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SPECIFICATIONS

BOOK 2

LABCRAFT INSTRUMENT SYSTEMS GENERAL SPECIFICATION

(NASA-CR-152570) ATMOSPHERE, MAGNETOSPHERE AND PLASMAS IN SPACE (AMPS). SPACELAB PAYLOAD DEFINITION STUDY. VOLUME 4, BOOK 2: LABCRAFT INSTRUMENT SYSTEMS GENERAL SPECIFICATION Final (TRW Defense and Space G3/12

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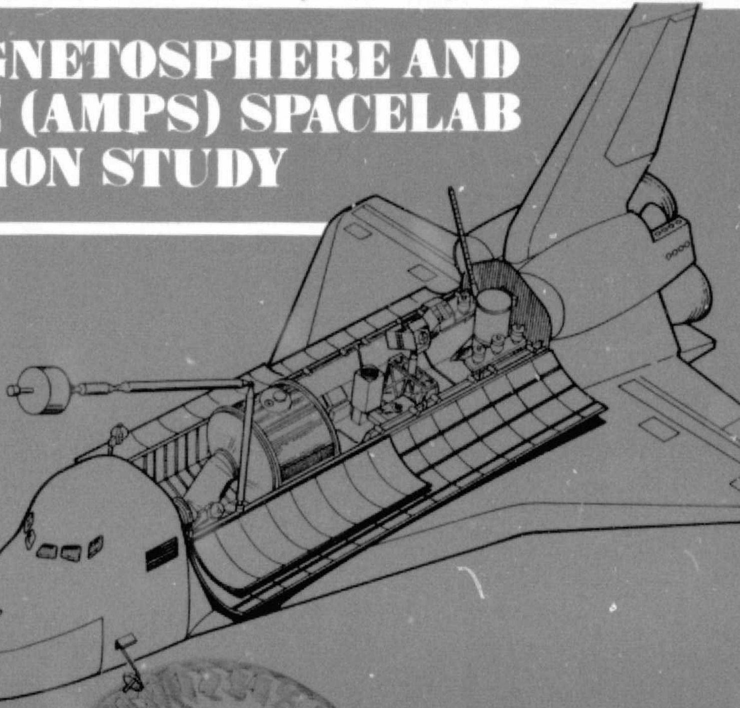
ATMOSPHERE, MAGNETOSPHERE AND PLASMAS IN SPACE (AMPS) SPACELAB PAYLOAD DEFINITION STUDY



Final Report
November 1976

Prepared for
National Aeronautics
and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland 20771

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ATMOSPHERE, MAGNETOSPHERE AND PLASMAS IN SPACE (AMPS)
SPACELAB PAYLOAD DEFINITION STUDY
FINAL REPORT

VOLUME IV
BOOK 2 - LABCRAFT INSTRUMENT SYSTEMS GENERAL SPECIFICATION

Document No.
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1. SCOPE

This specification establishes the interfaces between the scientific instruments and the Spacelab/Labcraft equipment. It defines the characteristics of the Spacelab/Labcraft equipment pertinent to the scientific instruments and the requirements placed on the scientific instruments by the Spacelab/Labcraft equipment. Requirements that apply only to individual instruments or special requirements that have been negotiated for individual instruments will be defined in the interface control documents (ICD's) for that instrument. Adherence to this specification is essential to achieve compatibility between the respective subsystems.

2. APPLICABLE DOCUMENTS

2.1 OVERRIDING DOCUMENT. The requirements stated in this document are derived from:

GSFC (TBD) Labcraft Program Specification

It is overriding in case of disagreement, except where specific waivers have been granted.

2.2 REFERENCE DOCUMENTS. The following documents of latest issue form a part of this specification to the extent specified herein.

2.2.1 Program level documents

(a)	ESTEC/MSFC SLP-2100	Spacelab Systems Requirements Document
(b)	ESTEC/MSFC SLP-2104	Spacelab Payload Accommodation Handbook
(c)	JSC-07700, Vol. XIV	Space Shuttle System Payload Accommodations (Level II), Program Definition and Requirements

2.2.2 Labcraft system requirements

(a)	NASA-NHB-XX	Safety Policy and Requirements for Payloads Using the National Space Transportation System
(b)	JSC-11123	Space Transportation System Payload Safety Guidelines Handbook
(c)	KSC-K-SM-14	Launch Site Accommodations Handbook for STS Payloads
(d)	MIL-E-5272C Sept. 1970	Environmental Testing, Aeronautical and Associated Equipment, General Specification for

(e)	JSC-08060	Space Shuttle System Pyrotechnic Specification
(f)	NSS HP1740.1	NASA Aerospace Pressure Vessel Safety Standard
(g)	SL-E-0001	Specification Electromagnetic Compatibility Requirements, Systems for the Space Shuttle Program
(h)	MIL-STD-1541	Electromagnetic Compatibility for Space Systems
(i)	27615-6007-RU-04	Labcraft Payload General Specification
(j)	27615-6004-RU-00	AMPS System Requirements Document

2.2.3 Mission assurance

(a)	FED-STD-209	Clean Room and Work Station Requirements, Controlled Environment
(b)	MIL-STD-889 Sept. 1969	Dissimilar Metals
(c)	NASA Document 10M33107	Design Guidelines for Controlling Stress Corrosion Cracking
(d)	NASA SP-8040	Failure Control, Metallic Pressure Vessels
(e)	MSFC-PROC-404	Gases, Drying and Preservation, Cleanliness Level and Inspection Methods
(f)	MIL-STD-810	Environmental Test Methods
(g)	MIL-STD-454	Standard General Requirements for Electronic Equipment
(h)	NHB 5300.4(1C)	Inspection System Provisions for Aeronautics and Space Systems Materials Components and Services.

3. SPECIFIC REQUIREMENTS

3.1 PALLET-MOUNTED INSTRUMENTS. This paragraph defines requirements for all scientific instruments intended for pallet mounting.

3.1.1 Mechanical interface. This paragraph describes the general mechanical requirements and constraints imposed on pallet-mounted instruments.

3.1.1.1 Instrument physical characteristics.

3.1.1.1.1 Stowed volume. The stowed volume and maximum dimensions of pallet-mounted instruments are limited by the pallet structure and by the Orbiter cargo bay envelope as defined in 4.1.3 of Reference 2.2.1(b). Additional constraints may be imposed by other elements of the total payload.

3.1.1.1.2 Deployed instruments. Pallet-mounted instruments may be deployed beyond the cargo bay envelope if such deployment is controlled to prevent contact with the Orbiter structure. Instruments exceeding the cargo bay envelope must have a capability for emergency ejection and/or retraction. Stowage of deployed instruments and satisfactory attachment to the pallet structure is required prior to reentry (same requirements as stated in 3.1.1.2 below). Deployment may employ a dedicated built-in mechanism or may use the Orbiter RMS. Other restrictions on deployable devices may result from consideration of the total payload design.

3.1.1.2 Mounting requirements. Instruments may be mounted on the Spacelab pallet in one of the following ways:

(a) Directly to pallet hardpoints

(b) To hardpoints via bridging secondary structure

(c) On the pallet panels

(d) On pallet cold plates

(e) Indirectly via other equipment

(f) Bridging between two pallet segments.

All mounting methods must comply with the structural limitations on the pallet as defined in 4.1.3 of Reference 2.2.1(b). In addition, all attachment methods shall be designed to survive the crash loads specified in 5.1.4 of Reference 2.2.1(b). Instrument mounting which bridges between pallet segments is a special case requiring careful analysis and prior approval before it can be proposed.

3.1.1.3 Design, construction, and finish. Instrument equipment manufactured per this specification shall conform to accepted standards for aerospace hardware and shall reflect good workmanship practices. Parts shall be free of cracks, bends, dents, chips or other defects and shall be clean and free of burrs, dirt, and other foreign material.

3.1.1.4 Alignment and orientation. All alignment or orientation requirements of the scientific instruments shall be provided by the instruments themselves. The Orbiter/Spacelab does not have any capability for providing a reference for physical alignment. (However, the Orbiter GN&C can provide Orbiter or a target state vector data in a variety of coordinate systems.) Alignment errors between the Orbiter IMU and the payload are expected to be at least 2 degrees.

3.1.1.5 Apertures and viewing. Scientific instruments requiring a clear field-of-view or operating envelope must be located on the pallet with due regard to obstructions from the Spacelab, the Orbiter vehicle, and other Labcraft payload elements. Early identification of such requirements is mandatory to ensure that they are met.

3.1.2 Electrical interface. This paragraph describes the general electrical requirements and constraints imposed on pallet-mounted equipment.

3.1.2.1 Electrical power. Electrical power for pallet instruments is available from three separate buses:

(1) A 28-volt DC essential power bus (limited to 25 watts total for any given payload)

(2) A normal 28-volt DC bus

(3) A three-phase 115/200-volt 400 Hz AC bus.

All payload power is distributed via distribution boxes (one per pallet) provided by the pallet and mounted on the pallet sill. No electrical power is available on the pallet during ascent or descent. Additional details on power quality and on total mission energy available to payloads may be found in 4.3 of Reference 2.2.1(b). Power control to any scientific instruments may be accomplished from the OAFD (all payload power), from the OAFD, or the pressurized module via the Spacelab CDMS to switches in the power distribution box or to switches in individual payload equipment.

3.1.2.2 Connectors and cabling. All interconnecting cabling to or between pallet-mounted scientific instruments must be provided as part of the instrument. All direct wiring or coaxial cabling from the instrument to Spacelab or Orbiter must also be provided. All cabling installations must include tiedowns and thermal protection. Cables which interfere with existing Spacelab or Labcraft equipment must incorporate compatible connectors as defined in References 2.2.1(b) and 2.2.2(i).

3.1.2.3 Grounds and shielding. The pallet-mounted scientific instruments shall follow the ground and shielding procedures as defined in Reference TBD.

3.1.2.4 Interface circuits. Standard interface circuit designs are to be used by each instrument. Specific application guidelines for each circuit option are presented in the respective section. Adherence to these guidelines by the instrument designer is required in order to guarantee specified operation of the interface.

3.1.3 Commands and data management. Data and command signals to or from pallet-mounted experiment instruments may be routed by direct wire or coax cable to the Spacelab or to the Orbiter via Spacelab or they may be routed via the pallet-mounted RAU. The RAU capabilities are defined in 4.4.2 of Reference 2.2.1(b). All pallet equipment shall include telemetry output signals which will indicate the state-of-health of the item as well as its operating mode.

3.1.3.1 Format. The command and data format for instruments interfacing with a RAU consists of 64 discrete on-off commands, 4 serial PCM data channels, each limited to 32 16-bit words, 4 serial PCM command channels, each limited to 32 16-bit words, a clock signal, and 128 flexible inputs in either discrete or analog form. The details of each of these interface lines can be found in 4.4.2 of Reference 2.2.1(b).

Hardwired data lines can either go to the high rate multiplexer, or directly to other instrument-peculiar equipment. The interface characteristics and format for data lines going to the high rate multiplexer may be found in 4.4.3 of Reference 2.2.1(b).

3.1.3.2 Display. The data display characteristics for pallet-mounted experiment instrumentation are defined in 4.4.6 of Reference 2.2.1(b). Additional dedicated display equipment can be mounted in the Spacelab or aft flight deck under the requirements of 3.2 or 3.3 of this specification.

3.1.3.3 Command and control. The command and control capabilities for instruments interfacing with a RAU are defined in 4.4.2 of Reference 2.2.1(b). Instruments hardwired to experiment-peculiar command and control equipment must be supplied with appropriate cabling, including tiedowns and thermal protection. The weight, thermal, and power requirements of this cabling will be charged to the experiment instrumentation.

3.1.3.4 Synchronization signals. The synchronization signals transmitted on the data bus and from the RAU are described in 4.4.2-4.4.4 of Reference 2.2.1(b).

3.1.3.5 Instrument output signals. The requirements for analog and digital data out of the scientific instruments mounted on the pallet are described in 4.4.2-4.4.4 of Reference 2.2.1(b).

3.1.3.6 Processing. Data from the pallet-mounted scientific instruments will either be fed to the RAU's for on-board computer processing (low data rate analog and digital) or to the high data rate multiplexer for recoding and/or transmission. A description of the data processing system and the on-board computer characteristics is given in 4.4.6 of Reference 2.2.1(b).

3.1.3.7 Recording. Data from the pallet-mounted instruments is recorded either in the high rate digital recorder at rates of 1, 2, 4, 8, 16, or 32 Mbps or in the mass memory unit interfacing with the on-board experiment computer. Descriptions of the capabilities are in 4.4 of Reference 2.2.1(b).

3.1.4 <u>Thermal Control Interface</u>. Experiment instrument thermal control requirements must be compatible with the capabilities of the Spacelab and with the Orbiter orientation. The primary method of heat dissipation shall be through the Spacelab/Orbiter cooling loop and/or by direct radiation to space. Equipment must be designed to minimize unwanted transfer of heat to adjacent payload elements. Active thermal control elements (e.g., heaters) may be employed and their power dissipation shall be part of the instrument power budget. A description of the thermal control capabilities for pallet-mounted experiment instrumentation is presented in 4.6.2 and 4.6.3 of Reference 2.2.1(b).

3.1.5 <u>Environmental Interface</u>. All pallet-mounted scientific instruments shall be designed to survive the launch and descent environment and operate within the on-orbit environment described in Section 5.2 of Reference 2.2.1(b).

3.1.5.1 Electric and magnetic fields. The design of scientific instruments shall include consideration of the effects of static or slowly varying magnetic and electric fields whether produced by the specific payload unit, by other payload components, or by the Spacelab/Orbiter vehicle. Further, scientific instruments shall not create magnetic or electric fields which interfere with the operation of Spacelab, the Orbiter, or other payload equipment nor which create hazards to the Orbiter or the crew.

3.1.5.2 Electromagnetic compatibility. All scientific instruments shall be compatible with the requirements of 2.2.2(c). Additional requirements may be imposed as a result of Labcraft systems analysis.

3.1.5.3 Cleanliness and contamination. Pallet-mounted scientific instruments must be low-offgassing and low-outgassing, and must not significantly contribute to the particulate contaminant level. The general requirements are specified in Reference 2.2.2(j). Instrument materials and processes shall conform to the requirements specified in Table I.

Table I. Material and Process Requirements - Pallet Instruments

Material Property or Process	Applicable Document	Applicable Paragraph
Outgassing	TBD	TBD
Offgassing	↓	↓
Toxicity		
Flammability		

3.2 MODULE-MOUNTED EQUIPMENT. This paragraph defines requirements for all scientific instruments and experiment supplied support equipment mounted in the Spacelab pressurized module.

3.2.1 <u>Mechanical interface</u>. This paragraph describes the general mechanical requirements and constraints imposed on instruments mounted in the Spacelab pressurized module.

3.2.1.1 Equipment physical characteristics. The total volume available inside the module is nominally constrained to 22 cubic meters consisting of the following areas:

(a) Rack space

(b) Ceiling storage

(c) Center aisle installation.

In defining the module configuration, reasonable allowance must be made for unrestricted crew movement and working conditions. Reference 2.2.1(b) defines the module volume available for payload equipment in more detail.

3.2.1.2 Mounting requirements. Module equipment may be installed in one of the following ways:

(a) In Spacelab-provided rack

(b) In special Labcraft racks

(c) In other Labcraft structures which attach to the Spacelab floor, and dome, or other approved locations

(d) In existing Spacelab stowage containers.

Additional on-orbit mounting of equipment is possible, including attachment to airlocks, optical windows, or to other Spacelab or payload equipment. However, such mounting configurations shall not be used for the ascent and descent flight phases. All mounting methods must comply with the load limits defined in 4.1 of Reference 2.2.1(b), and shall be designed to survive the loads defined in 5.1.4 of Reference 2.2.1(b).

Equipment which must be moved, deployed, or otherwise detached from the basic supporting structure shall include tiedowns, detents, handles, and other features necessary to insure safe and efficient on-orbit operation.

3.2.1.3 Design, construction and finish. Instrument equipment manufactured per this specification shall conform to accepted standards for aerospace hardware and shall reflect good workmanship practices. Parts shall be free of cracks, bends, dents, chips or other defects and shall be clean and free of burrs, dirt, and other foreign material.

3.2.2 Electrical interface. This paragraph describes the general electrical requirements and constraints imposed on scientific instruments and experimenter-supplied support equipment mounted in the Spacelab pressurized module.

3.2.2.1 Electrical power. Electrical power is available from three separate busses:

(1) A 28-volt DC essential bus (limited to 25 watts for the total Spacelab payload)

(2) A second 28-volt DC bus

(3) A three phase 115/200 volt 400 Hz AC bus.

All payload power is distributed via Spacelab electrical power distribution boxes. There is one box in the core segment and one in the experiment segment. Up to 1350 watts of power may be provided to the payload during ascent/descent. All power to Spacelab is controllable from the Orbiter AFD. In addition, each equipment item or assembly may have its power controlled manually from a panel in the module or automatically via the CDMS. Fault protection for module equipment shall be provided in accordance with the safety requirements of TBD.

3.2.2.2 Connectors and cabling. All interconnecting cabling between experimenter-supplied module mounted instruments or equipment and (1) other experimenter-supplied instruments or (2) Labcraft equipment must be provided by the instrument builder. All cabling installations must include tiedowns and thermal protection. Cables which interface with existing Spacelab or Labcraft equipment must incorporate compatible connectors as defined in References 2.2.1(b) and 2.2.2(i).

3.2.2.3 Grounds and shielding. The Spacelab pressurized module mounted instruments shall conform to the ground and shielding procedures as defined in Reference TBD.

3.2.3 Commands and data management. Data and command signals to or from scientific instruments and experimenter-supplied support equipment installed in the Spacelab pressurized module may be routed via the following paths:

(a) Directly to other payload equipment in the module, on the pallet, or on the OAFD

(b) Indirectly via an RAU to the Spacelab CDMS and then to any of the above equipment locations or to the Spacelab data storage or to the Orbiter communication link. Definition of the CDMS/RAU interface is given in Section 4.4 of Reference 2.2.1(b).

All equipment in the module shall include provisions for indicating state-of-health as well as operating mode.

3.2.3.1 Format. The command and data format for instruments interfacing with a RAU is given in Section 4.4.2 of Reference 2.2.1(b).

3.2.3.1.1 Hard wired data lines can either go to the high rate multiplexer or directly to other instrument peculiar equipment. The interface characteristics and format for data lines going to the high rate multiplexer may be found in Section 4.4.3 of Reference 2.2.1(b).

3.2.3.2 Display. The data display characteristics of Spacelab provide equipment are defined in Section 4.4.6 of Reference 2.2.1(b). Additional dedicated display equipment can be mounted in the pressurized spacelab or OAFD under the requirements of Paragraphs 3.2 or 3.3 of this specification.

3.2.3.3 Command and control. The command and control capabilities for instruments interfacing with a RAU are defined in Section 4.4.2 of Reference 2.2.1(b). Experiment peculiar command and control equipment must be supplied with appropriate cabling, including tiedowns and thermal protection. The weight thermal, and power requirements of this cabling will be charged to the experiment instrumentation.

3.2.3.4 Processing. Data from the scientific instruments and the instrumenter-supplied support equipment will either be fed to the RAU's for on-board computer processing (low data rate analog and digital) or to the high data rate multiplexer for recording and/or transmitting. A description of the data processing system and the on-board computer characteristics is given in Section 4.4.6 of Reference 2.2.1(b).

3.2.3.5 Recording. Experiment data is recorded either in the high rate digital recorder at rates of 1, 2, 4, 8, 16 or 32 Mbps or in the mass memory unit interfacing with the on-board experiment computer. Descriptions of these capabilities are in Section 4.4 of Reference 2.2.1(b).

3.2.3.6 Crew interface. Module equipment design shall incorporate features to exploit the technical training and manual skills of the Spacelab crew where such design can improve experiment operation or reduce payload cost. The crew should not be required to perform dull, routine, tedious tasks for extended periods nor required to accomplish tasks requiring extraordinary manual skills. To facilitate crew training scientific instrument control and display consoles should follow the general design techniques employed in the basic Spacelab CDMS.

3.2.4 Thermal control interface. Scientific instruments and instrumenter-supplied support equipment mounted in the Spacelab module must satisfy the constraints defined in 4.6.2 and 4.6.3 of Reference 2.2.1(b). The Spacelab provides three basic methods for thermal control inside the module:

(1) The Spacelab avionics air loop

(2) A water loop

(3) The cabin air loop, limited to 1 kilowatt of payload heat.

In addition, Spacelab provides four thermal capacitors and two cold plates to accommodate peak thermal loads.

3.2.5 Environmental interface. All module-mounted scientific instruments shall be designed to survive the launch and descent environments and operate within the on-orbit environments described in 5.1 of Reference 2.2.1(b).

3.2.5.1 Electric and magnetic fields. The design of module contained scientific instruments or instrumenter-supplied support equipment shall include consideration of the effects of static or slowly varying magnetic and electric fields whether produced by the specific instruments, by other payload components or by the Spacelab/Orbiter vehicle. Further, these instruments shall not create magnetic or electric fields which interfere with the operation of Spacelab, the Orbiter, or other payload equipment nor which create hazards to the Orbiter or the crew.

3.2.5.2 Electromagntic compatibility. All scientific instruments and instrumenter-supplied support equipment shall be compatible with the requirements of Reference 2.2.2(g). Additional requirements may be imposed as a result of Labcraft systems analysis.

3.2.5.3 Cleanliness and contamination. The contamination levels produced by the scientific instruments and instrumenter-supplied support equipment mounted in the Spacelab pressurized module must not cause dangerous or uncomfortable conditions for the crew or prevent proper functioning of instruments, sensors, or other critical equipment. Furthermore, when combined with the contributions from STS/Spacelab/Labcraft sources these dangerous or uncomfortable conditions must not be attained.

3.2.5.3.1 Materials and processes shall satisfy the requirements of 4.2 and of 1.4.5 of Reference 2.2.1(a).

3.3 ORBITER AFT FLIGHT DECK (OAFD) MOUNTED EQUIPMENT. Instrumenter-supplied support equipment may be required to be mounted in the OAFD to supply control, display, or other functions. Such equipment must satisfy the requirements specified in this paragraph.

3.3.1 Mechanical interface. This paragraph describes the general physical requirements and constraints imposed on OAFD equipment.

3.3.1.1 Structural attachment. OAFD equipment attachment to the basic Orbiter support structure will be via approved methods to be specified by NASA/JSC. The NASA will also specify the allowable loading for each of the separate OAFD panel areas.

3.3.1.2 Stowed volume. The panel dimensions, total panel area, and stowed volume for all OAFD equipment shall conform to the constraints set forth in 11.1 of Reference 2.2.1(c). The assignment of specific panel space to instrumen-supplied equipment will be made by the cognizant payload lead center.

3.3.1.3 Environments. OAFD equipment shall be designed to operate and/or survive the applicable environmental factors defined in 4 of Reference 2.2.1(c).

3.3.2 Electrical interface. This paragraph specifies the electrical design and interface requirements for OAFD equipment.

3.3.2.1 Electrical power. The total power available for OAFD payload-unique equipment shall not exceed 350 watts average during all prelaunch, ascent, descent, and post-flight operations. On orbit the Orbiter will provide 750 watts average and 1000 watts peak for payload OAFD equipment. This power is not chargeable to the payload; however, the energy consumed is payload chargeable. This power is 28 volts DC direct from the Orbiter fuel cells. Additional power (e.g., 115 volts 400 Hz) can be made available from the Spacelab power distribution system.

3.3.2.2 Connectors. OAFD equipment shall be designed to interface with the standard set of connectors defined in 11.1.3 of Reference 2.2.1(c).

3.3.2.3 Interconnecting cabling. Cabling between the OAFD equipment and Spacelab may include single wire, twisted shield wire pairs, or coax. Spacelab-Orbiter cabling interfaces are defined in 12.2.5 of Reference 2.2.1(c). Cabling between units on the OAFD must comply with the space limitations inherent in the console layout.

3.3.2.4 Circuit protection. OAFD equipment must include circuit protection devices to protect payload-unique wiring and equipment as well as to prevent the propagation of hazardous conditions.

3.3.2.5 Grounding and shielding. OAFD equipment shall conform to the grounding and shielding practices defined in TBD of Reference TBD.

3.3.3 Commands and data management

3.3.3.1 Display. The only display available to experimenters in the OAFD is for the digital engineering data at 64 kbps maximum. For this purpose the Multifunction Cathode Ray Tube Display System (MCDS) can be utilized. The display page can be used to depict alphanumeric and graphic information. The capability of the MCDS is described in 14.1.2.1.2 of Reference 2.2.1(c). Additional display units can be added and will be charged to the scientific instrument or experiment. The additional units must meet the requirements contained in 3.3 of this specification.

3.3.3.2 Command and control. All scientific instruments and instrumenter-supplied support equipment mounted in the OAFD must include its own command and control equipment. These devices must meet the requirements defined in all other parts of 3.3 of this specification.

3.3.3.3 Data handling. The Orbiter provides the capability to handle data via three interfaces as follows:

(a) Medium-band data:

(1)	S-band FM:	Analog 300 Hz - 4 MHz Digital 200 bps - 5 Mbps
(2)	Ku-band:	Analog 4.2 MHz Digital ≤2 Mbps or ≤4 Mbps

(b) Wideband data: Digital 50 Mbps maximum

(c) Engineering data: Digital 64 kbps, maximum.

3.3.3.4 Recording. Recording of medium-band and engineering data will be available in the OAFD to experimenters. The availability of recording capability for the wideband digital data is TBD. The recording capabilities for OAFD-mounted equipment are contained in 14.1.1.1.2 of Reference 2.2.1(c).

3.3.4 Thermal control interface. Cooling is provided to OAFD equipment by forced air from the orbiter environmental control and life support system. Standard 1-1/2 inch (38 mm) duct connections are provided. Other features of the cooling provisions are described in 10.1.3 and 11.1.3 of Reference 2.2.1(c).

3.3.5 Environmental interface. All instrument hardware to be installed on the OAFD shall be designed to survive the applicable ascent, descent, and ground environment (non-operating) and the applicable on-orbit operating environment specified in 4.2 and 7.5 of Reference 2.2.1(c).

3.3.5.1 Electric and magnetic fields. The design of scientific instruments or instrumenter-supplied support equipment shall include consideration of the effects of static or slowly varying magnetic and electric fields whether produced by the specific payload unit, by other payload components, or by the Spacelab/Orbiter vehicle. Further, no scientific instrument shall create magnetic or electric fields which interfere with the operation of Spacelab, the Orbiter, or other payload equipment nor which create hazards to the Orbiter or the crew.

3.3.5.2 Electromagnetic compatibility. OAFD equipment shall comply with the applicable portions of JSC Specification SL-E-0002, "Electromagnetic Characteristics, Requirements for the Space Shuttle Program."

3.3.5.3 Cleanliness and contamination. The contamination levels produced by the scientific instruments and instrumenter-supplied support equipment mounted in the Spacelab pressurized module must not cause dangerous or uncomfortable conditions for the crew or prevent proper functioning of instruments, sensors, or other critical equipment. Furthermore, when combined with the contributions from STS/Spacelab/Labcraft sources these dangerous or uncomfortable conditions must not be attained.

3.3.5.3.1 Materials and processes shall satisfy the requirements of 4.2 and of 1.4.5 of Reference 2.2.1(a).

3.4 SIPS-MOUNTED INSTRUMENTS. This section describes the general interface requirements which must be satisfied by instruments that are SIPS-mounted. The SIPS has two instrument-carrying canisters, each supported at its center by a yoke which can rotate independently of the other canister in an up-down direction (120 degrees freedom). Each canister in turn is connected to the yoke so as to provide a limited (±10 degrees) left-right rotational degree of freedom. Both yokes are attached to a common ±180-degree azimuth gimbal drive at the base. An optional roll gimbal about the instrument line of sight may be added internally to each canister.

3.4.1 Mechanical interface

3.4.1.1 Equipment physical characteristics. SIPS-mounted instruments shall interface directly with a special instrument support structure. The instrument design must include consideration of the limited capabilities and the design constraints imposed by the SIPS including the following:

(a) Weight limitations. The SIPS limitations are specified in Reference TBD.

(b) Dynamic loads. Disturbance torques reflected back upon the SIPS gimbal must be limited to less than TBD N-M and less than TBD N-M-sec of impulse. Internal momentum must be limited to less than TBD kg-m^2/sec.

(c) Flight loads. SIPS-mounted instruments will accept the ascent/descent loads imposed by the Orbiter as specified in Section 5.1.4 of Reference 2.2.1(b).

(d) Size restrictions. There is no minimum size for SIPS-mounted instruments. The maximum size for an instrument utilizing the roll gimbal is TBD x TBD x TBD. For those instruments not utilizing the roll gimbal the maximum size is TBD x TBD x TBD.

3.4.1.2 Mounting requirements. Instruments shall be mounted to the SIPS instrument support platform through the use of threaded inserts in the mounting platform. Instrument packages must have at least one preferred mounting face with appropriate mounting feed, although two orthogonal mounting faces will provide better mounting flexibility. The design of a package mount shall include consideration of flight loads, of instrument orientation, and ease of access for assembly, integration, test, calibration, and removal.

3.4.1.3 Design, construction, and finish. Instrument equipment manufactured per this specification shall conform to accepted standards for aerospace hardware and shall reflect good workmanship practices. Parts shall be free of cracks, bends, dents, chips, or other defects and shall be clean and free of burrs, dirt, and other foreign material.

3.4.1.3.1 Design safety factors. SIPS-mounted instruments shall be designed to meet the following factors of safety:

(a) Yield safety factor = 2

(b) Ultimate safety factor = 3.

3.4.1.3.2 Materials and processes. Instrument materials and processes shall conform to the requirements specified in Table II.

Table II. Materials and Process Requirements - SIPS Instruments

Material Property or Process	Applicable Document	Applicable Paragraph
Outgassing	TBD	TBD
Offgassing	↓	↓
Toxicity		
Flammability		

3.4.1.3.3 Protection covers. Instruments which are susceptible to contamination prior to use in flight will require a protective cover or cap. Such caps must be removable during integration when the SIPS enclosure will assume the contamination control.

3.4.1.4 Alignment and orientation. Instruments shall be capable of being installed, oriented, and aligned (in the SIPS payload coordinate system) during the integration process.

3.4.1.5 Apertures and viewing. A shadow mask shall be provided so that incident heat flux shall only fall upon the entrance aperture of the instrument.

The instruments shall be designed so that incident radiation up to and including the sun shall not damage the instrument.

3.4.2 Electrical distribution. The distribution of power, signals, and RF between instruments and the Spacelab/Orbiter is accomplished as exemplified in Figure 1.

3.4.2.1 Electrical power. Instruments shall utilize Spacelab-provided electrical power; 28 ±4 volts DC or 115 ± 5 percent 400 Hz AC. Of the two, the 28 volts DC is the preferred power.

3.4.2.2 Connectors and cabling. Standard connectors will be specified and shall be used to facilitate the use of standard electrical interfaces and cables. Connector locations should be selected with due consideration given to access for installation and removal.

3.4.2.2.1 Interconnecting cabling. Interconnecting cabling between slices or separate boxes of one instrument shall be provided with the instrument. Interconnecting cabling between instruments and Spacelab/Orbiter-provided services shall be provided by the integration contractor.

3.4.2.3 Grounding. All electrical power circuits must be grounded or isolated in accordance with Reference 2.2.1(b).

3.4.3 Commands and data management. The following requirements apply to those instruments which interface with the Spacelab CDMS. Instruments which have dedicated controls or which interface directly with display or storage devices must develop special interface requirements, or must include the interfacing hardware as part of the instrument equipment.

3.4.3.1 Commands. Instrument command may originate manually via the keyboard or they may be issued by the CDMS experiment computer. The key operating characteristics of the CDMS, including rates, formats, and command types are given in 4.4 of Reference 2.2.1(b). Ground commanding of experiment operation is possible and may be real time or delayed. Voice commands may also be used and entered by the crew via the CDMS keyboard. Command sequences which involve multiple functions, critical time sequences, or rapid command rates should be issued by the dedicated CDMS experiment computer and should be prepared as part of the dedicated flight software.

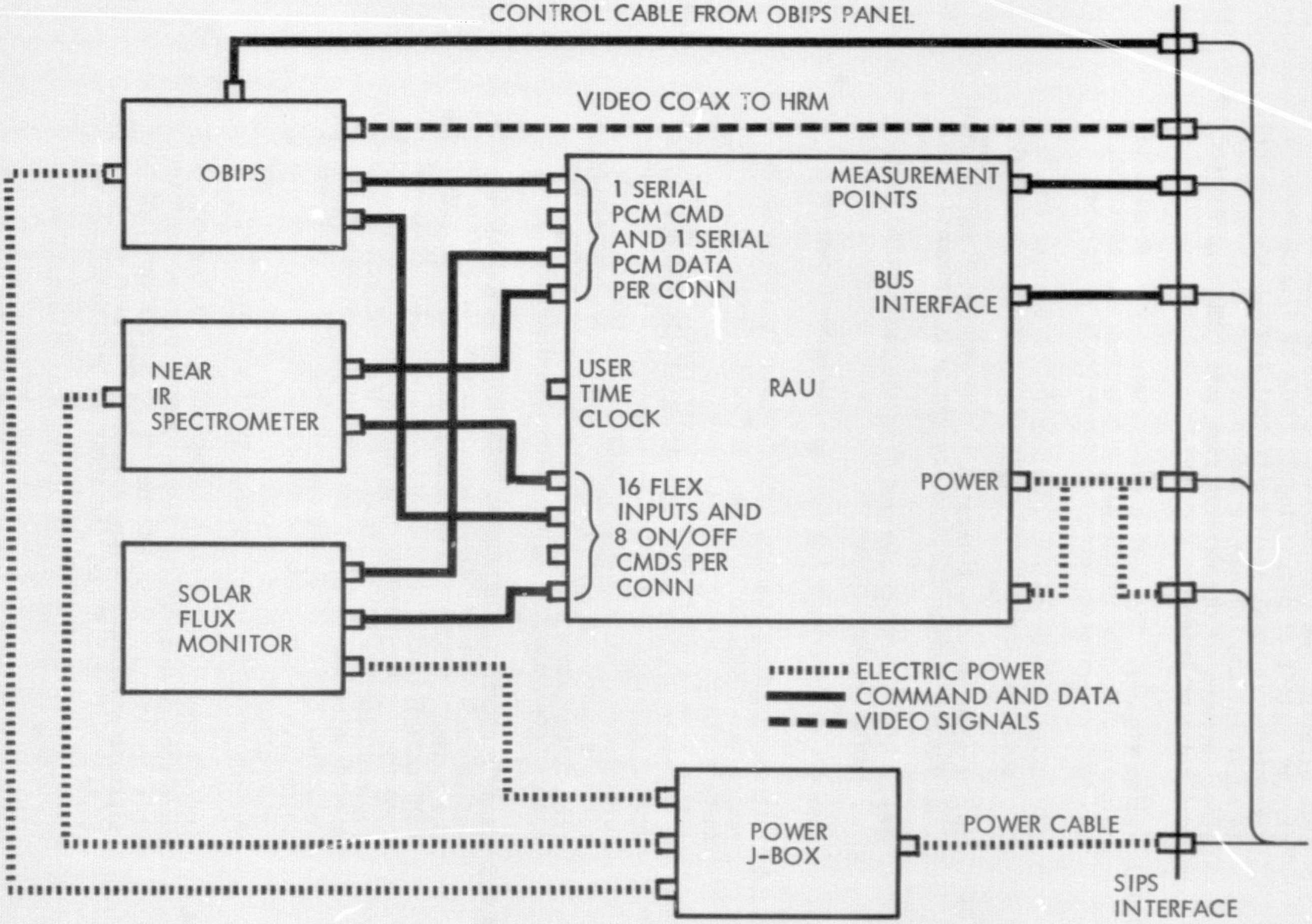

Figure 1. Typical SIPS/Instrument Interface

3.4.3.2 Data display. The CDMS includes a 12-inch, three-color CRT display capable of displaying 22 lines of 47 alphanumeric characters. A total of 128 different symbols are possible. In addition, the CRT can be programmed for vector display. Other features of the data display unit (DDU) are defined in 4.4.6.3 of Reference 2.2.1(b).

3.4.3.3 Timing signals. The CDMS employs various sync signals to maintain operation of the data bus system. In addition, the CDMS distributes various clock signals as follows:

(a) On-board GMT which originates in the Orbiter and is delivered through the serial PCM command RAU outputs.

(b) A user time clock located in the RAU which may be used for GMT update and time tagging of experiments

(c) A 1024 kHz clock derived from the master time unit (MTU) in the Orbiter.

See 4.4 of Reference 2.2.1(b) for additional details.

3.4.3.4 Instrument output signals. Data from instruments may be routed to an RAU, to the high rate multiplexer, or to the Ku-band signal processor (analog data). The RAU will accept analog data in the range of -5 to +5 volts and convert it to an 8-bit digital word. The RAU will also accept serial PCM and discrete data from an instrument. The high rate multiplexer (HRM) will accept serial digital data from multiple sources and at different data rates and multiplex these data into a single serial output bit stream. See 4.4 of Reference 2.2.1(b) for additional details.

3.4.3.5 Data Processing. Instrument data may be processed onboard and in real time and displayed, recorded, or transmitted to the ground. Processing of data is basically limited by the CDMS capabilities, particularly the on-board experiment computer. Other factors such as the requirements of other payload segments may further limit the processing capability. 4.4 of Reference 2.2.1(b) defines the processing and recording capabilities inherent in the CDMS. Instruments which have requirements in excess of the CDMS capacity may incorporate dedicated computers, mass memories, or other devices as part of the instrument flight inventory.

3.4.4 Thermal control interface. SIPS-mounted instruments will have the services of the SIPS standard thermal canister. This canister will be designed to produce a constant temperature environment (nominally 20 ±1°C) over a wide range of external heat fluxes and internal heat dissipation. The details of the standard canister are TBD.

3.4.5 Environmental interface. The SIPS will be exposed to the natural and induced environments imposed on all pallet-mounted equipment (see 5.2 of Reference 2.2.1(b)). Modification of these factors for canister-mounted equipment are defined in Reference TBD.

3.4.5.1 Magnetic and electric fields. The static (DC) and AC magnetic and electric fields originating from the Orbiter and Spacelab are given in Figure TBD through TBD for selected locations within the cargo bay. Instruments which are sensitive to magnetic or electric fields must include these field levels, plus any additional components from other payload elements, in their design. Further scientific instruments shall not create magnetic of electric fields which interfere with the operation of Spacelab, the Orbiter, or other payload equipment, nor which create hazards to the Orbiter or crew.

3.4.5.2 Electromagnetic compatibility. Instruments shall be designed to operate with the conducted interference levels and switching transients as specified in 7.7.2.2.3 of Reference 2.2.1(b). The radiated field levels for selected locations in the cargo bay are given in Figure TBD. As noted above, emissions from other payload elements must also be considered in the design. Further, all scientific instruments shall be compatible with the requirements of Reference 2.2.2(g).

3.4.5.3 Cleanliness and contamination. Instruments will be required to meet the general cleanliness characteristics specified in 7.11 of Reference 2.2.1(b). They must be low offgassing and low outgassing, and must not significantly contribute to the particulate contaminant level. In addition, the instruments must survive and/or operate within the Orbiter environment as defined in 4.3 of Reference 2.2.1(c), which includes such contamination sources as the RCS thruster firing, on-orbit dumping of water, overboard venting of gases, and normal outgassing/offgassing of Spacelab and Orbiter components.

3.5 ESP MOUNTED INSTRUMENTS.

This paragraph describes the general interface requirements which must be satisfied by instruments that are environmental sensor package (ESP) mounted. For this section, the term instrument is meant to include the instrument peculiar support electronics as well as the sensor.

3.5.1 Mechanical interfaces.

3.5.1.1 Instrument physical characteristics. ESP-mounted instruments may interface directly with the ESP instrument platform, on an external surface of the ESP, or with a boom structure. In any of these cases, the instrument design must include considerations of the limited capabilities and the design constraints imposed by the ESP including the following:

(a) Weight limitations. The Labcraft ESP weight limitations are specified in Reference 2.2.2(i).

(b) Deployment envelope. The deployment envelope limitations for instruments mounted on the ESP surface or the ESP booms are contained in Reference 2.2.2(i).

(c) Dynamic loads. All ESP surfaces are structurally limited and hence limited in terms of allowable loads. These limitations may be reflected in weight constraints (see above), or in deployment length, or in the deployment, rotation or slew rates. The ESP will be spin stabilized at a rate of from TBD to TBD revolutions per minute in the deployed configuration. This requirement places additional limits on the moments of inertia of the instruments. The dynamic load limitations for ESP mounted instruments are contained in Reference 2.2.2(i).

(d) Flight loads. The ESP will accept the ascent and emergency descent loads imposed by an attached payload as specified in 5.1.4 of Reference 2.2.1(b).

3.5.1.2 Mounting requirements. Instruments shall be mounted to the ESP by one of the following methods:

(a) Inserts in the instrument mounting platform

(b) Special surface plates

(c) Bosses on the boom structure

(d) Attachment to secondary structures mounted per (a) or (c) above.

Instrument packages must have at least one preferred mounting face with appropriate attach fittings, although two orthogonal mounting faces will provide better mounting flexibility. The design of a package mount shall include consideration of flight loads, of instrument orientation relative to the spin axis, and ease of access for assembly, integration, test, calibration, and removal.

3.5.1.3 Design, construction, and finish. Instrument equipment manufactured per this specification shall conform to accepted standards for aerospace hardware and shall reflect good workmanship practices. Parts shall be free of cracks, bends dents, chips or other defects and shall be clean and free of burrs, dirt, and other foreign material.

3.5.1.3.1 Design safety factors. ESP-mounted instruments shall be designed to meet the following factors of safety:

(a) Yield safety factor = TBD

(b) Ultimate safety factor = TBD.

3.5.1.3.2 Materials and processes. Instrument materials and processes shall conform to the requirements specified in Table III.

Table III. Material and Process Requirements - ESP Instruments

Material Property or Process	Applicable Document	Applicable Paragraph
Outgassing	TBD	TBD
Offgassing	↓	↓
Toxicity	↓	↓
Flammability	↓	↓

3.5.1.3.3 Protection covers. Instruments which are susceptible to contamination prior to use in flight will require a protective cover or cap. Such caps must be remotely removeable and preferably should be retained or captured following deployment.

3.5.1.4 Alignment and orientation. Instruments shall be capable of being installed, oriented, and aligned (in the ESP payloads coordinate system) during the integration process. The alignment accuracy relative to various ESP coordinate systems is limited as shown in Table IV.

Table IV. ESP Instrument Alignment Accuracy

Coordinate Set	Alignment Accuracy Limit
ESP body axes	TBD arc-sec
ESP spin axis	TBD arc-sec
ESP sun sensor LOS	TBD arc-sec
ESP earth sensor LOS	TBD arc-sec

3.5.1.5 Apertures and viewing. The ESP can provide up to 2 pi-steradians of viewing angle for instrument sensors. Instruments requiring aperture protection (e.g., sun shield, iris, etc.) must include such protective devices as part of the instrument design.

3.5.2 Electrical distribution. The distribution of power, signals, and RF energy between instruments and the ESP support subsystems will be as shown in Figure TBD.

3.5.2.1 Electrical power. Instruments will utilize the ESP power source which is a 28 ± TBD volt DC bus powered by a primary battery. In no case shall an instrument peak power load exceed TBD watts. Electrical power will be distributed on the ESP via an isolated two wire system. Each instrument must include an acceptable current limiting device (e.g., fuse or circuit breaker) to protect the ESP from shorts or overloads.

3.5.2.2 Connectors and cabling. Connectors shall conform to the requirements specified in Reference TBD. Cabling between instrument components may be supplied as part of the instrument. In such cases, the cable or wiring harness shall be built in accordance with the requirements of Reference TBD.

3.5.2.3 Grounding and shielding. Power loads shall have a minimum DC resistance of 50 megohms at 50 volts DC between either power lead (see 3.5.2.1 above) and the unit case or chassis. Signal leads shall comply with the grounding scheme illustrated in Figure TBD.

3.5.2.3.1 Shielding is required on all cables carrying RF and on all other signal lines having frequency components above TBD MHz. Shields shall be DC grounded at one end only. Additional shielding may be required to meet the EMI levels specified in Reference 2.2.2(h).

3.5.3 Commands and data management

3.5.3.1 Commands. The ESP will supply command signals to instruments in any of the forms defined in Table TBD. Only real time commands will be available. Command rates up to TBD kbps are possible.

3.5.3.2 Telemetry data. The ESP will receive all instrument data, format the data in one of several selectable formats and transmit the data stream to the Spacelab/Orbiter or to the ground. The instrument output data may be digital or analog (0 to +5 volts DC). Digital signals shall be defined by TBD volts to indicate a binary 1 and TBD volts for a binary zero.

3.5.3.3 Timing signal. The ESP will distribute various timing and/or sync signals for use by instruments. These signals are defined in Table TBD.

3.5.4 Thermal control interface. Instruments shall be designed to survive temperatures from TBD to TBD °C and to operate satisfactorily over ranges from TBD to TBD °C. All thermal control shall be passive (i.e., shall not consume power), and may include insulation, coatings, mirrors, and louvers or may be based on conduction to the ESP structure.

3.5.5 Environmental interface. In addition to the general environments defined in Section 4, ESP-mounted instruments shall be designed to comply with the following interface requirements.

3.5.5.1 Electromagnetic compatiblity. Instruments shall be designed to meet the EMC requirements specified in Reference 2.2.2(g).

3.5.5.2 Angular acceleration. Instruments shall be designed to operate at spin rates up to TBD RPM.

3.6 BOOM-MOUNTED INSTRUMENTS.

This section describes the general interface requirements which must be satisfied by instruments that are boom-mounted. The boom may be provided as Labcraft support equipment or it may be the Orbiter-provided remote manipulator system (RMS).

3.6.1 Mechanical interface. Boom-mounted instruments may interface directly with the boom or may interface mechanically with a special mounting structure or instrument housing. In either case, the instrument design must include consideration of the limited capabilities and the design constraints imposed by the boom including the following:

(a) Weight limitations. The Labcraft 15-meter mast and magnetometer boom limitations are specified in References TBD and TBD. The RMS can accommodate the entire Orbiter weight capability (see Section 8.0 of Reference 2.2.1(c)) and hence is not weight limited.

(b) Deployment envelope. The deployment envelopes for the 15-meter mast and the magnetometer boom are contained in References TBD and TBD. The RMS deployment envelope is given in Section 8 of Reference 2.2.1(c).

(c) Dynamic loads. All of the boom systems are structually limited and hence limited in terms of allowable loads. These limitations may be reflected in weight constraints (see above) or in deployment length or in the deployment or slew rates. The dynamic load limitations for each boom system are contained in References TBD, TBD, and TBD.

(d) Flight loads. The 15-meter mast and the magnetometer boom will accept the ascent/descent loads imposed by an attached payload. However, the RMS requires that the instrument package be detached and stowed separately during the ascent and descent phases of the flight.

3.6.1.1 Equipment physical characteristics. Boom-mounted instruments and/or instrument assemblies must comply with the Orbiter cargo bay envelope as defined in 2.2 of Reference 2.2.1(b). Any instrument (e.g., an antenna) which deploys from the boom must satisfy the same safety requirements as the boom itself (see 7.2.4.1 of Reference 2.2.1(b). The mass and inertia of extendible devices plus any angular momentum produced by boom-mounted instruments must be considered in establishing boom dynamic loading. To facilitate the layout of instrument payloads, boom-mounted instrument packages should be modularized wherever practicable.

3.6.1.2 Mounting requirements. Instruments may be mounted to the boom or to the instrument mounting platform by one of the following methods:

(a) Inserts in the mounting platform

(b) Bosses on the boom structure

(c) Special interface adapter (RMS only)

(d) Attachment to secondary structures mounted per a, b, or c above.

Instrument packages must have at least one preferred mounting face with appropriate attach fittings, although two orthogonal mounting faces will provide better mounting flexibility. The design of a package mount shall include consideration of flight loads, of instrument orientation, and ease of access for assembly, integration, test, calibration, and removal.

3.6.1.3 Design, construction, and finish. Instrument equipment manufactured per this specification shall conform to accepted standards for aerospace hardware and shall reflect good workmanship practices. Parts shall be free of cracks, bends, dents, chips or other defects and shall be clean and free of burrs, dirt, and other foreign material.

3.6.1.3.1 Design safety factors. Boom-mounted instruments shall be designed to meet the following factors of safety:

(a) Yield safety factor = TBD

(b) Ultimate safety factor = TBD.

3.6.1.3.2 Materials and processes. Instrument materials and processes shall conform to the requirements specified in Table V..

Table V. Materials and Process Requirements - Boom Instruments

Material Property or Process	Applicable Document	Applicable Paragraph
Outgassing	TBD	TBD
Offgassing	↓	↓
Toxicity	↓	↓
Flammability	↓	↓

3.6.1.3.3 Protection covers. Instruments which are susceptible to contamination prior to use in flight will require a protective cover or cap. Such caps must be remotely removeable and preferably should be retained or recaptured following deployment.

3.6.1.4 Alignment and orientation. Instrument may be installed, oriented, and aligned (in the Spacelab payload coordinate system) on the undeployed boom mast to the accuracies shown in Table VI.

Table VI. Undeployed Alignment Accuracy

Spacelab Axis	Instrument Location		
	Magnetometer Mast	15-Meter Mast	RMS/Pallet
X_L	TBD	TBD	TBD
Y_L	↓	↓	↓
Z_L	↓	↓	↓

Once the boom mast is deployed its position and orientation can be measured to the accuracies shown in Table VII. Instruments requiring better accuracy must provide additional measurement and control capabilities.

Table VII. Deployed Alignment Accuracy

Position/ Orientation	Instrument Location		
	Magnetometer Mast	15-Meter Mast	RMS Boom
X_L	TBD	TBD	TBD
Y_L	↓	↓	↓
Z_L			
ϕ			
θ			
ψ			

Position and orientation control for boom systems are limited by attitude perturbations (e.g., RCS firings), by the structural characteristics of the boom system, and by the boom control loop. Control capabilities for the three boom systems are presented in Table VIII.

Table VIII. Boom System Limit Cycle Excursions

Boom System	Position Control			Orientation Control		
	X_L	Y_L	Z_L	ϕ	θ	ψ
Magnetometer boom	TBD	TBD	TBD	TBD	TBD	TBD
15-meter mast	↓	↓	↓	↓	↓	↓
RMS						

3.6.1.5 Apertures and viewing. Instrument aperture and viewing angles shall include consideration of obstructions due to the Orbiter and Spacelab and the deployment position of the boom. Viewing angles in excess of 2 π steradians are possible for instruments mounted on the RMS or on the 15-meter mast.

3.6.2 Electrical distribution. The distribution of power, signals, and RF between instruments and the Spacelab/Orbiter is accomplished as shown in Table IX. If a cable is required for an RMS-mounted payload, the cable system must be provided as part of the payload.

Table IX. Electrical Distribution Systems.

Electrical Service	Magnetometer Mast	15-Meter Mast	RMS
Power	Cable	Cable	Battery or Cable
Electrical signals	Cable	Cable	RF link* or cable
Video/RF	Coax or RF link*	Coax or RF link*	RF link* or cable

*Orbiter payload interrogator

3.6.2.1 Electrical power. Instruments to be mounted on the magnetometer mast or the 15-meter mast may be designed to operate from Spacelab power (see Section 4.3 of Reference 2.2.1(b) or from a battery. Instrument packages which are deployed by the RMS may operate from a battery carried within the package or may use Spacelab power supplied via the cable system mentioned in the previous paragraph. Instruments on the 15-meter mast must be designed to accept DC voltage levels as low as TBD volts due to line losses between the Orbiter fuel cell and the instrument mounting point, or must be designed to use batteries or the Spacelab AC power. Power consumed by boom-mounted instruments should be minimized to alleviate thermal design and power transfer problems. Instruments using Spacelab power must conform to the requirements and limitations as stated in Sections 3.6, 4.3 and Appendix A of Reference 2.2.1(b). Boom-mounted instruments must contain fault protection adequate to protect the boom cabling.

3.6.2.2 Connectors and cabling. Any space-qualified connector may be used on boom-mounted instruments. In selecting a connector an allowance of TBD percent spare pins should be added to the basic requirements. Connector locations should be selected with due consideration given to access for installation and removal.

3.6.2.2.1 Interconnecting cabling between instrument modules shall be supplied with the instrument. Such cabling shall be designed to operate within the physical, electrical and thermal constraints imposed by the package design.

3.6.2.2.2 Other cabling such as from an instrument to an RAU or from one instrument to another may be provided as part of the instrument or as part of the total package design. The mast cable system will be supplied as part of the mast equipment complement.

3.6.2.3 Grounding. Boom-mounted instruments may require electrical isolation from the Orbiter/Spacelab structure. Isolation may be accomplished by an individual instrument or may encompass the total instrument package.

3.6.3 Commands and data management. The following requirements apply to those instruments which interface with the Spacelab CDMS. Instruments which have dedicated controls or which interface directly with display or storage devices must develop special interface requirements, or must include the interfacing hardware as part of the instrument equipment.

3.6.3.1 Commands. Instrument commands may originate manually via the keyboard or they may be issued by the CDMS experiment computer. The key operating characteristics of the CDMS, including rates, formats, and command types are given in Section 4.4 of Reference 2.2.1(b). Ground commanding of experiment operation is possible and may be real time or delayed. Voice commands may also be used and entered by the crew via the CDMS keyboard. Command sequences which involve multiple functions, critical time sequences, or rapid command rates should be issued by the dedicated CDMS experiment computer and should be prepared as part of the dedicated flight software.

3.6.3.2 Data display. The CDMS includes a 12-inch, three color CRT display capable of displaying 22 lines of 47 alphanumeric characters. A total of 128 different symbols are possible. In addition, the CRT can be programmed for vector display. Other features of the Data Display Unit (DDU) are defined in 4.4.6.3 of Reference 2.2.1(b).

3.6.3.3 Timing signals. The CDMS employs various sync signals to maintain operation of the data bus system. In addition, the CDMS distributes various clock signals as follows:

(a) On-board GMT which originates in the Orbiter and is delivered through the serial PCM command RAU outputs.

(b) A user time clock located in the RAU which may be used for GMT update and time tagging of experiments

(c) A 1024 kHz clock derived from the master time unit (MTU) in the Orbiter.

An absolute accuracy of 1 millisecond and a relative accuracy of 10 microseconds is anticipated with the above timing scheme.

3.6.3.4 Instrument output signals. Data from instruments may be routed to an RAU, to the high rate multiplexer, or to the Ku band signal processor (analog data). The RAU will accept analog data in the range of -5 to +5 volts and convert it to an 8-bit digital word. The RAU will also accept serial PCM and discrete data from an instrument. The high rate multiplexer (HRM) will accept serial digital data from multiple sources and at different data rates and multiplex these data into a single serial output bit stream. See Section 4.4 of Reference 2.2.1(b) for additional details.

3.6.3.5 Data Processing. Instrument data may be processed on board and in real time and displayed, recorded, or transmitted to the ground. Processing of data is basically limited by the CDMS capabilities, particularly the on-board experiment computer. Other factors such as the requirements of other payload segments may further limit the processing capability. Section 4.4 of Reference 2.2.1(b) defines the processing and recording capabilities inherent in the CDMS. Instruments which have requirements in excess of the CDMS capacity may incorporate dedicated computers, mass memories, or other devices as part of the instrument flight inventory.

3.6.4 Thermal control interface. Boom-mounted instruments must be designed to survive four different thermal environments as follows:

(a) Ascent environment; unpowered; cargo bay doors closed

(b) On-orbit environment; unpowered, boom retracted; cargo bay doors open

(c) On-orbit environment; power on or off; boom deployed

(d) Descent environment and post-landing heat soak; unpowered; cargo bay doors closed.

The impact of these environments is heavily influenced by the Orbiter design, by the mission profile which specifies sun angle orientation, and by the total payload layout and operating characteristics.

3.6.4.1 Ascent environment. During ascent, the Orbiter active thermal control system (ATCS) will provide a payload heat rejection capability of 5,200 Btu/hr (1.52 kW). Between liftoff and 140,000 feet, the circulating Orbiter coolant is not cooled and can reach temperatures as high as 80°F (26.7°C). At 140,000 feet the flash evaporator will begin operation and normal coolant temperature will be restored. The temperature of the cargo bay walls during this phase of flight will be as shown in Figure TBD of Reference 2.2.1(c). It is anticipated that all heat transfer from boom-mounted instruments will be via radiative processes, although use of the Orbiter/Spacelab coolant loop during ascent may be feasible. Since payload power is also limited to 1500 watts total during ascent, it is not anticipated that other payload segments will become significant heat sources.

3.6.4.2 On-orbit environment (retracted). Boom-mounted instruments may be exposed to various degrees of solar isolation and to thermal cycling due to earth eclipse. Limits on the solar incidence angle are imposed on the Orbiter per Figure 4-18 of Reference 2.2.1(c). The eclipse period is a function of the orbit inclination and line of nodes and may be on the order of 45 minutes maximum. The instrument may also be eclipsed by the body of the Orbiter or Spacelab or by other payload equipment prior to deployment. During this flight regime the cargo bay wall temperatures will be as shown in Figures 4-16 (doors closed) and 4-17 (doors open) of Reference 2.2.1(c). Temperatures of surrounding equipment are shown in Figure TBD.

3.6.4.3 On-orbit environment (deployed). Once deployed the instruments will be subjected to the same natural environment described above. However, the package will not be thermally coupled to the Orbiter cargo bay walls nor to other payload elements. In addition, the instruments may have power applied and will be configured for operation. All transfer of heat will be via radiative processes. The particular configuration of the total boom-mounted payload must be included as part of the thermal environment. This includes the physical configuration (location, surface finishes, etc.) as well as the electrical characteristics (peak power, duty cycle, etc.).

3.6.4.4 Descent environment. During descent, all boom instruments will be retracted. The key thermal influences on instrument temperature will be the initial temperatures of all payload equipment plus the temperature of the cargo bay walls (see Figure 4-13, 4-14, and 4-20 of Reference 2.2.1(c). The temperature data of Figure 4-20 shows temperatures with and without the post-landing purge.

3.6.5 Environmental interface. Boom-mounted instruments shall be designed to survive (non-operating) the ascent, descent, and on-orbit environmental conditions and to operate under the on-orbit environments specified in 5.2 of Reference 2.2.1(b). The following environmental interfaces may influence the location and/or performance of boom-mounted interfaces. These interface definitions represent only the environment which can be attributed to the Orbiter and Spacelab, and do not include contributions from other payload elements.

3.6.5.1 Magnetic environment. The static (DC) and AC magnetic field originating from the Orbiter and Spacelab are given in Figures TBD through TBD for selected locations within the cargo bay and for certain fixed distances (5, 10, 15 meters) outside the cargo bay. Instruments which are sensitive to magnetic fields must include these field levels, plus any additional components from other payload elements, in their design and/or selection of operating location.

3.6.5.2 Electromagnetic compatibility. Instruments should be designed to operate in the deployed condition and with the conducted interference levels and switching transients as specified in 7.7.2.2.3 of Reference 2.2.1(b). The radiated field levels for selected locations external to the cargo bay are given in Figure TBD. As noted above, these do not include emissions from other payload elements.

3.6.5.3 Cleanliness and contamination. Instruments will be required to meet the general cleanliness characteristics specified in Section 7.11 of Reference 2.2.1(b). In addition, the instruments must survive and/or operate within the Orbiter environment as defined in Section 4.3 of Reference 2.2.1(c), which includes such contamination sources as the RCS thruster firing, on-orbit dumping of water, overboard venting of gases, and normal outgassing/offgassing of Spacelab and Orbiter components.

4. GENERAL REQUIREMENTS

4.1 SOFTWARE. This paragraph establishes the software requirements placed on Labcraft experimenters and scientific instrument suppliers.

4.1.1 Purpose. The experiment and scientific instrument software defined in this section enables the flight crew operator to control and monitor the performance of payload experiments in flight. It also provides such features (entry points, exit points and logic) as are required to permit ground testing of each function performed and to permit in-flight testing of critical functions and permit training activities.

4.1.2 Compatibility. Experiment and scientific instrument software should reside either in dedicated computers supplied with the payload science instruments or instrumenter-supplied flight support equipment or reside in the Spacelab central CDMS experiment computer. All specifications below except 4.1.2.1 apply to the central CDMS experiment computer software only.

4.1.2.1 Dedicated computer compatibility. Dedicated computers are considered as a part of the scientific instrument, and are subject to the same interface compatibility requirements as the instruments themselves or the experiments of which they are a part. Where very high speed or complex computations are required, they will usually be performed in dedicated computers.

4.1.2.2 CDMS experiment computers compatibility. Experiment and scientific instrument data processing software residing in the Spacelab CDMS experiment computer shall be compatible with the Labcraft system management software package. This package coordinates the action of multiple experiments, prevents mutual instrument or FSE interference or environmental impact that would damage or seriously delay experiment operations. Further this Labcraft software package provides certain common use interface modules that are described below, but does not itself change the scientific instrument, or experiment computations required to perform the experiment operations. The experiment computer will generally perform simple computations such as limit checking, units conversion and display formatting.

4.1.3 Common-use interface modules. The payload user will be provided with a set of common interface modules that enable data to properly cross all commonly used software and Spacelab system interfaces, whether internal or external to the CDMS. These modules shall be callable via simple mnemonics. The calls shall have the form

NNNN..., P1, P2, P3 ...

where NNNN... is the name of the operation commanded and P1, P2, P3 ... are parameters or mnemonics that specify details of the information command, its timing, or other auxiliary parameters. The values of the parameters will be furnished by experimenters or instrument designers.

4.1.3.1 The design of the command calling language and the associated modules called shall be oriented to the experimenter or instrument designer for ease of their use in software development, and who are not necessarily familiar with the detailed operation of each internal or external Spacelab interface.

4.1.3.2 As a minimum the following operations will be provided with common interface modules:

(a) Transfer of set-up, calibration and operation control commands to payload equipment

(b) Transfer of timing and state vector information to payload equipment

(c) Transfer of data acquisition commands to payload equipment

(d) Receipt of science data from payload

(e) Receipt of feedback of commands from payload and from auxiliary equipment controlled

(f) Transfer of computed quantities to high rate multiplexer recorder or PCMMU for downlinking

(g) Transfer of data, control feedback and other quantities to CRT and other console displays

(h) Transfer of data to auxiliary test or ground support equipment, to Orbiter or to payload during ground test or training

(i) Acceptance of data from auxiliary test or ground support equipment during ground test or training

(j) Access to common data base modules

(k) Build of composite commands based on single command inputs

(l) Build of composite displays from single display commands.

4.1.3.3 Data rates and format requirements for the data crossing each interface shall be as specified in Reference 2.2.1(b).

4.1.4 Main memory occupancy. The maximum number of words that can be occupied in the main memory of the CDMS experiment computer by the software controlling payload operations during any one time period will be allocated prior to the start of software development for each mission and will be less than 35,000 sixteen-bit words for experiments that need not share main memory with other experiments.

4.1.5 Language. Experiment and scientific instrument software shall be written in a NASA-approved programming language. Current approved languages are HAL/S, FORTRAN (ANSI by 3.9 - 1966), CII 125S assembly language, and GOAL.

4.1.6 Software standards. The experiment and scientific instrument software shall comply with the software standards and guidelines as established in Reference TBD.

4.1.7 Responsiveness. Delays in the operation of the experiment or scientific instrument software shall be no more than two seconds in responding, with feedback, to any operator command.

4.1.8 Visibility. The experiment and scientific instrument software shall be designed such that the operator obtains sufficient display and visibility as to the quality of experiment performance. It shall provide him with error messages or other indications as are practical to advise him of errors or out-of-tolerance conditions.

4.1.9 Data quality assignment, annotation. The experiment and scientific instrument software shall enable the operator to assign data quality bits and/or make data annotation to all science data and performance data being preserved for future analysis.

4.1.10 Testability.The experiment and scientific instrument software shall contain such entry points, exit points and logic as required to permit ground and in-flight testing of each function performed.

4.1.11 Operators supported. The experiment and scientific instrument software shall concurrently distribute data to a maximum of three operator consoles, including one CRT each and the associated panel indicators, and receive commands from a maximum three keyboards and associated console switches.

4.1.12 Operator overrides, restart. The experiment and scientific instrument software shall permit the operator to override (1) error alarms no longer desired (2) error branches that interfere with experiment operation (3) values of constants no longer applicable. The operator shall be capable of restarting the software at pre-planned restart points.

4.1.13 Modularity. The experiment and scientific instrument software shall be designed such that the software controlling each individual instrument or each individual experiment be an independently callable software package. The design of these packages shall be such as to minimize their interdependence.

4.1.14 Test modules. The experiment and scientific software module shall be designed together with the software test modules sufficient to verify payload software integrity. These test modules may reside for test purposes either in the flight computer or in an external test computer, or other ground test equipment.

4.2 SAFETY

4.2.1 General system safety requirements. The System Safety Policy for the Labcraft equipment payload is to require the minimum safety requirements that will logically protect flight and ground personnel, the public, property, environment, elements of the transportation system during ground operations, normal landings, crash landings, aborts, flight emergency operations and normal flight operations, and emergency payload operations.

4.2.1.1 All specific or potential hazards which have the potential of inflicting injury to personnel or damage to equipment or property shall be controlled such that a safe interface between personnel and systems of concern exists in the presence of the hazard; a hazard is defined as the presence of a potential risk situation caused by an unsafe act or condition. All existing or potential hazards which cannot be controlled shall be classified as uncontrolled catastrophic or critical residual hazards.

4.2.1.2 All residual catastrophic and critical hazards must be approved by Labcraft equipment program management for inclusion in the system design and operations.

4.2.1.3 The scientific instrument safety requirements must adhere to all the requirements found in Reference 2.2.2(a). The safety requirements delineated in Reference 2.2.2(b) will be used as a guideline.

4.2.1.4 Additional general safety requirements are:

(a) No single point failure will adversely affect safety of the crew and no second failure in the same equipment will preclude successful abort of the mission

(b) The system will be designed as a minimum to be fail-safe

(c) Safety-critical redundant equipments shall be separated to prevent hazard propagation to the maximum extent practicable.

4.2.2 Specific safety requirements for flight systems. Scientific instrument design shall adhere to the specific safety requirements in the following paragraphs.

4.2.2.1 Flight operations. (a) No scientific instrument system shall impose restrictions on normal or contingent Space Shuttle operations (including intact abort and rescue operations) in which the safety of the Space Transportation System (STS) or flight personnel may be affected.

Instruments must have the capability of being returned to a safe or inert status at the termination of the experiment operations, including emergency shutdown provisions in the case of hazardous conditions.

(b) When instruments require some operation during ascent and reentry, they must not require any command action from the ground or the Shuttle crew during the powered flight phase except safing commands.

4.2.2.2 Free flying and retrievable items. (a) Free-flying items shall have command and control circuitry associated with their launching/propulsion systems which are designed to preclude inadvertent launch or firing in case of hardware failure.

(b) Free flying items which contain hazard sources (e.g., explosive devices) shall be designed such that their hazard producing functions are positively inhibited until at a safe distance from the Orbiter.

(c) Retrievable free flying items shall include provisions to permit pre-retrieval safing which can be verified by the Orbiter and ground crews prior to the performance of retrieval operations.

(d) The hazards of intercepting a free flying item (satellite, instruments, etc.) shall be controlled by TBD.

(e) Items extended outside the Orbiter payload bay envelcpe or outside Spacelab airlocks must have a capability for emergency ejection and/or retraction. This capability shall be provided by a dedicated system capable of control from the Spacelab and Orbiter.

(f) Items incapable of being properly stowed (be able to withstand crash landing loads) before landing of the Orbiter and that would be a potential hazard to the Orbiter shall have a redundant stowage mechanism or be capable of being ejected before reentry.

(g) Residual material following emergency retraction or ejection shall not interfere with the closure of Orbiter cargo bay doors or scientific airlock hatches.

4.2.2.3 Controls. (a) All switches shall be recessed or otherwise protected against accidental actuation.

(b) A rapid means of switching off power under emergency conditions shall be provided

(c) Automated control functions shall have manual override provisions.

(d) All safety-critical command and control circuitry associated with engine firing, primary propulsion systems or auxiliary propulsion systems shall be designed to preclude inadvertent firings in case of initial hardware failures

(e) Safety control functions (command override, emergency control provisions, etc.) shall derive their power from a source independent of the primary power supply.

4.2.2.4 Software. (a) The software shall conform to the following requirements.

TBD

4.2.2.5 Hazard detection monitoring. Hazard detection monitoring may be required.

4.2.2.6 Material – flammable, toxic, corrosive, fragile. The materials used shall adhere to the following material safety requirements.

(a) Flammable materials exposed to the ambient atmosphere shall be separated to prevent flame propagation paths. Similarly, separation of flammable materials from possible ignition sources is required to the maximum extent practicable. Consideration shall be given to:

(1) Reduction in the probability of ignition

(2) Restriction of any fire to a definable area

(3) Limitation of the rate and magnitude of the rise of temperature and pressure from any fire to prevent the loss of structural integrity

(4) Single barrier failures.

(b) Toxic, corrosive and/or flammable materials shall be stored and used such that failure of the primary container will not release the material into the cabin atmosphere. Provision shall be made for the safe collection and storage of used or spent materials, considering also their possible chemical or physical interaction. Use of the Orbiter vent system may be considered.

(c) Toxic materials and other materials determined by analysis and/or test to be hazardous (toxic, corrosive in odor producing) must be isolated from the crew and cabin system, and suitable measures for neutralization provided in case of hazard.

(d) Where hazards can occur due to the presence or contact of mutually incompatible materials, components at electrical differences or of chemically incompatible substances or incompatibility with oxygen, such components or substances shall be separated to the maximum practical extent.

(e) Hazardous fluids shall normally be dumped or vented overboard prior to reentry. If this capability cannot be utilized, the hazardous fluid containement shall be designed to remain intact under crash loads with assurance provided that tank integrity will not be violated by other equipment due to impact as a result of crash loads.

(f) The system components inside the Spacelab that require venting shall vent by-products into the Spacelab experiment vent system.

(g) Material which can shatter shall not be used in the module unless positive protection is provided to prevent fragments from entering the cabin environment. Photographic and optical equipment which cannot comply with this standard must be protected by suitable covers when not in use.

4.2.2.7 Consumables. (a) Cryogenic materials must be stored external to the Spacelab module shell in containers with adequate safety margins and venting provisions for flight and ground operations. Other consumable and cryogenic safety requirements are TBD.

4.2.2.8 Explosive. (a) Explosive devices capable of producing fragments or significant environment overpressure shall meet the requirements of Reference 2.2.2(e).

(b) Safety requirements for shape charges and solid rocket motors are TBD

(c) Destruct systems shall not be used

(d) Any explosive or pyrotechnic devices used for the jettison of hardware should be designed to be fail-operational/fail-safe.

4.2.2.9 Electrical. (a) High voltage systems shall be suitable insulated, isolated. Provisions for automatic cutoff of high voltage is required when access to high voltage equipment for adjustment, maintenance or repair is needed.

(b) Instrument grounding shall be such as to preclude electrical discharge hazards and shocks.

(c) Consideration shall be given to the control of potential explosive rupture of electrical/electronic components such as batteries and capacitors and other electrical hazards that could cause damage or injury to personnel or the elements of the Space Transportation System.

4.2.2.10 Pressure vessels. Pressure vessels shall be in accordance with Reference 2.2.2(f) or in accordance with ASME Boiler and Pressure Vessel Code, Section VIII, Divisions 1 and 2. If pressure vessels are used which are not in accordance with NSS HP 1470.1, then these pressure vessels must be tested to demonstrate fluid compatibility of the vessel with the contained fluid per NSS HP 1740.1. Pressure vessels shall normally be installed exterior to the Spacelab cabin, and suitable regulation, pressure relief, and flow restriction provided so that flow into the cabin is limited to the capability of the Spacelab vent system. Small pressure vessels may be permitted inside the cabin provided they do not have a credible explosive failure mode and their failure will not expose the crew or vehicle to hazard. A safe margin of 4 to 1 should be used in the design of all pressure vessels internal to the cabin.

4.2.2.11 Mechanical equipment. Rotating machinery must be protected by suitable guards. Where machinery is highly stressed, containment for possible failure must be provided. Exposed sharp corners, edges and protrusions shall be avoided.

4.2.2.12 Electromagnetic compatibility. All system/equipments or functions installed in or associated with the Spacelab or Orbiter shall be classified as EMI Critical if their failure or unintended operation could cause one or more of the following:

Loss of life or injury to flight or ground crew.

The system/equipment shall be designed per the safety requirements of Reference 2.2.2(g).

4.2.2.13 Non-ionizing radiation. Equipments which include microwave (200 MHz to 25.4 GHz) sources shall be designed to preclude crew exposure to greater than 10 mW/cm^2.

4.2.2.14 Radioactive radiation. Equipments that contain radioactive materials or contain equipment that generated ionizing radiation shall be identified and approval obtained for their use.

4.2.2.15 Audio noise. The noise produced by experiment equipment shall not exceed (TBD).

4.2.2.6 Environments influences. All Labcraft equipment shall be designed so that it can withstand the launch, operational, and reentry dynamic environment and the maximum crash landing loads defined in Reference 2.2.1(c) without failures, leaking hazardous fluids, or releasing equipment, loose debris and particles which could damage other experiments and equipment, the Spacelab/Orbiter or cause injury to the crew.

4.2.2.17 Reusable hardware. Payloads and derivations of payloads (including line replaceable units and associated integrator-supplied equipment) utilized for previous missions shall be verified for:

(a) Any maintenance and/or refurbishment affecting safety

(b) Safety of reuse in view of gradual wearout of the hardware or subtle degradation in previous use.

4.3 ENVIRONMENTAL INTERFACE. All Labcraft instruments to be flown on Spacelab/Orbiter shall be designed to survive and/or operate under the environmental conditions defined in this section.

4.3.1 General. The Orbiter is designed to carry payloads into orbits which may have inclinations from 28.5 degrees to 56 degrees and orbital altitudes from 100 to 300 nautical miles. A normal mission includes a powered ascent to a nominal orbit, final adjustment using the OMS, a 7-day on-orbit stay, a reentry, landing, and post-landing cool down. Abort of a flight is possible during ascent or at any time prior to reentry. In addition, a crash landing condition is postulated wherein the physical integrity of all payload equipment must be maintained.

4.3.1.1 In addition to the Shuttle-induced environments during a typical mission, instruments must be designed to operate and survive in the natural environment of space.

4.3.2 Pressure. All instruments shall be designed to operate with ambient pressures as low as 4.7 by 10^{-11} torr or shall include their own pressurization. Instruments must be designed to survive external pressures as high as 1.05 bars and rates of change of pressure up to TBD torr/sec.

4.3.3 Thermal vacuum. Instruments shall be designed to survive (non-operating) under ambient temperature-pressure environments as listed below:

Condition	Temperature (°K)	Pressure (bar)
Storage	TBD	1.013 ± 0.013
Pre-launch	TBD	1.013 ± 0.013
Ascent	TBD	TBD to 1.026
Post-landing	TBD	1.013 ± 0.013

4.3.4 Vibration. Instruments shall survive the vibration/acoustic environment as defined in 4.2.2.2 and 4.2.2.3 of Reference 2.2.1(c).

4.3.5 Acceleration. Instrument designs shall be compatible with the acceleration levels defined in Table 7.6 of Reference 2.2.1(c). During instrument operation, the minimum acceleration level which can be achieved will be TBD m/sec^2.

4.3.6 Radiation environment. The natural radiation environment as defined in Reference TBD shall be used for the applicable operating and non-operating instrument regimes during orbital flight.

4.3.7 Magnetic environment. The magnetic environment within the Orbiter cargo bay is defined in 4.2.2.8 of Reference 2.2.1(c). Instruments requiring a clean magnetic environment must be removed from the Spacelab/Orbiter influence via booms or ESP.

4.4 SPECIAL INTERFACES. A number of devices which are critical to the AMPS mission will create special interfaces for all elements of the Spacelab payload. These special interfaces are defined below.

4.4.1 Vehicle charging. The electron accelerator will emit a beam of electrons of variable and controllable current and voltage. If this emitted beam is not neutralized by a return current collected from the ambient plasma, the Orbiter structure could become charged to a high voltage. Such charging could lead to high voltage breakdown with attendant arcing, current surges, localized heating or melting, and other potentially hazardous consequences. It is therefore essential that a sensor for measuring the potential of the vehicle relative to the local plasma be included with the electron accelerator package. The electron accelerator shall be operated such that the vehicle potential never exceeds TBD volts relative to the plasma. If necessary passive (deployment of return current collecting areas) or active (positive ion emitters) methods shall be used to keep the vehicle potential within this limit.

4.4.2 Radioactive sources. Any instrument that contains radioactive materials shall be identified and approved prior to their use. The production of ionizing radiation due to the accelerator electron beam intercepting portions of the Spacelab/Orbiter is a possibility and specific safety features must be built into the payload to minimize or prevent this hazardous condition from occurring.

5. TESTING

5.1 GENERAL TESTING REQUIREMENTS

TBD

5.2 SCIENTIFIC INSTRUMENT GROUND SUPPORT EQUIPMENT. Each scientific instrument shall have supporting ground equipment. This dedicated GSE shall, as a minimum, satisfy the following functional requirements:

(a) Ground hoisting/handling

(b) Ground transportation

(c) Environmental protection

(d) Work stands or other integration aids

(e) Prelaunch checkout

(f) Ground power.

Additional GSE may be required to satisfy functions such as loading of expendables, equipment alignment, storage, prelaunch or post-launch calibration, and interface verification.

5.2.1 General requirements. The following requirements shall apply to all scientific instruments.

5.2.1.1 Transportability. GSE shall be designed to meet the same transportation requirements as the Labcraft payload (see 5.).

5.2.1.2 Safety. The design of all GSE shall include consideration of safety requirements and the reduction of hazards to ground personnel as outlined in 4.2.

5.2.1.3 Interfaces. GSE shall be compatible with the following interfaces:

(a) Labcraft flight equipment

(b) Level IV, III, II, and I integration facilities

(c) Orbiter and Spacelab.

In particular, instrument GSE design must reflect the manned aspects of payload design, the flight software, the cleanliness requirements of Spacelab, the schedule constraints of Orbiter payload integration, and the limited access to payloads during launch site integration.

5.2.2 Environments. GSE may be subject to any of the following operating and non-operating environments. Exposure may be repeated through various cycles and may involve extended periods of time.

5.2.2.1 Operating environment. The nominal GSE operating environment will be within the values defined in Table III-1.

5.2.2.2 Transportation environment. GSE may be exposed to any or all of the enviromental factors specified in Table III-1.

5.2.2.3 Storage environment. GSE shall be designed to survive (without damage) exposure to the storage environment identified in Table X.

Table X. GSE Environments

Environmental Parameter	Units	Parameter Value Versus Condition		
		Operating	Transportation	Storage
Temperature	^{o}C	TBD	TBD	TBD
Pressure	kg/cm^2	↓	↓	↓
Relative humidity	%	↓	↓	↓
Acceleration	G	↓	↓	↓
Vibration	G^2/Hz	↓	↓	↓
Shock		↓	↓	↓
Cleanliness		↓	↓	↓

5.2.3 Electrical requirements

5.2.3.1 Electromagnetic compatibility. All GSE shall be designed to minimize the output of spurious radiated or conducted interference and shall be designed to isolate or minimize the effects of externally generated interference. As a minimum, all GSE shall meet the requirements specified in TBD.

5.2.3.2 Fault protection. All GSE shall include circuit breakers, fuses, or other devices to protect flight equipment and the GSE from damage due to shorts, grounds or other circuit faults.

5.2.3.3 Electrical power. Instrument GSE shall be designed to operate from commercial 60 Hz power sources operating at a nominal 110/220 volts with either single or three phase power available.

5.2.3.4 Ground. EGSE shall be designed to comply with the applicable portions of OSHA safety standards, other governmental wiring regulations, the National Electrical Code, and the specific characteristics of the Labcraft payload, the Spacelab, and/or the Orbiter vehicle as well as any local facility characteristics. Safety considerations shall not be compromised in the configuration of a GSE ground scheme.

5.2.3.5 Orbiter interfaces. EGSE interfaces with the instruments installed in the Orbiter shall be via existing payload umbilicals defined in 4.10 of Reference 2.2.1(c).

5.2.3.6 Spacelab interfaces. Instrument GSE shall use the existing Spacelab CDMS capabilities to carry out payload checkout wherever possible and providing it is the most economical approach.

5.2.4 Controls and displays. GSE may utilize the Spacelab CDMS controls and displays for Level III/II and Level I integration. However, a separate capability must be provided for Level IV integration.

5.2.5 Software. Checkout software operating through the GSE may be required during integration or prelaunch checkout to satisfy schedule constraints or to meet technical objectives.

5.2.6 Performance. GSE shall have a performance capability compatible with the system requirements. Factors of safety will apply to mechanical equipment design. For electrical GSE, performance parameters such as measurement accuracy shall include design tolerances to allow for operator error, degradation of calibration, aliasing errors, digitizing errors and other anticipated error sources. All GSE should reflect consideration of the operating personnel in terms of ease of operation, use of unambiguous controls and data presentation, and judicious use of automatic sequencing. Where feasible, GSE should include buillt-in calibration sources and should also indicate when faults or out of tolerance conditions are present.

6. HANDLING, SHIPPING AND STORAGE

(TBD)

7. NOTES

7.1 ABBREVIATIONS AND ACRONYMS

AMPS	Atmosphere, Magnetosphere, and Plasmas in Space
ATCS	Active Thermal Control System
CDMS	Command and Data Management System
DDU	Data Display Unit
EGSE	Electrical Ground Support Equipment
EMC	Electromagnetic Compatibility
EMI	Electromagntic Interference
ESP	Environmental Sensor Package
FSE	Flight Support Equipment
GMT	Greenwich Mean Time
GN&C	Guidance, Navigation, and Control
GSE	Ground Support Equipment
HRDR	High Rate Digital Recorder
HRM	High Rate Multiplexer
IMU	Inertial Measurement Unit
LOS	Line of Sight
MCDS	Multifunction Cathode Ray Tube Display System
MGSE	Mechanical Ground Support Equipment
MMU	Mass Memory Unit
MTU	Master Time Unit
OAFD	Orbiter Aft Flight Deck
OMS	Orbital Maneuvering System
PCM	Pulse Code Modulation
PCMMU	PCM Master Unit
RAU	Remote Acquisition Unit
RCM	Reaction Control Motor
RCS	Reaction Control System
RMS	Remote Manipulator System
SIPS	Small Instrument Pointing System
STS	Space Transportation System
TBD	To be determined.

7.2 DEFINITIONS OF TERMS

Airlock. An intermediate volume between vacuum and a pressurized volume which can be pressurized or depressurized on command.

Assembly.A combination of assembled components forming a self-contained operating unit necessary to the operation of a subsystem, such as power inverters, heat exchangers, etc.

Caution. A condition where a hazard to crew safety could develop if no remedial action is taken.

Central integration site. An assembly and checkout site, where Spacelab buildup, experiment installation and post-installation checkout activities are performed.

Checkout. A sequence of activities and processes to examine the performance of a unit, subsystem, or system under various operating conditions.

Component. An article composed of a group of assembled parts which is a self-contained element of a complete operating unit and performs a function necessary to the operation of the assembly; such as meters, valves, actuators, etc.

Docking module. A remoable module that can be installed in the forward end of the payload bay to provide shirt sleeve transfer to another Orbiter or space vehicle equipped with a compatible docking device.

Emergency. A condition where an immediate hazard exists threatening crew safety.

Engineering model. A full-size structural model, dimensionally correct (including interfaces), with subsystems functionally identical to the flight unit (but not necessarily fully qualified), and comprising all system constituents necessary to assembly any flight configuration will be maintained to reflect the flight configuration.

Environmental sensor package. A self-contained subsatellite capable of supporting a variety of scientific instruments. It is spin-stabilized and has no active orbit maneuvering capability. It can be either free flying, or attached to the RMS or other Orbiter attached appendage.

EVA. Creman activities conducted outside the spacecraft pressure hull or within the payload bay when the payload bay doors are open, during flight operations.

Experiment. The performance of the scientific or applications investigation undertaken to discover unknown phenomena, establish the basis of known laws, or to evaluate applications processes and/or equipment.

Experiment computer. The computer that is a part of the CDMS that will give computer support to payload experiment performance and monitoring.

Fail-safe. The ability to sustain a failure and retain the capability of terminating a flight without injury to personnel or vital spacecraft systems.

Flight success. The proper functioning of Spacelab, its subsystems, and the experiment support equipment provided to the users, but not of the experiments themselves.

Flight unit. Any flight configuration having met all qualification and acceptance test requirements.

Hatch. Door for personnel ingress and egress.

High rate multiplexer. A multiplexer that is a part of the CDMS that will be capable of multiplexing experiment-produced outputs from various payload equipments to form a single digital bit stream for downlinking or hi-rate recording purposes.

Igloo. A pressurized and temperature controlled compartment. For housing of Spacelab subsystem equipment on pallet only missions.

Instrument. Se Scientific instrument.

Instrument installation. The physical installation of instruments on Spacelab experiment racks or rack sets, sections, pallet sections, or Labcraft equipment.

Instrument integration. Those Spacelab program activities that are performed to assure physical and functional compatibility of instruments with the Spacelab, with other instruments, with GSE, with FSE, with the test, operational, and storage environments, and with ground and flight personnel.

Integration. A combination of activities and processes to assemble components, subsystems, and system elements into a desired configuration and to verify compatibility between the constituents of the assembly.

Integration levels. The major steps (integration levels) in ground operational processing of Spacelab, following refurbishment, and of its experiment payload are:

Level I	Integration and checkout of the Spacelab and its payloads with the Shuttle Orbiter, including the necessary preinstallation testing with simulated interfaces.

Level II	Integration and checkout of the combined payload equipment and Spacelab elements (e.g., racks, racks sets, and pallet segments) with the flight subsystem support elements (i.e., basic module, igloo) and extension modules, when applicable.
Level III	Combination, integration and checkout of Spacelab elements (e.g., racks, rack sets, and pallet segments) with payload equipment already installed, and of payload and Spacelab software.
Level IV	Integration and checkout of payload equipment with individual payload mounting elements (e.g., racks and pallet segments).

Interface. The physical and operational common boundary between two constituents of a system. The major Labcraft payload interfaces are:

Labcraft/Spacelab interface

Labcraft/ground support interfaces

Labcraft/subsystem interfaces

Labcraft/pallet segment interfaces

Labcraft/scientific instrument interfaces.

Labcraft equipment (LC/E). That portion of the payload which supports scientific instruments and completes the interface between the payload and Orbiter/Spacelab and between the payload and the crew.

Labcraft support equipment. Labcraft support equipment is a category of flight equipment required to achieve Labcraft mission objectives. It includes subsatellites (ESP's). releases, masts, and other hardware required to assembly, mount, control, and generally support the scientific instruments.

Launch site. The Kennedy Space Center (KSC) or Western Test Range (WTR). Current Spacelab operational processing studies have been based upon utilization of KSC as the prime launch site with WTR being considered for later activation.

Line replaceable unit (LRU). The assembly level at which replacement on Spacelab takes place during maintenance operations.

Maintenance. The actions taken to retain an item in a specified condition by systematic inspection and servicing; and the actions taken to restore an item to such condition, including fault detection, repair, item replacement, and verification.

Mission. The planning and execution of an experiment program to achieve a particular science, applications, or technology objective; it may involve one or more flights.

Mockup. A full-scale replica, dimensionally correct, with all equipment simulated in actual size, to be used for internal arrangement studies. A mockup shall be capable of transportation via air, land or sea.

Module. A pressurized manned laboratory suitable for conducting science, applications and technology activities on Space Shuttle Sortie missions. A section of the module will be devoted primarily to subsystem support for experiments mounted in the module or on the pallet, (basic module) and one or more additional sections may be devoted primarily to housing experiment apparatus and activities (extension module).

Multi-mission support equipment (MMSE). Equipment available from Orbiter/Spacelab inventory which can be used by several Spacelab payloads.

Offgassing. The releasing of gases or vapors from the surface of a solid during exposure to vacuum usually taking place over a short time period.

Orbital maneuvering system (OMS). An auxiliary tankage and pressurization system that can be installed in the Orbiter payload bay in incremental kits to increase the on-orbit maneuvering capability of the Shuttle Orbiter.

Orbiter turnaround. The time between landing and launch of the same Orbiter.

Outgassing. The releasing of trapped or contained gases or vapors from the interior of a solid or porous material during exposure to vacuum pumping, often over a long time period.

Pallet. An external unpressurized platform for mounting telescopes, antennas and other instruments and equipment requiring direct space exposure for conducting science and applications activities on Space Shuttle Sortie missions; the pallet may be composed of segments.

Pallet coldplates. Stainless steel plates, 0.5m by 0.75m, that can be mounted on the inner pallet panels for dissipating thermal energy. Each plate can dissipate up to 1 kW.

Pallet element mode. A flight configuration in which one or more pallet segments, carrying self-contained experiments, may be mounted at any suitable location within the Orbiter payload bay, requiring no other Orbiter support. Pallet elements may be flown taking advantage of available volume and weight of any Shuttle flight.

Pallet panels. The inner and outer skins or coverings of the pallets, all of which act as structural members of the pallet structure. Instruments can be mounted on the inner skin panels.

Pallel-only-mode. A flight mode utilizing only the pallet, with subsystem support from the Orbiter and/or from igloo mounted subsystem equipment. Pallet only flights shall have the same Orbiter resources interfaces as the module/pallet flights.

Part. A piece of equipment that cannot be further disassembled without destroying its usefulness.

Principal investigator. A scientist responsible for establishing scientific mission objectives and instrument operation, and fc. scientific data analysis.

Prototype. A Spacelab unit, built to flight configuration definition, that differs from the flight unit only with respect to its testing history.

Qualification. Determination that an article or material is capable of meeting all design and performance requirements established for the item. An item can be qualified by test, by analysis, or by similarity to a qualified item.

Racks. Removable/reusable assemblies that provide structural mounting and connects to supporting subsystems (power, thermal control, data management, etc.) for experiment equipment which is housed in the pressurized module.

Remote acquistion unit. A unit that is a part of the CDMS that is capable of interfacing with payload instruments and other equipments. Interface signals transmitted may be of analog, discrete on-off or serial digital bit stream types.

Remote manipulator system (RMS). A manipulator system providing one manipulator arm stowed inside the payload bay but outside the Spacelab dynamic envelope. A second arm can be provided, if required, but will be weight chargeable to the Orbiter payload.

Residual-hazard. Hazard for which safety or warning devices and/or special means or procedures have not been developed or provided for counteracting the hazard.

Safe-life. A design philosophy under which failure or abort will not occur because of undetected flaws or damage during the service life of the vehicle; also, the period of time for which the integrity of the system can be ensured in the expected operating environments.

Scientific instrument. A unit or assembly of hardware designed specifically for the generation of signal or stimuli or for the acquisition of scientific data. Also referred to as an instrument.

Shirt sleeve environment. An atmospheric environment habitable for men without protective pressure suits.

Shuttle interface equipment. Equipment facilitating the interfacing of Spacelab with the Shuttle Orbiter.

Shuttle Orbiter. The orbital flight vehicle of the Space Shuttle transportation system.

Shuttle Orbiter payload. Anything transported during the mission by the Shuttle Orbiter vehicle and not weight chargeable to the basic Orbiter. For Spacelab missions, the Shuttle Orbiter payload consists of the Spacelab with the Spacelab payload, crew, consumables, and all Orbiter payload chargeable support equipment, whether installed in the payload bay or elsewhere in the Orbiter.

Shuttle Orbiter payload bay. A cylindrically shaped compartment inside the Orbiter of 18.288m (60 feet) length and 4.752m (15 feet) diameter for accommodation of payloads.

Small instrument pointing system. An accurate pointing system consisting of two instrument carrying canisters each supported at its center by a yoke which can rotate independently of the other canister. Greater than 2π field of views and ±90 degree roll capability is incorporated into the design.

Sortie flight. A short duration (nominally 7 days extendable up to 30 days) flight, which is conducted in low-earth orbit using the Shuttle Orbiter and equipment attached to it for experiments, observations and other space activities.

Spacelab. A laboratory designed for space operations, composed of modules and pallets suitable for accommodating instrumentation for conducting research and application activities on Shuttle Sortie flights. On a given flight, the Spacelab configuration can be comprised of a module only, a pallet only, or a combination of a module and a pallet.

Spacelab payload. All experiments, experiment support equipment, and experiment required consumables, carried by Spacelab or elsewhere in the Orbiter, associated with Spacelab missions.

Software. All non-hardware items necessary to operate a computerized system, such as programs, instructions, subroutines, etc.

Subsystem. A collection of hardware capable of performing a major system function or related functions,

Testing. A sequence of activities and processes to determine, under real or simulated conditions, the capabilities, limitations, reactions, effectiveness, reliability or suitability of materials, parts, components, subsystems and systems.

User. The organization or individuals having responsibility for payloads installed in a Spacelab.

Warning. A condition where a hazard to crew safety will develop unless immediate remedial actions are taken.