functional interfaces between the facility/instrument/experiment equipment and Spacelab (e.g., dimensions, torque values, electrical connector pin locations, and functions) is required.

C. Experiment Certification - Certifies compliance with the requirements of Mission Requirements on Spacelab Instrument/Experiment (MROSIE) document and the Instrument Interface Agreement and identified instrument/experiment open items. Details concerning specific methods and required data will be contained within the Mission Implementation Agreement.

D. Cleaniness Certification - Certification of the level of cleanliness of the deliverable flight hardware and ground support equipment shall be provided. The certification shall be signed by the representative of the facility/instrument/experiment developer.

E. Operating Time and Cycle Log - An Operating Time and Cycle Log for cycle and/or time-critical facility/instrument/experiment equipment items shall be included in the IRDP. The log for each item shall indicate total time/cycles allowed, time/cycles accumulated for each storage, operation or test, time/cycles remaining.

F. Safety Compliance Data - Provide data identified in the "Safety Policy and Requirements for Payloads Using the STS" and as detailed in the Mission Implementation Agreement.

G. Weight and Balance Sheet - A Weight and Balance Sheet specifying the mass properties (dimensions, weight, and location of the center of gravity) of each individual item of facility/instrument/experiment equipment that is handled as an assembly shall be provided in the IRDP. Each sheet shall contain a sketch of the equipment identifying the reference axes used to locate the center of gravity.

H. Pressure Vessel Log - A log of all pressure vessels which records the test history and exposure to various fluids and proof pressure data shall be included in the IRDP.

Additional data may be required from the Investigator/Experiment Developer during the integration cycle for anomaly investigation or data correlation. This data may include such items as predelivery as - run acceptance test procedures, calibration curves, schematics, drawings, etc., and should be readily available at the integration sites and at the POCC.

2.5.2 Flight Operations

Written procedures are also required for inflight onboard crew operations as well as POCC operations.

An example format for preparing inflight onboard crew operations is shown in Figure 2-26. This example lists some of the procedures for a vestibular experiment. The onboard procedures will ultimately be written in the standard STS flight procedure format and will be included in the Payload Flight Data File. This data file is an experiment data reference for use by the payload crew during mission onboard operations. The payload crew will require training in the operation of the experiments. The investigator will determine training requirements as well as train the payload crew and use the above described procedures in the training activities. Training is a means of verifying the inflight procedures.

The experiment POCC operations procedures will be used to prepare overall POCC integrated procedures.

3.0 MISSION IMPLEMENTATION PROCEDURES

This section discusses the mission implementation process, first in a generic sense, and then considering instrument/experiment development occurring at various times with respect to the mission implementation schedule. The information presented draws on the current methods and practices established in implementing Spacelab Missions 1, 2, and 3.

3.1 GENERAL MISSION REQUIREMENTS FOR SPACELAB INSTRUMENTS/EXPERIMENTS

For Spacelab instruments/experiments the general mission requirements and mission implementation approach, as discussed here, will apply regardless of when an instrument/experiment developer is assigned a mission. A developer, who proceeds ahead with his project before he is assigned a mission, should give careful thought to accommodations available, constraints or limitations that might result when resources are shared with other investigators, compatiblity with the STS and other potential experiments, safety, and the verification of his hardware and operations procedures.

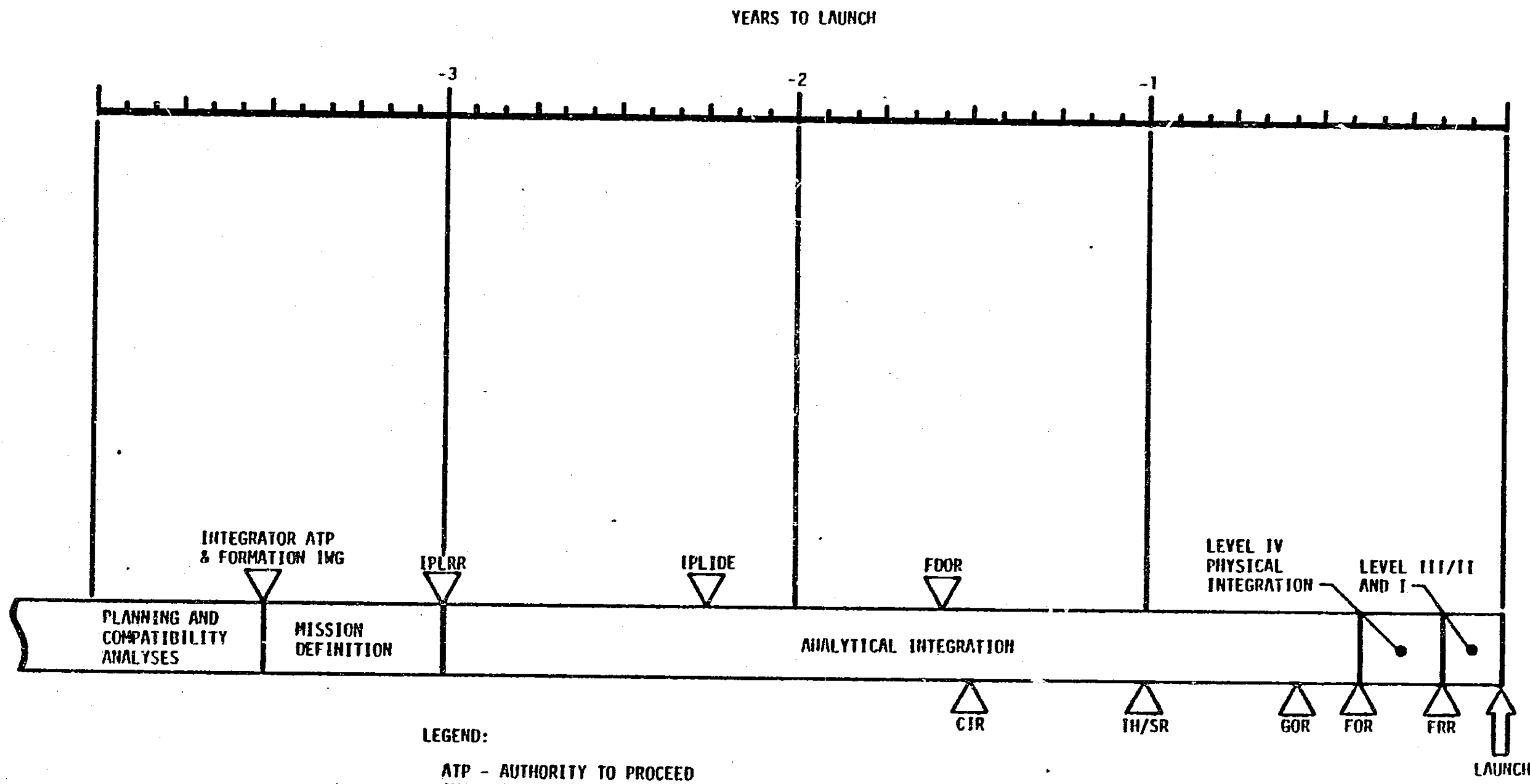
3.1.1 Generic Mission Schedule

Figure 3-1 shows a generic Spacelab mission implementation schedule. The schedule represents a major mission, similar to Spacelab Mission 3, and could be shorter for partial missions. Payload integration milestones are shown as well as the major STS milestones.

3.1.2 Payload Integration Management Responsibilities

Management responsibilities as currently defined for Spacelab missions involve the following NASA organizations:

Organization	Responsibility
Shuttle Payload Integration and Development Office (SPIDOP), Johnson Space Center (JSC)	Integration of Spacelab into the Orbiter. JSC will provide STS flight design and manage crew activity planning and real time flight operations.
Payload Project Office, Kennedy Space Center (KSC)	Integration of total cargo at the launch site, transportation of staged Spacelab hardware to the integration sites, and support of facilities and services required for integration.



LEGEND:

ATP - AUTHORITY TO PROCEED
IWG - INVESTIGATOR'S WORKING GROUP
IPLRR - INTEGRATED PAYLOAD REQUIREMENTS REVIEW
IPLIDE - INTEGRATED PAYLOAD INITIAL DESIGN EVALUATION
FDOR - FINAL DESIGN AND OPERATIONS REVIEW
CIR - CARGO INTEGRATION REVIEW
IH/SR - INTEGRATED HDW./SOFTWARE REVIEW
GOR - GND. OPERATIONS REVIEW
FOR - FLIGHT OPERATIONS REVIEW
FRR - FLIGHT READINESS REVIEW

(CIR, IH/SR, GOR, FOR, FRR: STS MILESTONES)

FIGURE 3-1. GENERIC MISSION IMPLEMENTATION SCHEDULE

Organization	Responsibility
Spacelab Program Office (SLPO), Marshall Space Flight Center (MSFC)	Design, development, test, and delivery of Spacelab. Manage Level III and II integration and assessment of verification of integrated Spacelab/payload interfaces.
Spacelab Payload Project Office (SPPO), MSFC (This office has Payload Mission Management responsibility for Spacelab Missions 1, 2, and 3.)	Mission planning and definition of the payload, definition and implementation of payload/Spacelab integration hardware and software, manage Level IV integration and train payload crew for payload operation.

3.1.3 Experimenter/Investigator Information Required for Payload Integration

The experimenters/investigators, through the release of the Experiment Requirements Document (ERD), provide much of the information needed by the Payload Mission Manager to perform the total payload integration task. In addition, the experimenter/investigator must provide his requirements in the areas of:

- Ground Operations
- Flight Operations.

Ground Operations include the requirements for installation, test, checkout, calibration, servicing, off-line support, ground software support, and flight preparation. Proper testing and checkout of the instrument/experiment in the installed condition provides the investigator ensurance of proper instrument/experiment functioning in space.

To support Flight Operations requirements experimenters/investigators need to provide their requirements on:

- Orbit parameters (altitude, inclination, etc.)
- Pointing (targets, viewing time, etc.)
- Operating cycle (number, time, etc.)
- POCC support (commands, data processing, etc.)

3.1.4 Interface Compatibility

After all experimenter requirements have been integrated into a payload system that can be accommodated by the STS, IIA's are negotiated with all the investigators. This document becomes the controlling interface definition document in which the investigator is ensured a compatible interface and adequate resources for proper operation of his instrument/experiment. Adherence by the investigator to the agreed-to-interfaces in the design of his instrument/experiment is necessary so that the Payload Mission Manager can ensure that the accommodations required by each instrument/experiment are properly allocated, and that the integrated payload is compatible. A formalized configuration management procedure is in effect at the time the IIA is baselined and any changes are processed and incorporated according to these procedures.

Instruments are to be designed and verified by test, inspection, or analysis to ensure compatibility with the approved interfaces. The investigator/equipment developer is responsible for the design, fabrication, and test requirements relative to the instrument/experiment performance, reliability quality, etc., and for ensuring that the specific objectives of his experiment are achieved.

3.1.5 Safety

The Safety Policy and Requirements (SP&R) Document, NHB 1700.7, is the top level document that defines safety policy and basic safety requirements applicable to Spacelab payload missions; and takes precedence over all other applicable documents.

The requirements presented in the SP&R document are intended to protect flight and ground personnel, the STS, other payloads, GSE, the general public, public and private property, and the environment from payload related hazards. These requirements apply to all payload hardware including new designs, existing designs (reflown hardware), and hardware designed primarily for commercial use.

3.1.6 Verification Of Instruments For Flight

Equipment verification must be performed by the experimenter prior to the integration of equipment into a Spacelab payload. Verification requirements are given in Spacelab Payload Mission Manager Verification Requirements for Instruments, Facilities, MPE, and ECE, document JA-061, MSFC. The procedures call for the instrument developer to submit a verification plan for Payload Mission Manager approval and the reporting of results for each item of equipment verification. An Integration Readiness Data Package is to accompany the instrument/experiment to the integration site. The equipment verification requirements of JA-061 do not include requirements to verify equipment performance.

As part of the verification procedures instrument developers will hold instrument/experiment reviews in which the Payload Mission Manager will participate and review compliance with mission requirements. Instrument developers will also be expected to participate in Integrated Payload Reviews and the Integration Readiness Review.

Inflight operations procedures (used by payload specialists) will be verified by the experimenter/investigator during training of the payload specialists in the operation of instruments/experiments.

3.1.7 Investigator/Developer Participation In Operations

The overall philosophy of operation of Spacelab payloads is based on the investigator/instrument developer being responsible for all aspects of the performance of his instrument and for the resultant data from its operation. This applies not only to its operation in flight, but also to each test, calibration, servicing or other operation both before and after the flight. The assembly/integration and flight operation of each instrument will therefore require the participation of the investigator, or his designee, in fulfilling the responsibilities for performance, functional operation, and in achieving satisfactory data and results. It is expected that the investigator/instrument developer will actively support:

- Operations
- Crew Training
- POCC Operations
- Flight Readiness Review.

In keeping with the above operational philosophy, each investigator will be expected to support the integration of his instrument into a Spacelab Payload and its preparation for flight. This support will include participation with the processing team to plan ground operations, and conduct the necessary operations at Level IV, III/II, and I integration. The Payload Mission Manager will negotiate for the investigator with KSC for the performance of launch site functions for the integrated payload. The investigator will provide and operate all instrument peculiar support equipment and connections required for these integration activities. He will provide all maintenance, repair, and servicing required on his equipment including providing spares, parts, tools, etc. During the flight portion of the mission, the investigator will be required to provide the necessary support to the operation of his instrument from the POCC, or from another location as determined by the investigator in conjunction with the Payload Mission Manager. The investigator is also expected to support/conduct the post-flight deintegration of his experiment equipment and perform any post-flight processing of his equipment, including return shipment to his facility.

The payload specialists will require training in the operation of the instruments/experiments selected for flight. It will, therefore, be necessary for the investigator to participate in determining the training requirements and in the training of the payload specialists. This training may be done at the investigator's homesite, the instrument development site, or the payload integration and launch site. The Payload Mission Manager will manage the training activities and coordinate the schedules of the payload specialists including STS related training at JSC.

For reasons similar to those for the flight operations, it may be necessary for personnel other than the investigator to support flight operations by operating equipment, monitoring data, or assisting in trouble shooting from the POCC. In these cases, it will be necessary for the investigator to assist in training these personnel in those experiment related duties that are required to provide ground support to the flight operations. Also, it is expected that investigators participating in POCC operations will require indoctrination and training in the operation of POCC equipment and practices. The Payload Mission Manager will arrange for the investigators to receive this training where required.

Following completion of payload integration and final assembly preparations of Spacelab, and before its installation into the Orbiter, a payload Flight Readiness Review will be held by the Payload Mission Manager. Investigators will be requested to participate in this review to determine and verify the flight readiness of their instrument/experiment and certify payload specialist training for operating their experiments.

3.1.8 Mission Implementation Agreements

The Mission Implementation Agreement (MIA) is made between the Payload Mission Manager and each investigator to establish the commitment of resources needed to satisfy the mission requirements. The MIA will be initiated by the Payload Mission Manager to fully define each investigator's participation and

and programmatic resource commitments. The agreement with the investigator will:

- Identify all items of hardware and software
- Establish schedules and milestones to include experiment development, integrated payload reviews, major tests, and delivery of equipment to the Level IV integration site
- Establish participation of the investigator in mission planning and operation.

The agreement will address any exceptions or peculiar accommodations for Spacelab resources not identified in the SPAH.

Changes to the MIA can be made by mutual agreement of the investigator and the Payload Mission Manager.

3.1.9 Change Control Procedures

The Payload Mission Manager and instrument/experiment developer will control any changes/modifications or additions after baselining of the ERD and the IIA through the configuration management procedure, outlined by the Payload Mission Manager. This configuration management procedure is the structure through which an investigator may obtain approval for change from the Payload Mission Manager.

3.1.10 Post Flight Reporting

The total analysis of data and the reporting of results from the flight reside with the investigator. However, to determine improvements in operations and to reduce potential problems in future flights, each investigator will be required to furnish to the Payload Mission Manager a brief report or statement regarding the success of his instrument's operation, achievement of expected results, and definition of any problems encountered with the accommodations, resources, and interfaces provided to him on the flight.

3.1.11 Investigators' Working Group (IWG)

A working group comprised of the investigators, or their representatives, and chaired by the assigned Mission Scientist will be formed to represent mission level science, applications, and technology interests. The IWG will be responsible for the selection of payload specialists, provide an appropriate forum for the development of interdisciplinary tradeoff assessments and recommendations and related science/payload system engineering incompatibilities, and provide scientific support to the POCC operations.

3.2 INSTRUMENT DEVELOPMENT IN PHASE WITH THE MISSION SCHEDULE

This section will develop the data requirements needed and the time frame required in the mission implementation of an instrument/experiment developed in phase with the mission schedule.

3.2.1 Relationship Of Instrument Development To Mission Implementation

A schedule showing the relationship between instrument development and mission implementation is presented in Figure 3-2. Instrument development was assumed to start with a conceptual phase with mission assignment occurring during the preliminary design phase.

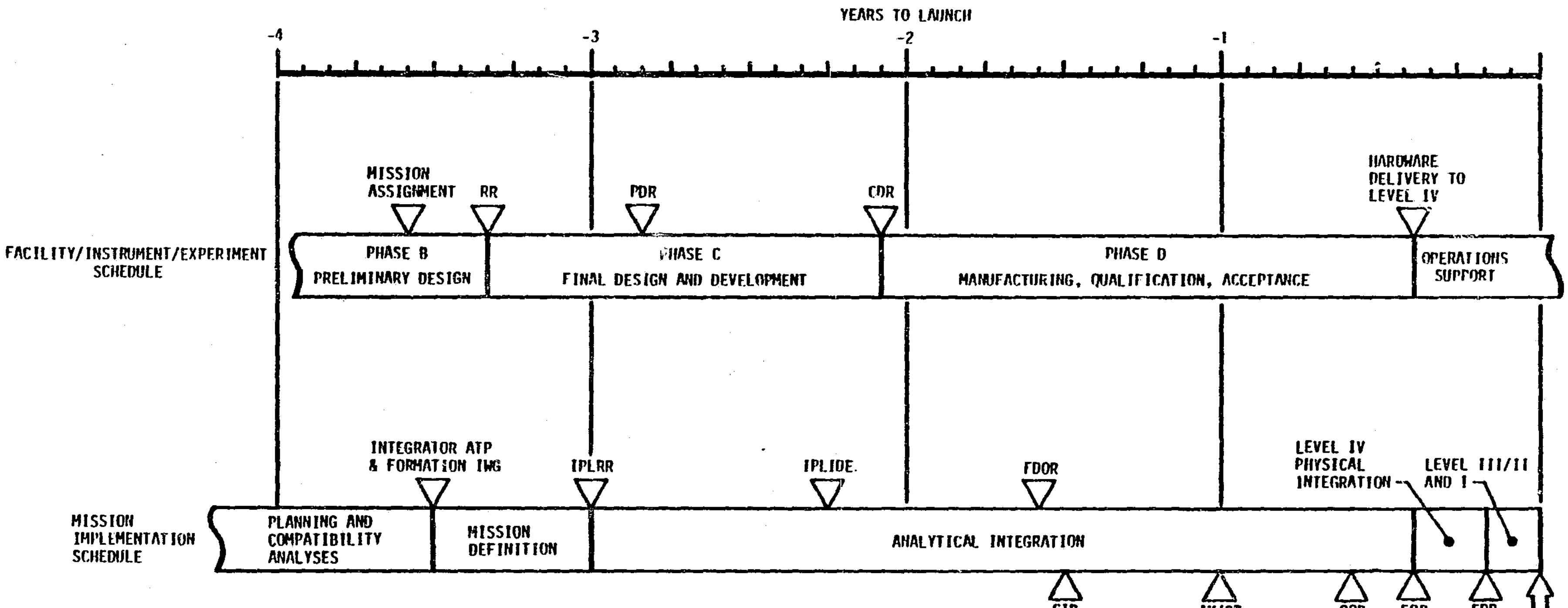
3.2.2 Information/Data Flow Between Experimenter and Payload Mission Manager

Figure 3-3 shows the same mission implementation and experiment development schedules along with data requirements and delivery dates. The information exchange shown in this figure is based on the Spacelab Missions 1, 2, and 3 documentation requirements, and is typical of the payload integration process. This documentation is discussed briefly in the following paragraphs.

The Mission Requirements on Spacelab Instruments/Experiments (MROSIE) document is initiated by the Payload Mission Manager and identifies the information needed by the Payload Mission Manager which is to be provided by each investigator or by the facility developers as the agent for investigators utilizing their facilities. It defines the areas where facility developer/investigator participation is needed during ground and flight operations, and sets forth the safety and compatibility requirements which must be met in facility/instrument/experiment design and are mutually beneficial to facility developers, investigators, and the Payload Mission Manager in achieving a safe and successful mission.

The MIA also initiated by the Payload Mission Manager, is made with each of the facility developers/investigators to establish the commitment of resources needed to satisfy the mission requirements.

The ERD is the first major input by the investigator or instrument developer to the Payload Mission Manager. An ERD is prepared by each investigator and identifies the technical requirements the instrument developer places on the



LEGEND:

RR - REQUIREMENTS REVIEW
PDR - PRELIMINARY DESIGN REVIEW
CDR - CRITICAL DESIGN REVIEW
(RR, PDR, CDR: EXPERIMENT RELATED)
ATP - AUTHORITY TO PROCEED
IWG - INVESTIGATOR'S WORKING GROUP
IPLRR - INTEGRATED PAYLOAD REQUIREMENTS REVIEW
IPLIDE - INTEGRATED PAYLOAD INITIAL DESIGN EVALUATION
FDOR - FINAL DESIGN AND OPERATIONS REVIEW
CIR - CARGO INTEGRATION REVIEW
IH/SR - INTEGRATED HDW./SOFTWARE REVIEW
GOR - GND. OPERATIONS REVIEW
FOR - FLIGHT OPERATIONS REVIEW
FRR - FLIGHT READINESS REVIEW
(CIR, IH/SR, GOR, FOR, FRR: STS MILESTONES)

FIGURE 3-2. INSTRUMENT DEVELOPMENT IN PHASE WITH MISSION IMPLEMENTATION SCHEDULE

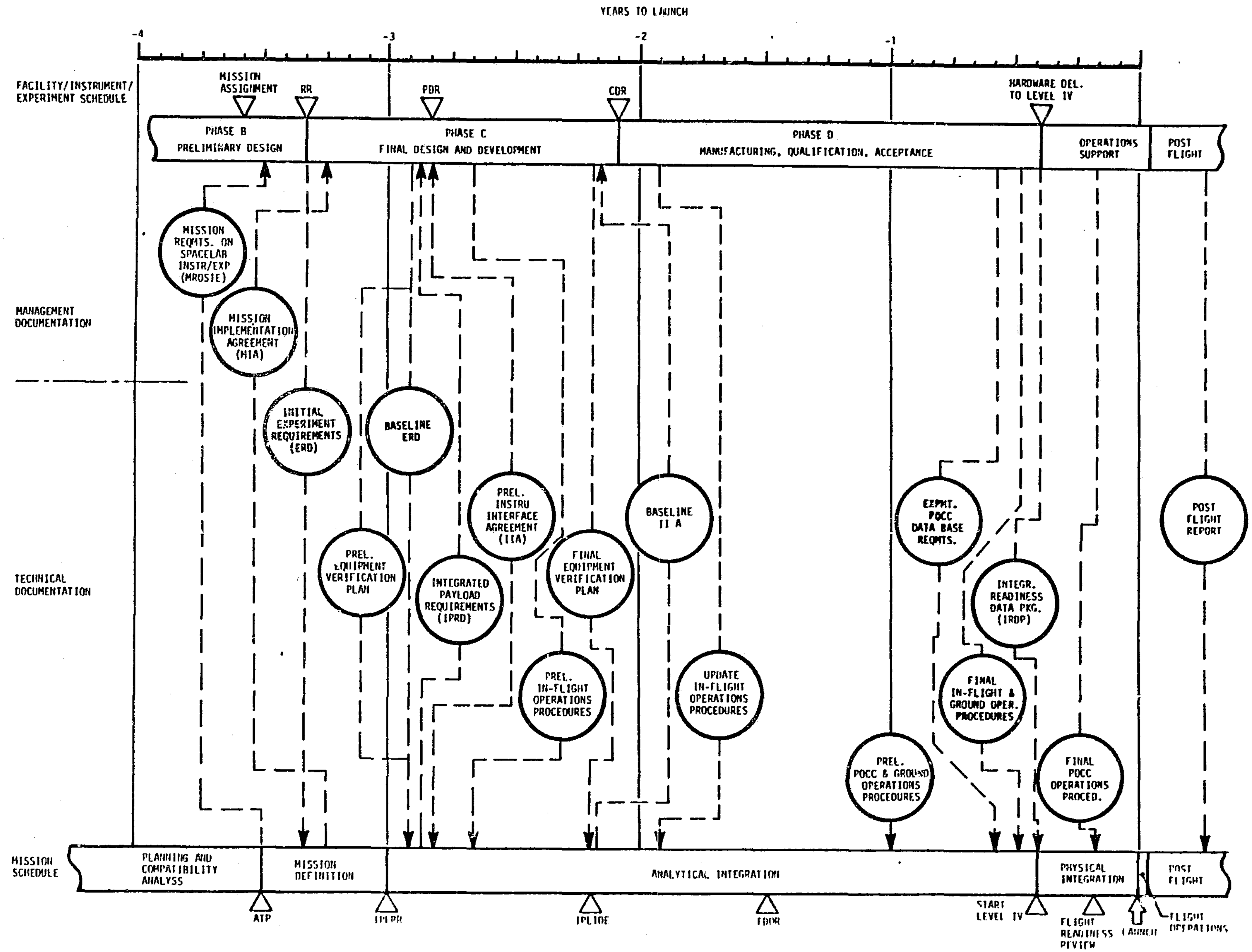


FIGURE 3-3. DOCUMENTATION FLOW BETWEEN THE PAYLOAD MISSION MANAGER AND INVESTIGATOR WHEN INSTRUMENT DEVELOPMENT IS IN PHASE WITH MISSION IMPLEMENTATION

STS and MPE in order to accomplish his objectives. Updates to the initial requirements are made as shown in Figure 3-3.

The baseline Integrated Payload Requirements Document (IPRD) is released after all investigation requirements have been reviewed and the mission requirements defined. This document defines the STS resources available and allocated to each individual experiment. It is used by the Payload Mission Manager to control mission requirements and resource allocation changes. As part of the IPRD and subject to its control, the Ground Integration Requirements Document (GIRD) and the POCC Requirements Document are published under separate covers. Requirements for Level IV integration and payload requirements for Level III/II and I integration staging, and post landing are defined in the GIRD. The POCC Requirements Document serves as the detailed requirements interface between the Spacelab Payload Project and the Johnson Space Center (JSC). The IPRD is a controlled document and changes to its contents require the appropriate approval.

The IIA is the exclusive document used jointly by the Payload Mission Manager and the instrument developer to establish, control, and define in detail all experiment interfaces with the STS, experiment related Mission Peculiar Equipment (MPE), Mission Dependent Equipment (MDE), and other elements of the payload systems.

The Equipment Verification Plan (EVP) baselines equipment to be verified, lists requirements to be verified, gives a description of each test and analysis to be performed, and a schedule for each test and analysis to be conducted. A Verification Report is issued after the completion of each analysis and test.

The investigator will be expected to provide operations procedures to include both payload integration and flight operations. Integration procedures cover all necessary tests, checkout, calibration, etc. of his equipment. Also, procedures covering inflight operation by the payload specialist, as well as POCC operations, are required.

The Integration Readiness Data Package consists of drawings, mass properties data, safety data, and certification of compliance with the MROSIE and IIA. These data accompany the experiment equipment to the integration site.

Finally, each investigator is required to furnish the Payload Mission Manager a brief report regarding the success of his instruments' operation, achievement of expected results, and definition of any problem, with respect to accommodations, resources, and interfaces provided to him. This report is submitted within 60 days after landing.

3.3 INSTRUMENT DEVELOPMENT UNDERWAY OR COMPLETED BEFORE A MISSION IS ASSIGNED

This section develops the data requirements needed and the time frame required for the mission implementation of an instrument/experiment developed prior to being assigned a mission. Mission assignment was arbitrarily chosen as occurring after phase D of hardware development. Mission assignment could occur at any time during the latter part of the instrument development phase with essentially the same implementation process resulting.

3.3.1 Mission Implementation Relationship

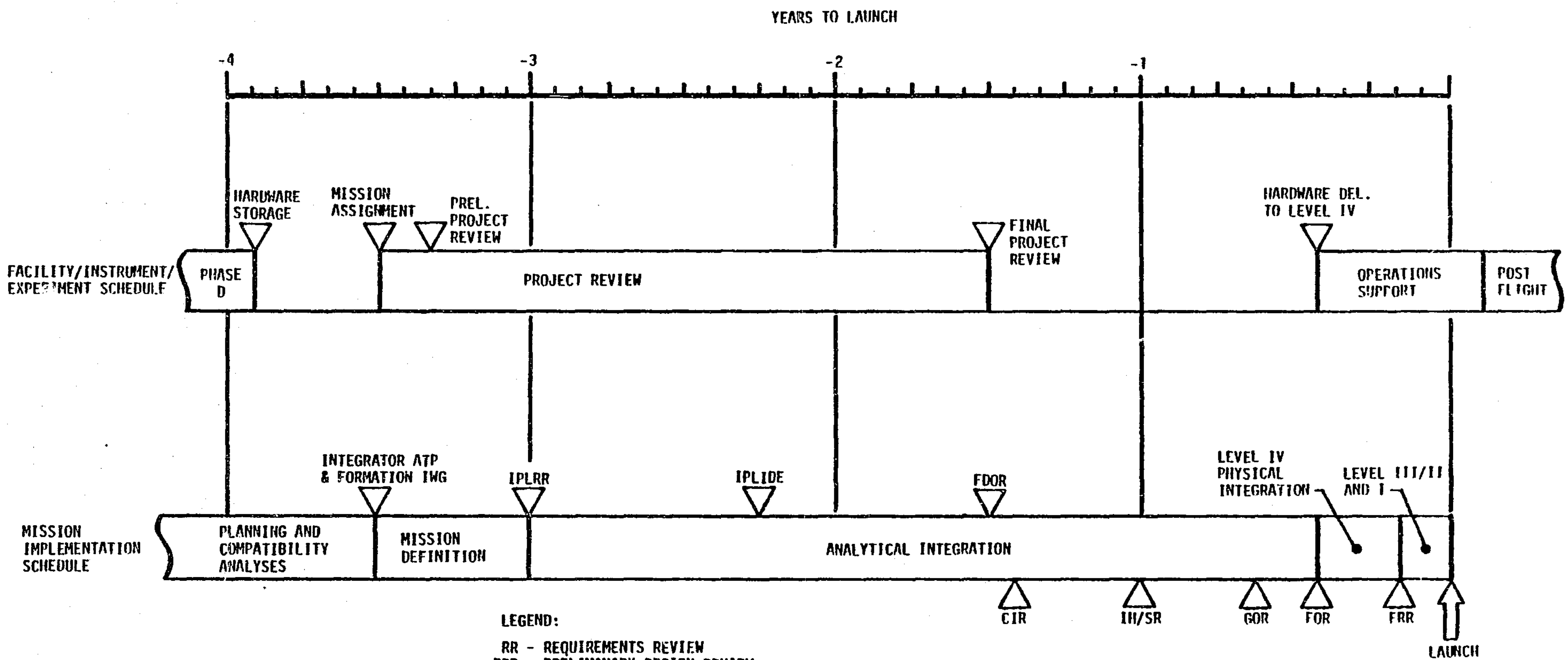
Figure 3-4 shows the instrument development schedule. The schedule shows a project review phase commencing with mission assignment and lasting until the Final Design and Operations Review (FDOR). The extent of this review will depend on many factors, some of which are mission dependent. The investigator can minimize the impact on his equipment design and operation requirements by following closely the requirements placed on all STS users with respect to safety (As defined in NHB 1700.7) and interface compatibility.

3.3.2 Information/Data Flow When Mission Is Assigned

Figure 3-5 indicates the documentation flow between the Payload Mission Manager and instrument developer when an instrument is developed prior to mission assignment.

The Mission Requirements Document (MROSIE) and MIA are initiated in the same time frame with respect to the mission implementation schedule as discussed earlier. The information flow from the investigator to the Payload Mission Manager is quite different since most of the data pertaining to the instrument's requirements, operations procedures, and equipment verification plan have already been documented.

Experiment requirements, in the format of MSFC Form 3591, should be transmitted to the Payload Mission Manager upon mission assignment. This data package should be complete and represent final requirements, and also include final detailed drawings, schematics, and all analyses (stress, thermal, pointing, etc.) performed as of that date.



LEGEND:

RR - REQUIREMENTS REVIEW
PDR - PRELIMINARY DESIGN REVIEW
CDR - CRITICAL DESIGN REVIEW
ATP - AUTHORITY TO PROCEED
IWG - INVESTIGATOR'S WORKING GROUP
IPLRR - INTEGRATED PAYLOAD REQUIREMENTS REVIEW
IPLIDE - INTEGRATED PAYLOAD INITIAL DESIGN EVALUATION
FDOR - FINAL DESIGN AND OPERATIONS REVIEW
CIR - CARTO INTEGRATION REVIEW
IH/SR - INTEGRATED HDW./SOFTWARE REVIEW
GOR - GND. OPERATIONS REVIEW
FOR - FLIGHT OPERATIONS REVIEW
FRR - FLIGHT READINESS REVIEW

$\left.\begin{matrix}\text{CIR}\\ \text{IH/SR}\\ \text{GOR}\\ \text{FOR}\\ \text{FRR}\end{matrix}\right\}$ STS MILESTONES

FIGURE 3-4. INSTRUMENT DEVELOPMENT COMPLETED PRIOR TO MISSION ASSIGNMENT

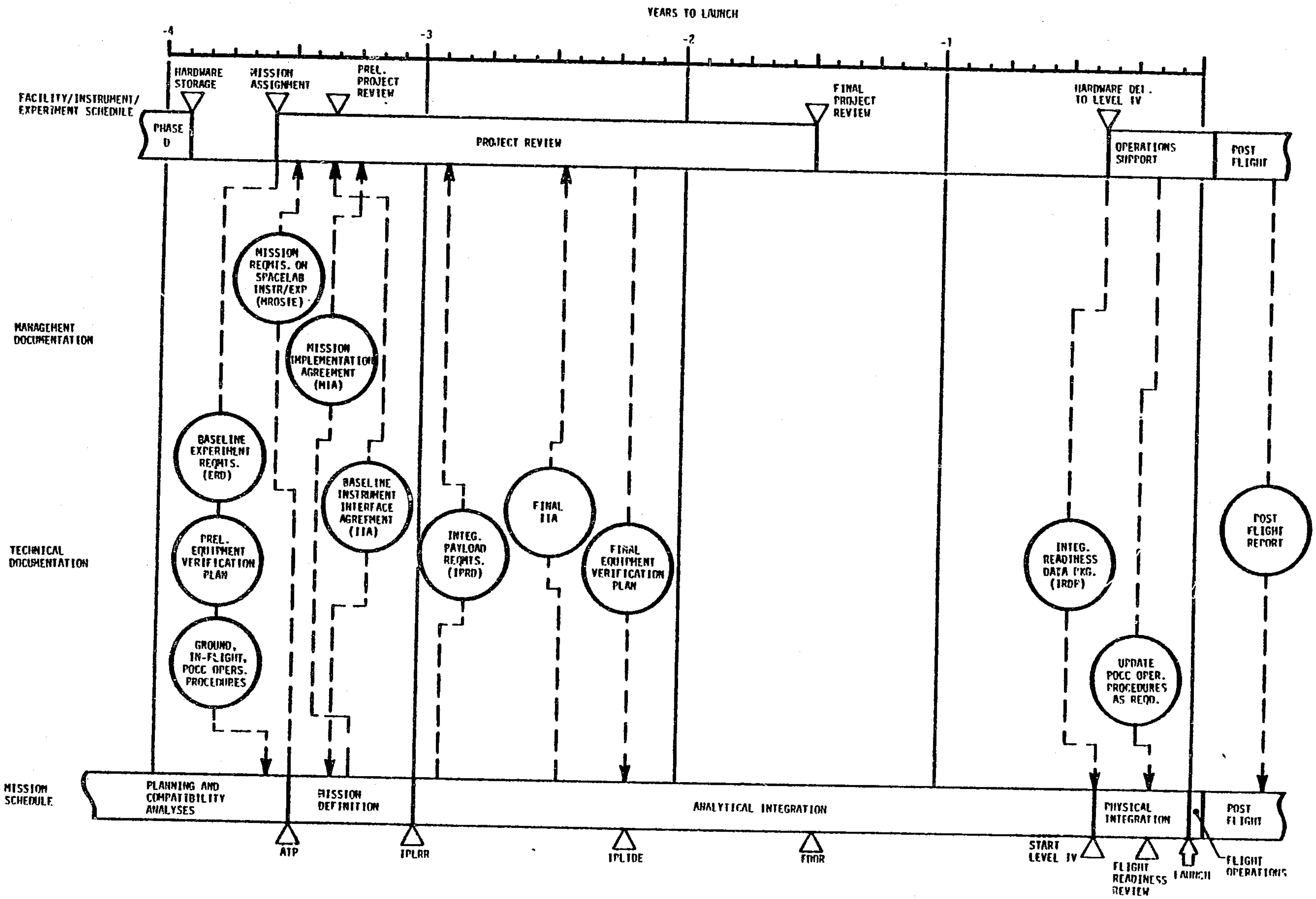


FIGURE 3-5. DOCUMENTATION FLOW BETWEEN PAYLOAD MISSION MANAGER AND INSTRUMENT DEVELOPER WHEN INSTRUMENT DEVELOPED PRIOR TO MISSION ASSIGNMENT

After the first project review with the Payload Mission Manager the baseline IIA is ready to be formulated. As has been stated in previous sections the IIA is used to establish, control, and define all instrument/experiment interfaces with the STS, experiment-related MPE, MDE, and other elements of the payload system.

After all instrument requirements have been reviewed and assessed the Payload Mission Manager releases the IPRD which establishes integration guidelines, resource accommodations for all experiments, and flight parameters.

As Figure 3-5 indicates, the preliminary Equipment Verification Plan should be submitted at the time of mission assignment. The results of each analysis or test (Verification Reports) should be included in this transmittal. Since the requirements in some cases for the verification process are related to such documents as the IIA, IPRD, equipment specifications (MPE), it may be necessary to perform certain verification functions only after these documents are released.

Much of the required data that make up the Integrated Readiness Data Package (IPRD) will have already been prepared. Some segments of this package, however, may not be completed and will require attention during the Project Review Period.

Preliminary ground, inflight, and POCC operations procedures should be submitted when a mission is assigned. Verification of inflight procedures will be accomplished during the crew training activities in which the investigator will participate. POCC operational procedures will be updates as required following completion of Level IV integration activities.

APPENDIX A. REFERENCED DOCUMENTATION LIST

Copies of the documents referenced in the text of this report can be obtained from the appropriate NASA center.

National Aeronautics and Space Administration
Johnson Space Center
Attention: Code JM62 or JM66
Johnson Space Center, NASA, Houston, Texas 77058

DOCUMENT TITLE	DOCUMENT NUMBER
Space Shuttle System Payload Accommodations, Volume XIV	JSC 07700
Shuttle Orbiter/Cargo Standard Interfaces, JSC 07700, Vol. XIV, Attachment 1	ICD 2-19001
Shuttle Vehicle/Spacelab Structural/Mechanical Interfaces	ICD 2-05101C
Shuttle Vehicle/Spacelab Avionics Interfaces	ICD 2-05301
POCC Capabilities Document	JSC-14433
Space Transportation System Payload Safety Guidelines Handbook	JSC-11123
Vacuum Stability Requirements of Polymeric Materials For Spacecraft Application	JSC-SO-R-0022A
Nonmetallic Materials Design Guidelines And Data Handbook	JSC-02681

National Aeronautics and Space Administration
George C. Marshall Space Flight Center
Attention: Documentation Repository, AS25D
Marshall Space Flight Center, AL 35812

DOCUMENT TITLE	DOCUMENT NUMBER
Spacelab Payload Accommodations Handbook (SPAH)	ESA SLP/2104
SPAH Avionics Interface Definition	Appendix A
SPAH Structural Interface Definition - Module	Appendix B
SPAH Structural Interface Definition - Pallet	Appendix B-1
SPAH Thermal Interface Definition	Appendix C (To be published)

DOCUMENT TITLE	DOCUMENT NUMBER
Payload Operations Control Center Format Standards	JA-053
Spacelab Payload Mission Operations	JA-063
Spacelab Program Software Users'Guide	MDC G6854B
Experiment Computer Operating System (ECOS) Design Specification	ECO-8945A
ECOS Requirements Definition Document	MDC ¢6862C
Spacelab High Rate Multiplexer (HRM) Format Standards	MSFC-STD-630
Spacelab Experiment Computer Application Software (ECAS) Display Design and Command Usage Guidelines	MSFC-PROC-711
Experiment Checkout Equipment (ECE) to be Utilized at Kennedy Space Center (KSC), May 31, 1979	Memo MSFC-JA31
Safety Policy and Requirements For Payloads Using the Space Transportation System	NHB 1700.7
Spacelab Payload Safety Implementation Approach	JA-012
Safety and Environmental Health Standards	MMI 1700.4B
Spacelab Payload Mission Manager Verification Requirements for Instruments, Facilities, MPE, and ECE	JA-061
Electromagnetic Compatibility Requirements On Spacelab Payload Equipment	MSFC-SPEC-521
Bonding, Electrical, and Lighting Protection, For Aerospace Systems	MIL-B-5087B
Dynamic Environment For Spacelab Experiments, Components, and Equipment	Memo MSFC
Spacelab Mission 1 Integrated Payload Requirements Document	MSFC JA-010
Spacelab Mission 2 Integrated Payload Requirements Document	MSFC NR-JA-017
Spacelab Mission 3 Integrated Payload Requirements Document	MSFC NR-JA-019
Spacelab Mission 1 MPE Requirements Document	MSFC JA-049

DOCUMENT TITLE	DOCUMENT NUMBER
Spacelab Mission 2 MPE Requirements Document	To Be Published
Spacelab Mission 3 MPE Requirements Document	To Be Published
Racks Electrical Equipment, 19 Inch, and Associated Panels	MIL-STD-189
Air Transport Equipment Cases and Racking	ARINC 404A
Electrical, Electronic, and Electromechanical Parts Program Requirements for Spacelab Experiments	ISM00002
Materials Selecting Guide For MSFC Spacelab Payloads	MSFC-HDBK-527
Screening Test Methods Employing A Thermal Vacuum For The Selection Of Materials To Be Used In Space	ESA Specification PSS 09/QRM-02T

National Aeronautics and Space Administration
John F. Kennedy Space Center
Attention: NWSI-D
Kennedy Space Center, FL 32899

KSC Launch Site Accommodations Handbook for STS Payloads	KSC K-STSM-14.1 K-STSM-09, Vol. VI
Kennedy Management Instruction, KSC Safety Program	KMI 1710.1