Spacelab
NEWS REFERENCE

esa
european space agency

Rec'd 7 Nov. 1983

NASA
National Aeronautics and
Space Administration

Marshall Space Flight Center
14M983

SPACELAB NEWS REFERENCE
ERRATA SHEET

The following are changes to the joint NASA/ESA Spacelab News Reference.

Chapter 1.5: A Cooperative Venture

Paragraph 2, Sentence 3: Change to read "ESA states participating in the development of Spacelab are the member states Belgium, Denmark, France, the Federal Republic of Germany, Italy, The Netherlands, Spain, Switzerland and The United Kingdom and associate member state Austria.

Paragraph 2: Delete last sentence that begins with "Sweden did not ..."

Paragraph 4, Line 3: Replace "Spacelab epitomises" with "the Spacelab program epitomises."

Chapter 2.1: Historical Background

Paragraph 4, Line 6: Delete "signed in Paris in August 1973" and insert "which took effect on September 24, 1973."

Chapter 2.4: The Cooperative Venture

Paragraph 1, Line 8:" Delete the sentence beginning "Likewise, the European industrial consortium ."

Paragraph 2, Line 1: Replace "management of" with "coordination in."

Paragraph 2, Line 3: Change "makes" to "seeks" and "decisions" to "agreements."

Paragraph 2, Line 15: Replace "ESTEC" with "ESA."

Chapter 2.4, Page 2-8: Replace diagram with attached diagram.

Appendix E

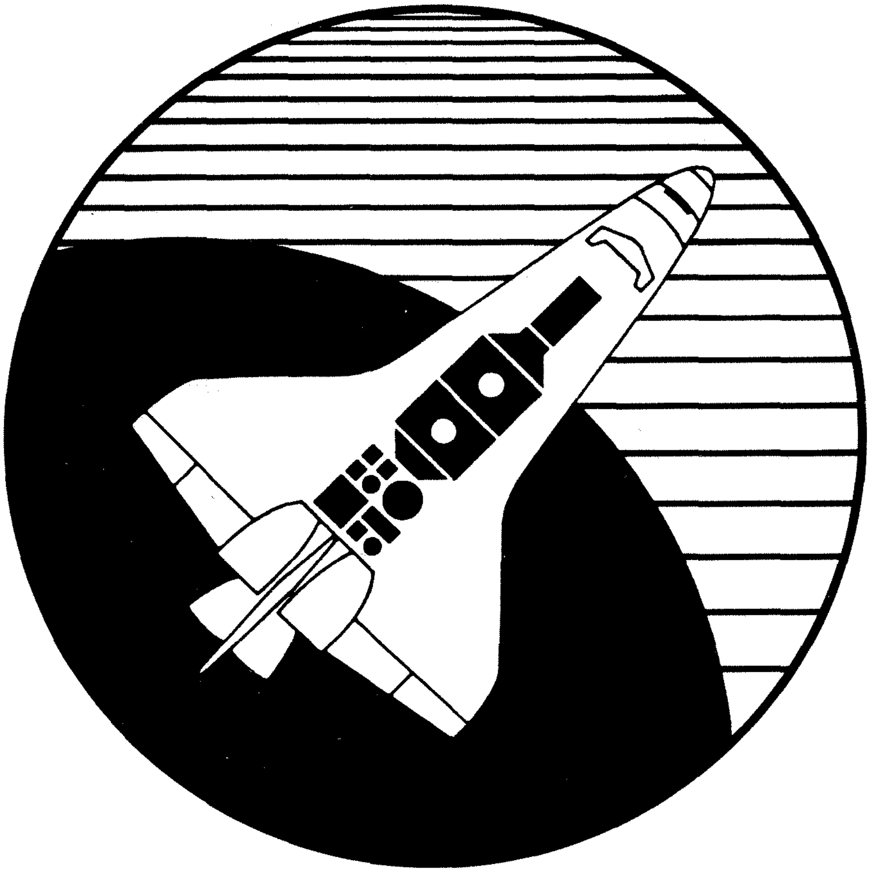
Page B-1: Replace "VFW-FOKKER ERNO" with "MBB-ERNO (previously VFW-FOKKER ERNO)."

Page B-1: Replace "Hawker Sidely" with "British Aerospace."

Page B-3: Replace "OKG" with "VFW" (replacing OKG).

Nov. 3, 1983

Spacelab
NEWS REFERENCE



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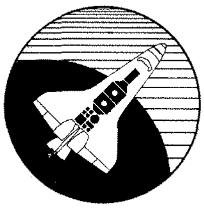
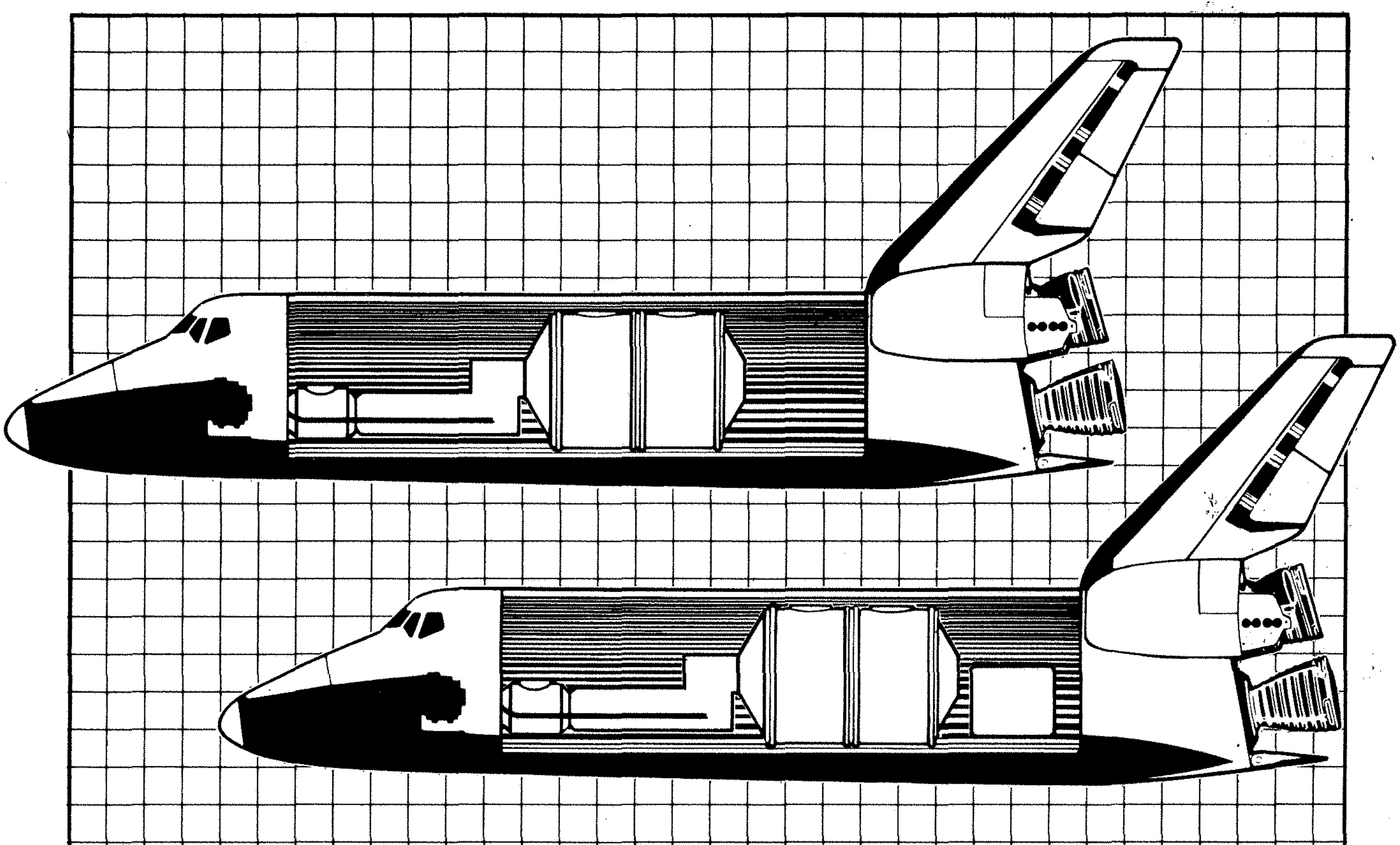
1. INTRODUCTION

Although space scientists have collected data from research satellites for more than two decades, one dream has been unfulfilled. Scientists want to tend their own experiments in space without having to become full-time astronauts or entrust their research to others. They also want to retrieve and refurbish experiment instruments and bring back laboratory specimens for further study. In Spacelab, this dream at last is realized. Spacelab converts the Shuttle into a versatile research center for scientists to use in space.



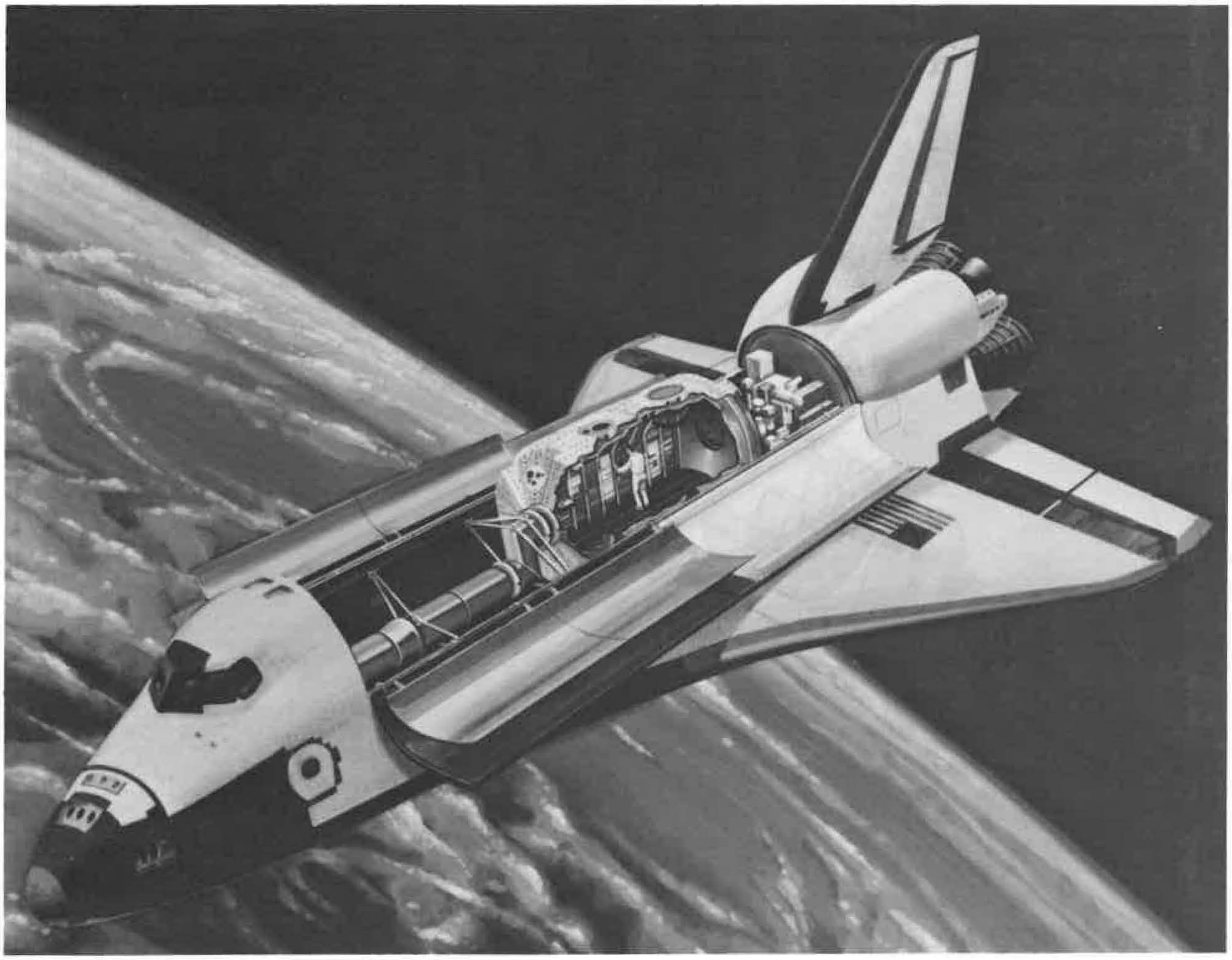


1. INTRODUCTION

1.1 Spacelab Elements

Spacelab is a modular laboratory system installed in the Space Shuttle orbiter and exposed to space when the cargo bay doors are opened. It consists of two elements: an enclosed, pressurized laboratory module containing utilities, computers, work areas and instrument racks for experiments; and unpressurized platforms, called pallets, where such equipment as telescopes, antennas and sensors are mounted for direct exposure to space. These units may be used separately or in various combinations, returned to earth, and reused on other flights. Spacelab can be outfitted with several tons of laboratory instruments for studies in astronomy, physics, chemistry, biology, medicine and engineering.

The habitable laboratory module consists of two segments, the core and the experiment segments, which can be used in a long configuration (both segments) or a short configuration (core segment only) to provide a shirtsleeve laboratory environment. The core segment contains all essential subsystems, and the experiment segment offers additional space for experiments. Scientists working in the module can handle equipment, react to unforeseen developments or data as experiments progress, accept targets of opportunity, change plans and even change the direction of their research in a way that cannot be achieved with remotely controlled payloads on satellites.

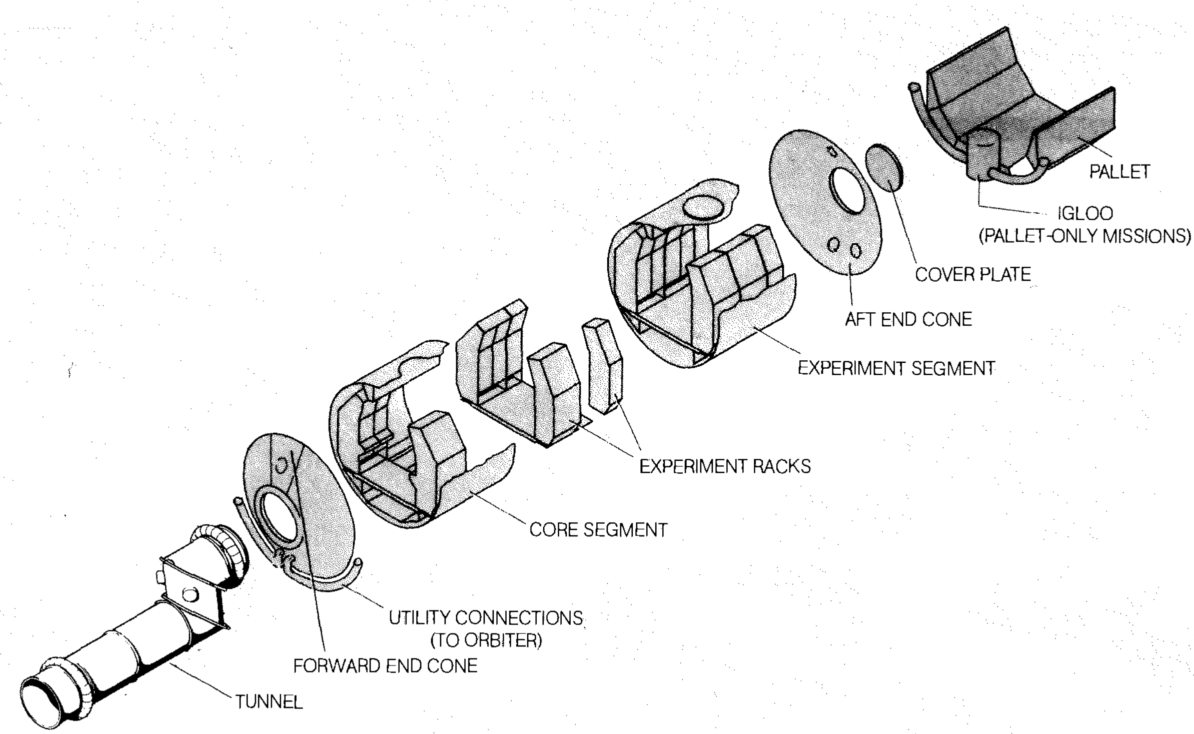


Spacelab in orbit

The other major element is the unpressurized pallet, a mounting platform for instruments or experiments that require open exposure to the space environment. As many as five Spacelab pallets can be flown in the cargo bay, individually or with two or three linked together in "trains." When pallets are used without a module, the subsystems necessary for experiment operation are contained in a pressurized cylinder or "igloo" mounted on the first pallet, and scientists operate the experiments from the aft flight deck of the Shuttle orbiter. If precise pointing is required by the payload, a pallet-mounted Instrument Pointing Subsystem (IPS) is available.

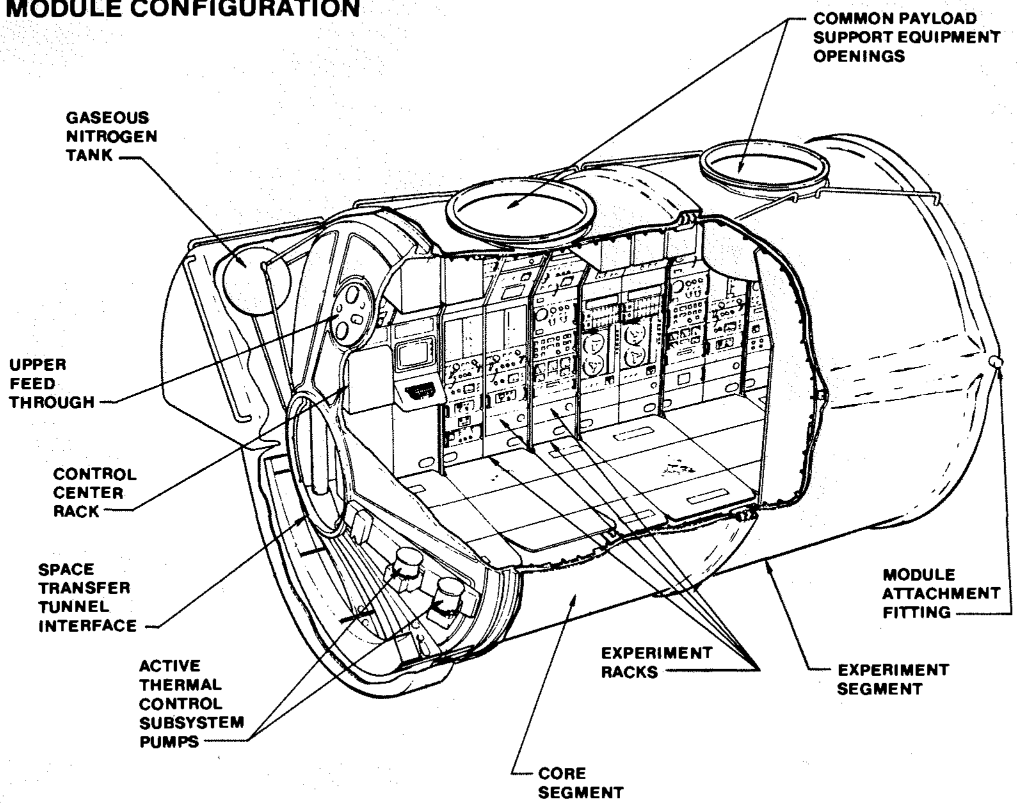
The module segments and pallets can be used in various combinations to suit the needs of particular missions. The habitable module may be flown alone or with one or more pallets. On missions that do not require an enclosed module, the pallets alone can be used. Several flight configurations are possible to support a variety of mission requirements in different scientific disciplines. The long module alone provides the largest pressurized volume for Spacelab experiments, while the five-pallet configuration provides the largest exposed payload platform. Pallet-only missions may carry from one to five pallets. Module-plus-pallet combinations providing both pressurized volume and exposed platform area include the short module with two or three pallets and the long module with one or two pallets.

Spacelab depends on the Shuttle; it can be used only inside the orbiter and sharing the orbiter's resources. The Shuttle provides Spacelab's transportation to and from space, vehicle attitude control and maneuvering capability, utilities service, crew living quarters and some storage area. The Shuttle-Spacelab combination serves, in effect, as a short-duration space station for scientific research.

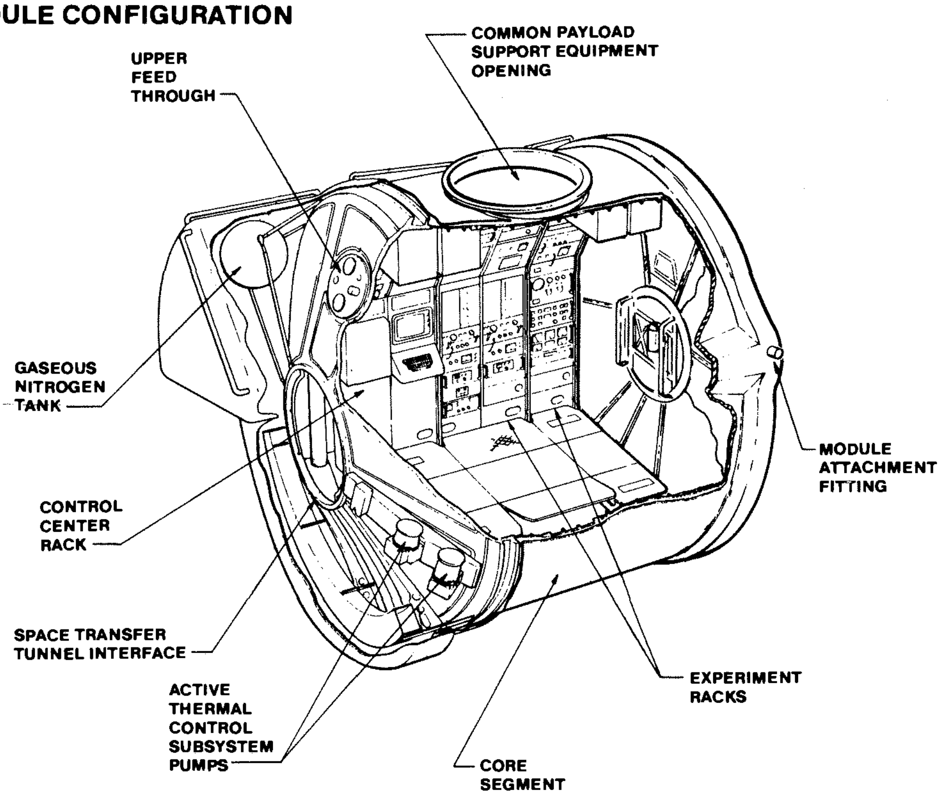


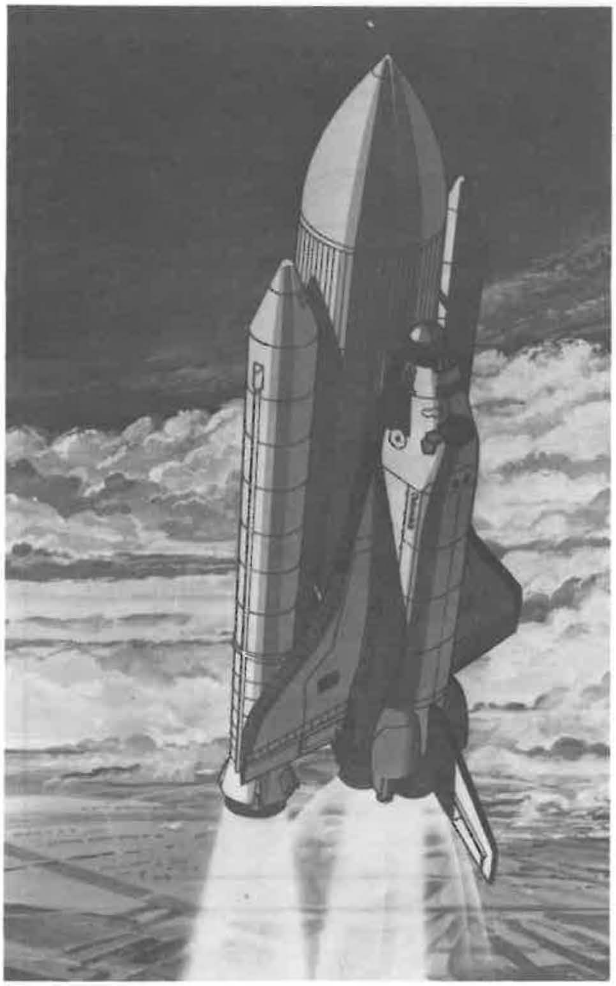
MAJOR SPACELAB ELEMENTS

LONG MODULE CONFIGURATION



SHORT MODULE CONFIGURATION






NASA
United States

1.2 Spacelab Mission Cycle

Spacelab's versatility as a multidisciplinary research center is invaluable to scientists; its availability to hundreds of experimenters is ensured by the fact that Spacelab can be used again and again, in different configurations to serve different research requirements. Like the Shuttle, Spacelab is designed for extended service.

On a typical mission, Spacelab is launched in the Shuttle, operated in orbit for up to nine days and returned to earth. Spacelab can be installed as the only cargo in the Shuttle on a dedicated mission, or Spacelab elements can share space with other items, such as deployable satellites, as part of a mixed cargo. Upon landing, Spacelab is unloaded and its modular components are serviced and refurbished for use on another mission. The recycling process thus allows repeated, economical use of this orbiting laboratory. A broad spectrum of scientific study is now possible in the readily reusable Spacelab.

1.3 Spacelab Science

As a laboratory in space, Spacelab offers unique opportunities for scientific research and scientific investigators. Until the advent of Spacelab, scientists did not have ready access to space; now researchers can do "hands on" experiments in a laboratory situated in the midst of space. They can also retrieve their valuable instruments for reuse on later missions.

The orbital environment offers many advantages for research in a broad range of disciplines: a global view of the earth below, an unobscured view of the heavens above, immersion in the magnetic and electric fields of space, and freedom from the effects of gravity. Biologists can study the effects of weightlessness on various organisms, from simple bacteria to the complex human body. Astronomers can observe the stars and planets with greater clarity and precision. Materials scientists can form stronger and purer metals and crystals and can create new composite materials. Space is full of potential as a new work environment for scientists.

Another distinct opportunity Spacelab offers is the active participation of scientific investigators. From the first stages of experiment development to the actual operation in orbit, scientists are involved in the Spacelab mission. Experiments are selected for flight on a competitive basis, and each is carried out under the aegis of a principal investigator. In orbit, the experiments are conducted by payload specialists onboard Spacelab but the principal investigators on the ground can monitor their experiments, communicate with the payload specialists, and in some cases operate the experiments by remote control. Thus, scientists can exercise onboard control of their investigations.

1.4 Spacelab Crew

Spacelab is designed for use by scientists and engineers who are not necessarily astronauts. In Spacelab, they gain the advantages of a space environment while working comfortably with equipment and in surroundings that are essentially like their laboratories on earth.

Spacelab crew working inside the laboratory module

To operate all the scientific instruments and experiments, the various Spacelab systems, and the orbiter typically requires a crew of six: a two-member Shuttle crew and a four-member science crew. The science crew is responsible for conducting all Spacelab experiments.

Of the four scientists, two or three are payload specialists selected to represent the investigators whose experiments are carried onboard. Sometimes principal investigators themselves may fly on a mission as payload specialists. Payload specialists are scientists who normally work in universities, industries, government agencies, or research institutes in the United States or in other countries. Their responsibilities are to operate the payload experiments and serve as test subjects for a number of biomedical investigations.

One or two other science crew members, the mission specialists who are astronauts from Johnson Space Center (JSC) in Texas, are responsible for the management of orbiter resources for Spacelab and for the operation of Spacelab subsystems supporting the scientific payload. They also provide considerable support in operating the experiments and performing any extravehicular activity (EVA) that may be required. The orbiter is flown by the commander and the pilot, both pilot astronauts from the astronaut corps at Johnson. The duty station of the Shuttle crew is the flight deck, the upper part of the front section of the orbiter.

For a continuous 24 hours-a-day Spacelab operation, the work program is divided into two shifts. The crew for each shift typically includes a payload specialist, mission specialist, and pilot astronaut. The daily cycle for each crew member is eight hours of sleep followed by 16 hours awake during which 8.5 to 10.5 hours of productive work can be expected. The daily cycle is arranged so that all crew members are awake together for sufficient time to allow briefings, updating of flight plans, and checklist reviews.

1.5 A Cooperative Venture

In 1973, the European Space Research Organization, which in 1975 became the European Space Agency (ESA), decided to develop a manned space laboratory as Europe's contribution to the United States' new Space Transportation System (STS). The Spacelab program has been a decade-long cooperative endeavor of the European Space Agency and the National Aeronautics and Space Administration (NASA).

ESA is responsible for funding, designing, developing, building and delivering Spacelab. An industrial consortium of some 50 industrial firms in 10 European countries participated in construction of the flight hardware. ESA ~~member~~ states include Belgium, ; France, Italy, the Netherlands, Spain, Switzerland, the United Kingdom and the Federal Republic of Germany, with Austria as an associate member. ~~Sweden did not participate in the construction of Spacelab.~~

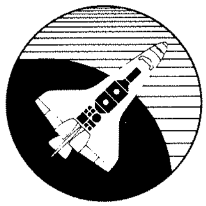
NASA is responsible for operating Spacelab as an integral part of the Space Transportation System. As manager of Spacelab missions, NASA has developed major new ground facilities at various field centers for Spacelab processing, crew training, operations control and data handling.

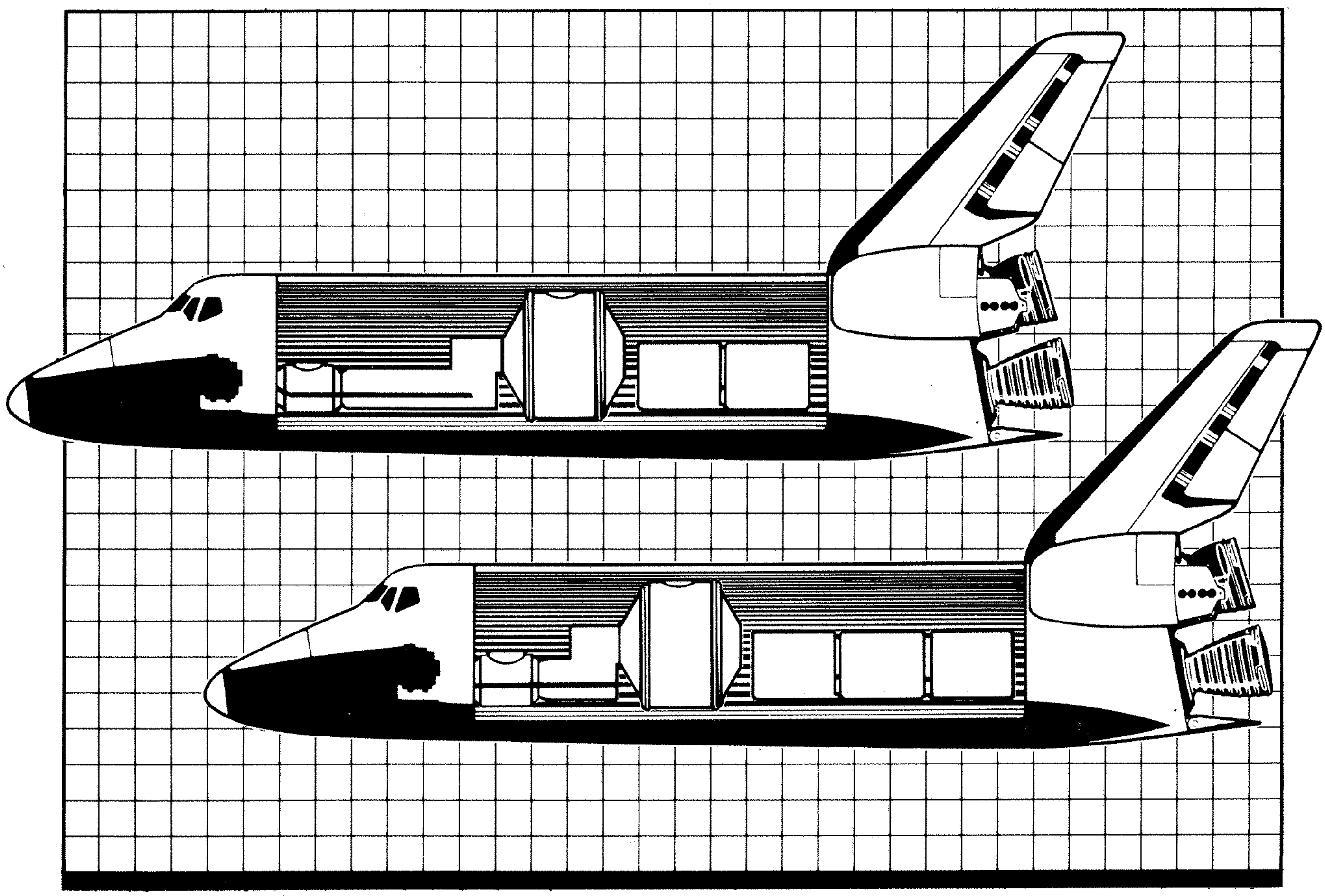
More than any other program in the history of the peaceful exploration and utilization of space, Spacelab epitomizes the fruitful results of international cooperation. New levels of political, technical and managerial cooperation have been established not only between the western European nations that designed and built Spacelab but also between ESA and NASA.

2. SPACELAB HISTORY, ORGANIZATION AND RESPONSIBILITIES

The Spacelab program is a cooperative venture between the European Space Agency (ESA) and the National Aeronautics and Space Administration (NASA) of the United States. A Memorandum of Understanding between the two agencies outlines specific areas of responsibility. ESA designs, funds, manufactures and delivers Spacelab; NASA operates Spacelab in the Space Shuttle. Spacelab is ESA's contribution to the Space Transportation System.

Technically and managerially, the Spacelab program has broken new ground in international communication and cooperation. The unique system of shared responsibilities devised for the Spacelab program has succeeded and is a proven model for future collaboration.





2. SPACELAB HISTORY, ORGANIZATION AND RESPONSIBILITIES

2.1 Historical Background

In 1969, Europe was invited by the United States to participate in the post-Apollo space program. The European Space Conference in 1970 authorized studies of a transportation system and various orbital systems. When the United States approved NASA's Space Transportation System in 1972, the program deemed most suitable for European collaboration was Spacelab. At the Ministerial Meeting of the European Space Conference in Brussels in December 1972, the European Ministers responsible for space entrusted the European Space Research Organization (ESRO), the predecessor of ESA, with the task of implementing the Spacelab Program as a special project.

During Phase A concept studies, close ties were established between ESRO and NASA at the working level with joint participation in payload group meetings and coordination of technical activities.

Phase B system-definition studies were carried out to provide ESRO member states with a firm costing on which to base their final choice among alternative design concepts. When that decision was made in August 1973, Spacelab became a confirmed ESRO program and an integral part of the Space Shuttle program.

The keys to this cooperative program were, and remain, two agreements: a Memorandum of Understanding between NASA and ESRO, and an Intergovernmental Agreement between the United States and nine participating European states. The Intergovernmental Agreement, signed in Paris in August 1973, delegates responsibility for the cooperative program to ESRO (later ESA) and NASA. The Memorandum of Understanding ~~was initialed in Paris in August 1973~~ and was signed by Dr. James Fletcher, NASA Administrator, and Dr. Alexander Hocker, ESRO's Director General, in September 1973 in Washington. It apportions responsibilities, specifies the deliverables associated with the program, and provides guidelines for the program elements.

which took effect on Sept. 24, 1973

The Memorandum assigns certain tasks to each agency and establishes the following major objectives of the cooperative program:

- Design, development, manufacture, and delivery of the first Spacelab flight unit as an element to be integrated with the Space Shuttle;
- Use of the Space Shuttle and Spacelab systems for peaceful purposes;
- Production and procurement of additional Spacelab flight units;
- Appropriate exchanges and interaction in the development and use of the Space Shuttle and Spacelab systems; and
- Possible extension of this cooperation as warranted by the mutual interests of the European partners and the United States.

Signature Ceremony for the Memorandum of Understanding

To ensure efficient execution of the principles of the Memorandum of Understanding, a Joint Spacelab Working Group (JSLWG) was formed. This group comprised representatives from ESRO and NASA and was co-chaired by the ESRO Head of Spacelab

Program and the NASA Spacelab Program Director. In essence this cooperative and joint method has remained in effect throughout the decade since it was first devised. The users' requirements were provided to this working group by the Joint Users Requirements Group (JURG), which no longer meets.

In 1974, the Spacelab Program entered the design and development phase, and ESRO awarded a six-year contract for the development of Spacelab to a European industrial team led by the German firm VFW-Fokker/ERNO. At that time, Spacelab became the largest joint space program undertaken by Europe and the United States. ESA's Spacelab development management team was located at the European Space Technology Center (ESTEC) in Noordwijk, the Netherlands.

By 1975, ESRO had taken on a new shape and name as the European Space Agency (ESA). Within ESA, Spacelab became a directorate, and a Director of Spacelab Program was appointed. Major progress was made on the definition of the first Spacelab payload, a joint European/United States venture with experiments and crew to be provided from both sides of the Atlantic.

The establishment of the Spacelab Payload Integration and Coordination in Europe (SPICE) team at Porz-Wahn, Germany, in 1976 further strengthened the belief in a concerted European effort for the utilization of Spacelab.

Meanwhile, NASA Headquarters designated Marshall Space Flight Center (MSFC) in Alabama as its lead organization for monitoring Spacelab development and managing the first missions. Marshall began work on a tunnel to connect Spacelab to the orbiter crew compartment. Other NASA installations also began a major effort to develop facilities for processing and integrating Spacelab hardware, crew training, data processing, and mission operations and control.

The first European payload specialists were chosen in 1977 and the first American payload specialists in 1978. Meanwhile, steady technical progress in Spacelab development continued as the Spacelab Utilization Program was inaugurated in Europe and an agreement was reached on the funding of the first Spacelab payload, jointly developed by NASA and ESA.

Both the Shuttle and Spacelab met with technical and financial challenges during the next two years, and there were inevitable delays in the program. However, in 1980, the engineering model of Spacelab was handed over to NASA, and NASA demonstrated its acceptance of Spacelab by ordering a second Spacelab flight unit.

Events moved with greater speed in 1981. An engineering model of the pallet, equipped with U.S. developed subsystems and experiments, became the first orbiter payload and the first Spacelab component to fly when it was included in the second Space Shuttle flight in November 1981. The first flight unit of Spacelab (Configuration I, module and one pallet) was formally accepted by ESA and NASA and was shipped to NASA's Kennedy Space Center (KSC) in Florida. The launch date for the first Shuttle flight wholly dedicated to Spacelab was set for the fall of 1983 on STS-9.

In the course of Spacelab's history, senior management in ESA and NASA monitored progress through several principal milestones:

- The Preliminary Requirements Review (PRR) in 1974 established a conceptual baseline for subsequent reviews and gave preliminary approval to higher level system specifications and plans.
- The System Requirements Review (SRR) in 1975 updated the system requirements and served as a start for the final subsystem definition and design phase.
- The Preliminary Design Review (PDR) in 1976 was a technical review of the basic design approach, leading to authorization for the engineering model design and manufacture.
- The Critical Design Review (CDR) in 1978 formally established the production baseline for the first flight unit.
- At the Final Acceptance Review (FAR) in 1981, ESA formally accepted the Spacelab module flight unit and two pallets from ERNO and NASA accepted them from ESA.
- At the Final Acceptance Review (FAR) in 1982, ESA formally accepted the flight units of the Spacelab igloo and three more pallets from ERNO and NASA accepted them from ESA.
- The Design Certification Review (DCR) was completed in the United States in 1983; senior management from NASA, ESA and their prime contractors certified the flightworthiness, safety and specification compliance of Spacelab.

A number of Spacelab activities culminated in 1982. Flight Unit Configuration I was formally accepted by

NASA in February in an unveiling ceremony attended by George Bush, Vice-President of the United States. In March, the second engineering model pallet, also equipped with U.S. developed subsystems and experiments, flew successfully on the Space Shuttle's third flight. Flight Unit Configuration II (igloo and pallet only) was delivered, and the European part of the first Spacelab payload was shipped to Kennedy. Meanwhile, NASA and ESA teams were preparing Spacelab and its first payload for a fall 1983 launch, and a second production model of the Instrument Pointing Subsystem (IPS) was ordered by NASA.

2.2 Responsibilities of ESA

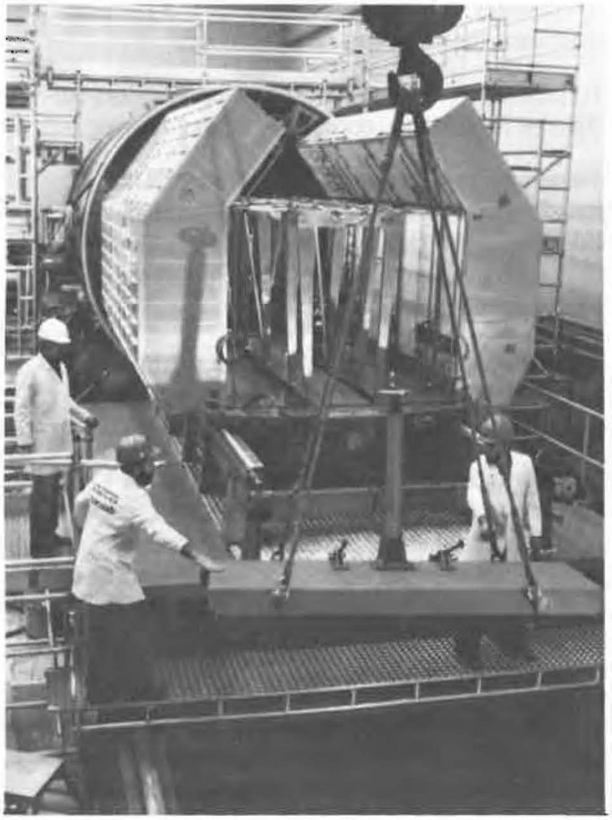
Representing the European Partners, ESA has the following responsibilities:

- To fund, design, develop, manufacture and deliver a Spacelab and associated equipment according to mutually agreed specifications and time schedule;
- To establish in Europe the production capability to ensure that the United States can procure additional Spacelabs, components and spares at reasonable prices;
- To ensure a sustained engineering capability to meet the Spacelab mission operating requirements of the United States; and
- To provide necessary contingency arrangements for the production of Spacelabs, components, and spares in the United States in the event that the European partners fail to meet these responsibilities.

More specifically, the tasks undertaken by ESA include the definition, design to jointly established requirements, development, manufacture, qualification, acceptance testing and delivery to NASA of one Spacelab flight unit, one engineering model, two sets of ground support equipment, initial spares, and documentation. Subsequent flight units and associated equipment are procured by NASA in Europe at a negotiated price.

The main items designed, developed, and manufactured are pressurized modules, pallets, igloo, instrument pointing subsystem, ground support equipment, payload support equipment, interface equipment and associated software. The program also includes planning for ground operations, experiment integration, checkout, test and maintenance, and planning for flight operations, including mission control, crew training and data management.

On the European side, two levels of responsibility are exercised: one by ESA and the other by ERNO, the prime contractor. ESA's role in the Spacelab program is that of overall project management. ESA defines all applicable project requirements and interfaces with the Spacelab payloads, the Shuttle orbiter, the experiment integration facilities, and the pre- and post-launch operations facilities. ESA also establishes and keeps up-to-date all relevant documents, coordinates activities with NASA and ensures that agreed upon NASA/ESA requirements are provided to the contractor. Furthermore, ESA provides direction to the contractor, reviews and monitors the various stages of the work, and eventually accepts the end products.



Construction of Spacelab elements at ERNO

The prime contractor organizes the work through a number of co- and subcontractors. The complexity of the operation can be judged by the industrial team organization given in detail in the appendix. There are 10 co-contractors and 36 subcontractors. The prime contractor ensures that all are aware of the latest technical information, design requirements and agreements. The prime contractor also monitors progress, advising and directing to meet critical reviews, test and integration dates, and supervises the financial arrangements involving several different currencies.

Although NASA is responsible for the operation of Spacelab, certain technical support tasks remain for ESA within the overall operational plan, and especially during the early flights. ESA integrated the European part of the payload for the first Spacelab mission. Additionally, ESA provides a sustaining engineering capability for Spacelab hardware through the first two missions.

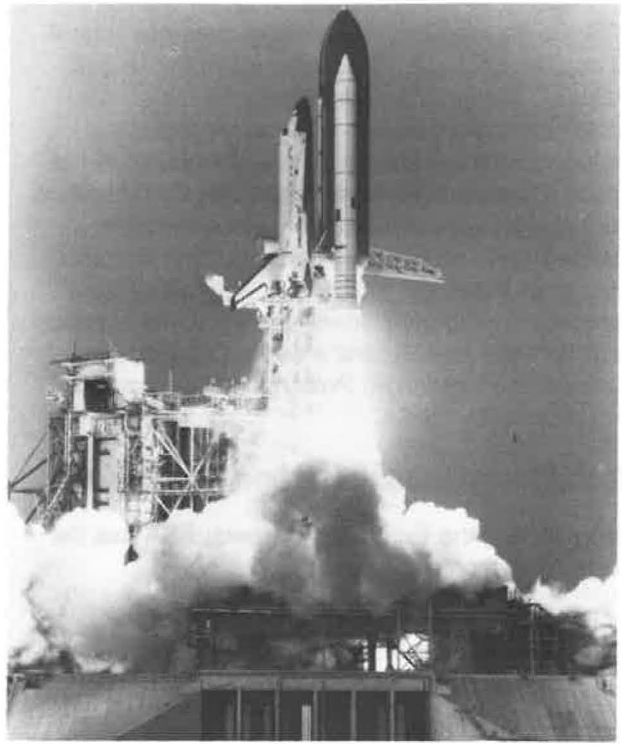
2.3 Responsibilities of NASA

As its part of the cooperative program, the Government of the United States, represented by NASA, has the following responsibilities:

- To provide information and advice;
- To provide assistance, technology, and hardware as mutually deemed necessary for the development and manufacture of Spacelab;
- To procure only from the European Partners additional Spacelabs, components and spares;
- To refrain from separate and independent development of any Spacelab substantially duplicating the design and capabilities of the first Spacelab (unless the European Partners fail in their responsibilities);
- To use Spacelab as an integrated element in the Space Transportation System for the peaceful exploration and use of space; and
- To inform the European Partners of plans for future use of the Space Shuttle system, especially of future concepts that may lead to modifications of the present Spacelab, with a view to extending cooperation beyond the present agreement.

In addition, the United States is responsible for developing, building, and operating the Shuttle, and making it available for European use on either a cooperative (no-cost) or cost reimbursable basis. The agency is also responsible for all operational activities once Spacelab is delivered and for management of NASA-sponsored Spacelab missions. These activities include experiment integration and checkout, Spacelab integration and checkout, launch operations, crew training, verification flight tests and instrumentation, flight operations, post-flight processing and refurbishment, data acquisition, preliminary data processing and distribution of data.

To verify the performance capabilities of Spacelab and its compatibility with the Shuttle orbiter, NASA designed, developed and installed special in-



strumentation in Spacelab to support Verification Flight Tests (VFT) on the early missions. The Verification Flight Instrumentation (VFI) included sensors, gauges, monitors, and a data system for evaluating Spacelab performance and measuring the induced environment around Spacelab.

The NASA organization to integrate Spacelab with the Space Shuttle and operate it includes the following entities:

The **Office of Space Flight** at NASA Headquarters, Washington, D.C., has overall responsibility for the Space Transportation System. The following divisions are responsible for Shuttle and Spacelab operations:

> The *Spacelab Division* is responsible for the interface between Spacelab and the Shuttle. The Spacelab Division also is responsible for monitoring the European development work; managing the development by NASA of peripheral components necessary for the successful operation of Spacelab; managing the development of necessary operational facilities at Marshall, Johnson and Kennedy centers and managing operations and payload support.
>
> The *Customer Services Division* is responsible for pricing, manifest (flight allocations) and utilization of Space Transportation System (STS) resources, including Spacelab. Like the Shuttle, Spacelab is available to STS customers.

The *Space Shuttle Operations Office* is responsible for the orbiter, propulsion, solid rocket boosters and external tank, logistics, and all flight and ground operations and payload support.

The **Office of Space Science and Applications, Spacelab Flight Division**, at NASA Headquarters is responsible for planning and implementing NASA-sponsored Spacelab payloads.

The **NASA Marshall Space Flight Center (MSFC)** in Huntsville, Alabama, which is responsible for the development, production and delivery of the Space Shuttle main engines, the solid rocket boosters, and the external tank, has responsibility for two separate Spacelab activities:

- Spacelab development related work, including the development by NASA of peripheral components, such as the transfer tunnel and the vertical access kit, necessary for the successful operation of Spacelab; technical and programmatic monitoring of the Spacelab design and development work in Europe; provision of technical expertise in support of ESA; and provision of payload support and verification flight testing of Spacelab during its first missions.

- Management of the payloads for the first three Spacelab missions; the first Spacelab mission is a cooperative venture by ESA and NASA, including joint experiment selection and development of the experiment integration and testing requirements.

The **NASA Johnson Space Center (JSC)**, near Houston, Texas, which is responsible for the development, production and delivery of the Shuttle orbiter, is also responsible for all Shuttle flight operations, including Shuttle flight planning, training of astronauts for manned space flights, and the control and monitoring of Space Shuttle flights from lift-off until completion of the landing. Furthermore, Johnson is responsible for managing Spacelab 4, the fifth dedicated Spacelab mission. (The fourth dedicated Spacelab mission, called D-1, is managed by Germany.)

The **NASA Kennedy Space Center (KSC)** at Cape Canaveral, Florida, is responsible for the Shuttle launch and recovery facilities, pre-launch checkout and launch of the Space Shuttle and its payload, and ground turnaround and support operations, including the development of Spacelab processing facilities, ground operations management, and all launch operations until completion of lift-off.

The **NASA Goddard Space Flight Center (GSFC)** at Greenbelt, Maryland, is responsible for receiving, monitoring, processing, and distributing science and engineering data from Spacelab payloads. Goddard also manages the Tracking and Data Relay Satellite System (TDRSS) and the NASA Communications Network (NASCOM), which provide voice and data communications links between the Spacelab Data Processing Facility and the rest of the Spacelab data network.

During the design and manufacturing phases, NASA teams monitored the Spacelab development controlled by ESA in order to ensure Shuttle/Spacelab compatibility and to have the necessary depth of knowledge to operate Spacelab, integrate the experiments into Spacelab, and then integrate Spacelab into the Space Shuttle system.

2.4 The Cooperative Venture

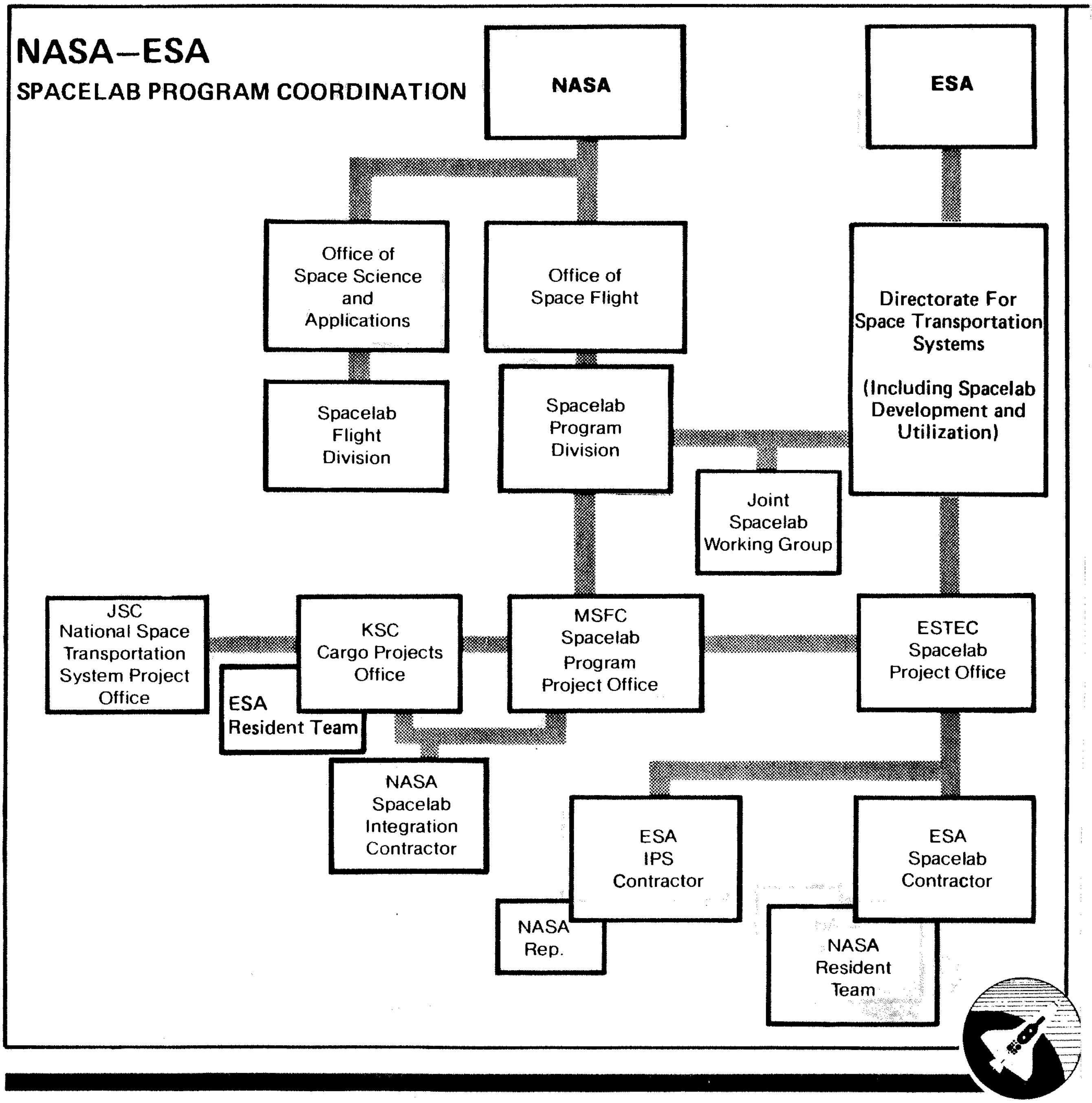
The need for joint consultations and joint decision-making processes and for a real visibility of progress was agreed upon early in the discussions between NASA and ESA. At the same time, the scientists on both sides of the Atlantic who would be flying experiments needed to be kept informed of decisions and to convey their requirements. ~~Likewise, the European industrial consortium had to be informed of NASA/ESA decisions and requirements.~~ Therefore, in 1973, a unique management relationship was implemented; in essence, this cooperative management scheme remains effective after 10 years in practice.

A key element in the ~~management of~~ the Spacelab program is the Joint Spacelab Working Group (JSLWG), which ~~makes~~ top-level (Level I) ~~decisions~~ that affect the interest of both agencies. The Spacelab Programme Requirements (Level I) documents the basic requirements for the Spacelab program established by the joint working group and is the highest level control document for all Spacelab activities. The Joint Program Plan for Spacelab describes initial working arrangements, phasing, schedules, and resources for executing the program; it has been supplemented by many other more detailed plans. The decisions made and plans approved at Level I are then put into practice at Level II – the program offices at ~~ESTEC and~~ NASA – and so on down the levels of responsibility similar to most other aerospace programs.

Much emphasis is placed on stringent documentation control, without which a program of Spacelab's complexity would quickly disintegrate. United States and European documentation had to mesh at various levels. Guidelines established jointly early in the program (1974) enabled the massive flow of documents to be handled and acted upon in a timely manner.

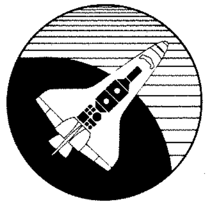
The definition of payloads to be carried by Spacelab for the first mission was a joint U.S./European responsibility involving cooperative planning. Payload development, however, was assigned to various agencies.

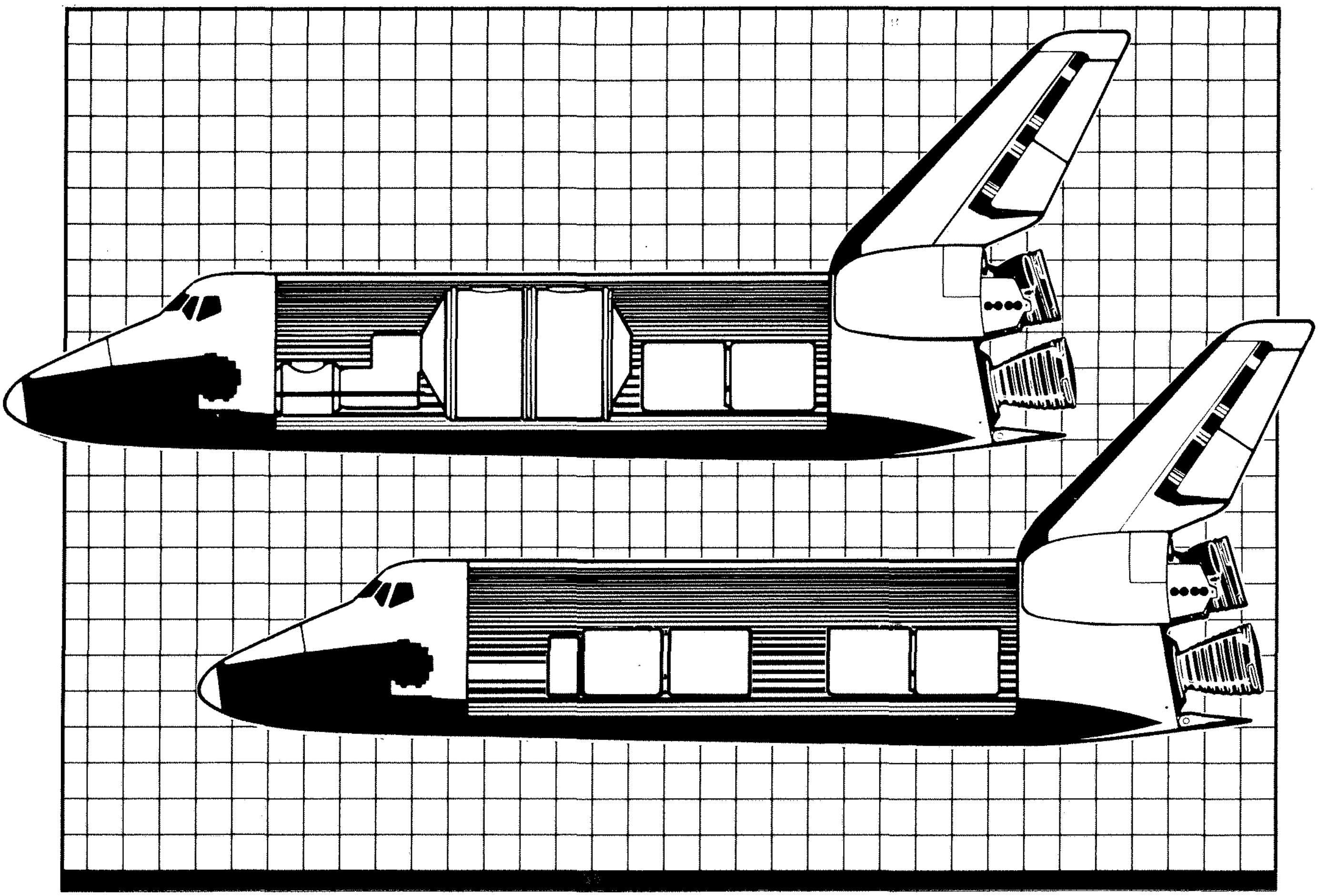
Throughout the design and development process, the two agencies have interacted to meet such common objectives in the Spacelab program as versatile laboratory facilities, rapid user access, and minimum interference with Shuttle turn-around activities. Operational concepts influenced the design and construction of Spacelab elements to ensure that the experiment cycle, Spacelab cycle and Shuttle cycle of operations would interlock smoothly. Just as Shuttle development impacted Spacelab design, so did Spacelab design affect the Shuttle concept. During the decade of development leading to Spacelab's first flight, NASA and ESA have worked cooperatively toward the realization of this integral component of the Space Transportation System. The pattern exists for further cooperation in utilizing Spacelab to its full potential.



3. TECHNICAL DESCRIPTION

Spacelab is assembled from many interrelated and interchangeable parts. This chapter describes the major components and subsystems that constitute Spacelab. It includes descriptions of the physical features of the various elements, their functions and their locations within Spacelab.





3. TECHNICAL DESCRIPTION

3.1 Module

The Spacelab habitable module is the scientist's laboratory in orbit. It is a pressurized compartment that provides a safe shirt-sleeve environment in which science crew members can conduct their experiments.

In addition to providing the room in which scientists can work, the module provides several pieces of standard equipment of the kind that would be found in a laboratory on earth. It also provides additional equipment designed to enable scientists to take best advantage of the unique environment of space to conduct their research.

3.1.1 MODULE STRUCTURE

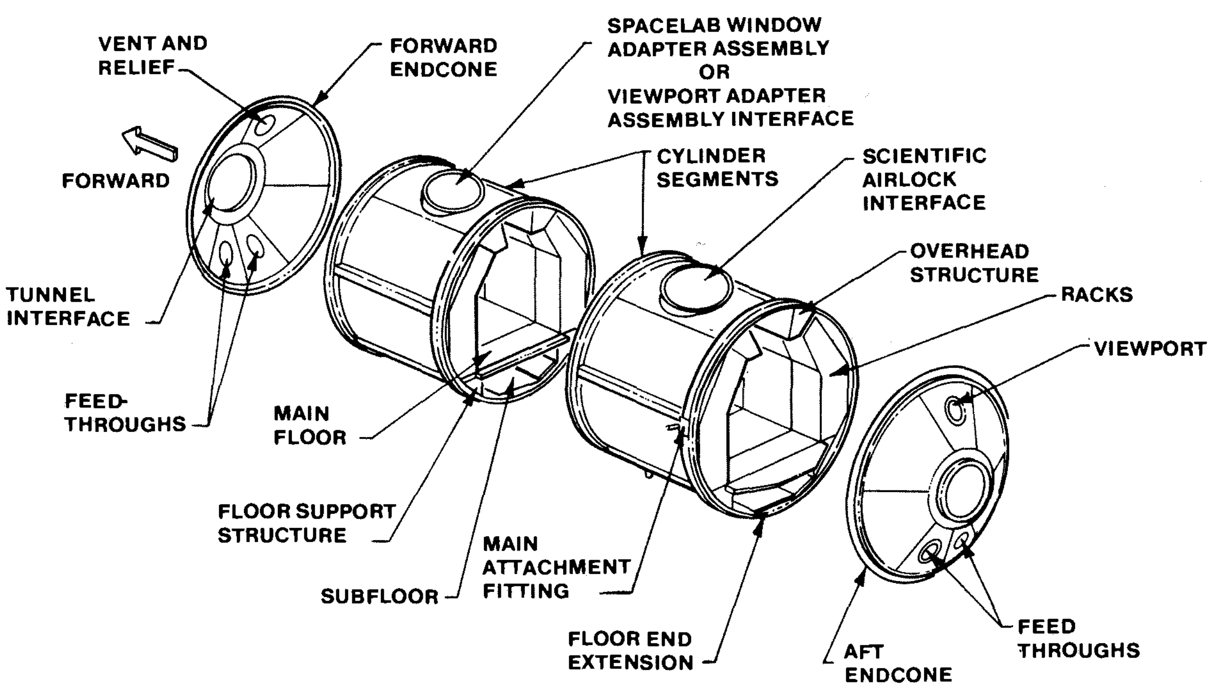
The module consists of either one or two cylindrical segments closed off at each end by conical sections called end cones. The compartment can be shortened or lengthened depending upon the scientific requirements of a particular mission. The short module consists of only one cylindrical section – the core segment – and the forward and aft end cones. The long module consists of two sections – the core segment and experiment segment – and the end cones. The module can be mounted at various locations in the orbiter cargo bay, and is connected to the crew compartment of the orbiter by a passageway called the Spacelab Transfer Tunnel.

The module is designed to accommodate a positive pressure differential up to 1.1 bar (15.9 psi) and a negative pressure differential of 34 mbar (.5 psi).

3.1.1.1 Primary Structure

The primary structure includes the module cylinder segments and end cones, which form the laboratory shell; the module floor support structure and overhead support structure; and the fittings by which the module is structurally attached to the orbiter.

MODULE STRUCTURE



Cylinder Segments

The two cylindrical sections that make up the core and experiment segments of the module are identical in size, shape, and composition. Each is a 4.06 m (159.1 in.) diameter shell, that is 2.7 m (106.07 in.) long. The ceiling skin panel of each segment contains a 1.3 m (51.2 in.) diameter opening for mounting Common Payload Support Equipment such as the Viewport Adapter Assembly, Spacelab Window Adapter Assembly, and the Scientific Airlock. When Common Payload Support Equipment is not used, the openings are closed with cover plates which are bolted in place.

The shell itself is made from 2219-T851 aluminum plate panels that have been machined and roll formed. Each panel has an integrally machined waffle pattern. Eight individual panels are butt-welded together to form the shell of each module segment. The shell ranges in thickness from .16 cm (.06 in.) to .35 cm (.14 in.).

At the ends of each shell segment are rings machined from aluminum roll ring forgings. Each ring is 24.05 cm (20 in.) long and 4.1 m (195.8 in.) in diameter at the outer skin line. The rings are butt-welded to the skin panels of the shell.

Each cylinder shell segment incorporates provisions for mounting the orbiter attachment fittings, end cones, floor support structure, overhead support structure and subfloor.

End Cones

The forward and aft end cones are bolted to the cylinder segments to complete the laboratory shell. The end cones are 78.2 cm (30.8 in.) long truncated cones. The large end of the cone is 4.11 m (161.9 in.) in diameter, and the small end is 1.3 m (51.2 in.) in diameter.

The structure consists of six aluminum skin panels butt-welded to each other and to the two end rings. The panels are machined from 2219-T851 aluminum plate and the end rings are machined from aluminum roll ring forgings.

Each cone has three 40 cm (16.4 in.) diameter cutouts, two located at the bottom of the cone and one at the top. Feedthrough plates, for routing utility cables and lines, can be installed in the lower cutouts of both end cones. The Spacelab viewport assembly can be installed in the upper cutout of the aft end cone, and the upper cutout of the forward end cone is for the vent and relief valve. When cutouts are not used, they are closed off by cover plates which are bolted in place.

The Spacelab Transfer Tunnel connects to the 1.3 m (51.2 in.) diameter opening in the forward end cone. The opening in the aft end cone is closed off by a blanking plate, which is bolted in place.

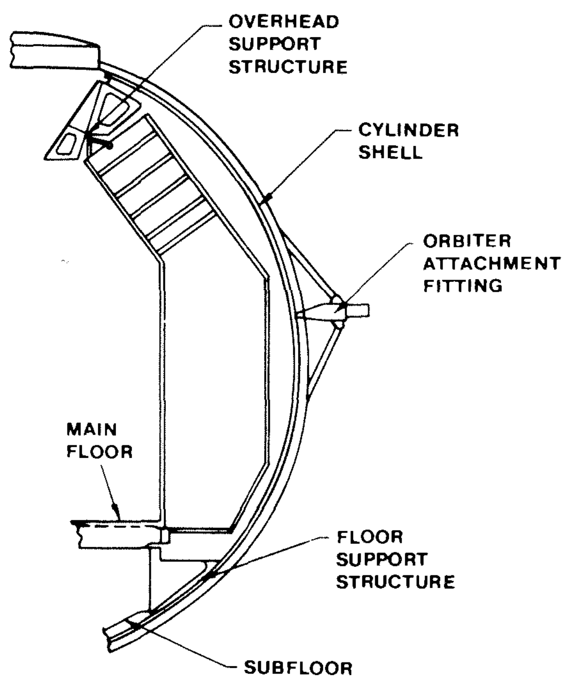
Seal Assemblies

To form a pressure-tight facility, module shell components are joined by Gask-O-Seal assemblies. The seals consist of double butyl seals molded onto an aluminum ring base. Clamping the ring flanges deforms the elastomer to fill the seal cavity and ensure airtightness.

Floor Support Structure

The floor support structure, on which the Spacelab main floor and experiment racks rest, consists of two triangular built-up beams. One beam extends the full length of each side of each cylinder segment. The beams are bolted to the cylinder end rings.

In addition to supporting the floor when it is installed, the floor support structure also provides a hardened track on which mechanical ground support equipment can roll the floor and racks in and out of the module during Spacelab integration. The racks and floor are normally integrated as a single unit and outfitted with experiments before they are installed into the module.



MODULE SUPPORT STRUCTURE

Overhead Support Structure

The overhead support structure has attachment provisions for experiment racks, overhead storage containers, Environmental Control Subsystem air handling ducts, handrails and lights.

The structure consists of two beams, one on each side of the module centerline. Each beam is actually two parallel beams, one quadrilateral in shape and the other triangular. They are bolted together to form a single continuous member. The quadrilateral beam is similar to the floor support segment. The triangular beam, however, is made in three sections, one of which can be removed when Common Payload Support Equipment such as the Viewport Adapter Assembly, Spacelab Window Adapter Assembly, or Scientific Airlock, is installed in the ceiling panel.

The beams are built-up riveted assemblies made of sheet aluminum and aluminum plate. Rack support struts are machined from titanium.

Orbiter Attachment Fittings

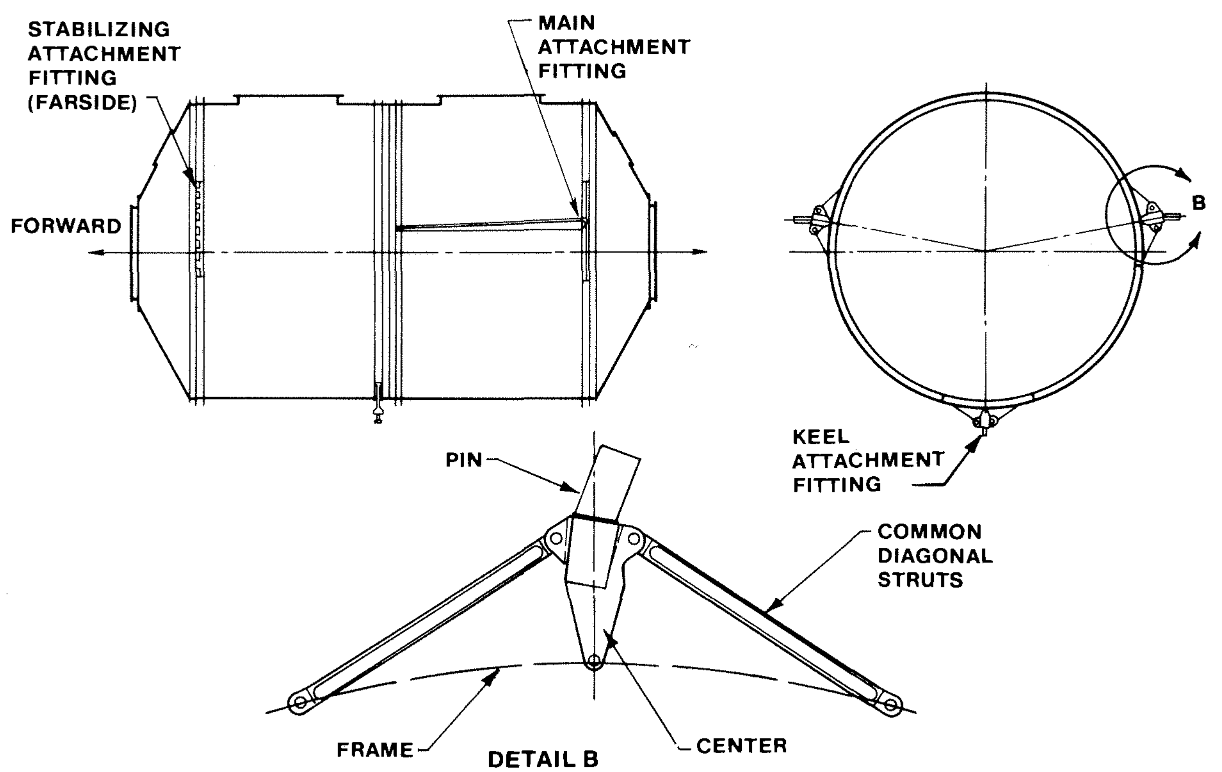
The Spacelab module is carried in the cargo bay of the Space Shuttle orbiter and is held in place by a set of four attachment fittings. A single set of three longeron fittings (two primary and one stabilizing) and one keel fitting is required for installing either the long or short module.

The longeron fittings anchor the module along the port and starboard sides of the cargo bay. The keel fitting anchors the module to the bottom centerline of the cargo bay.

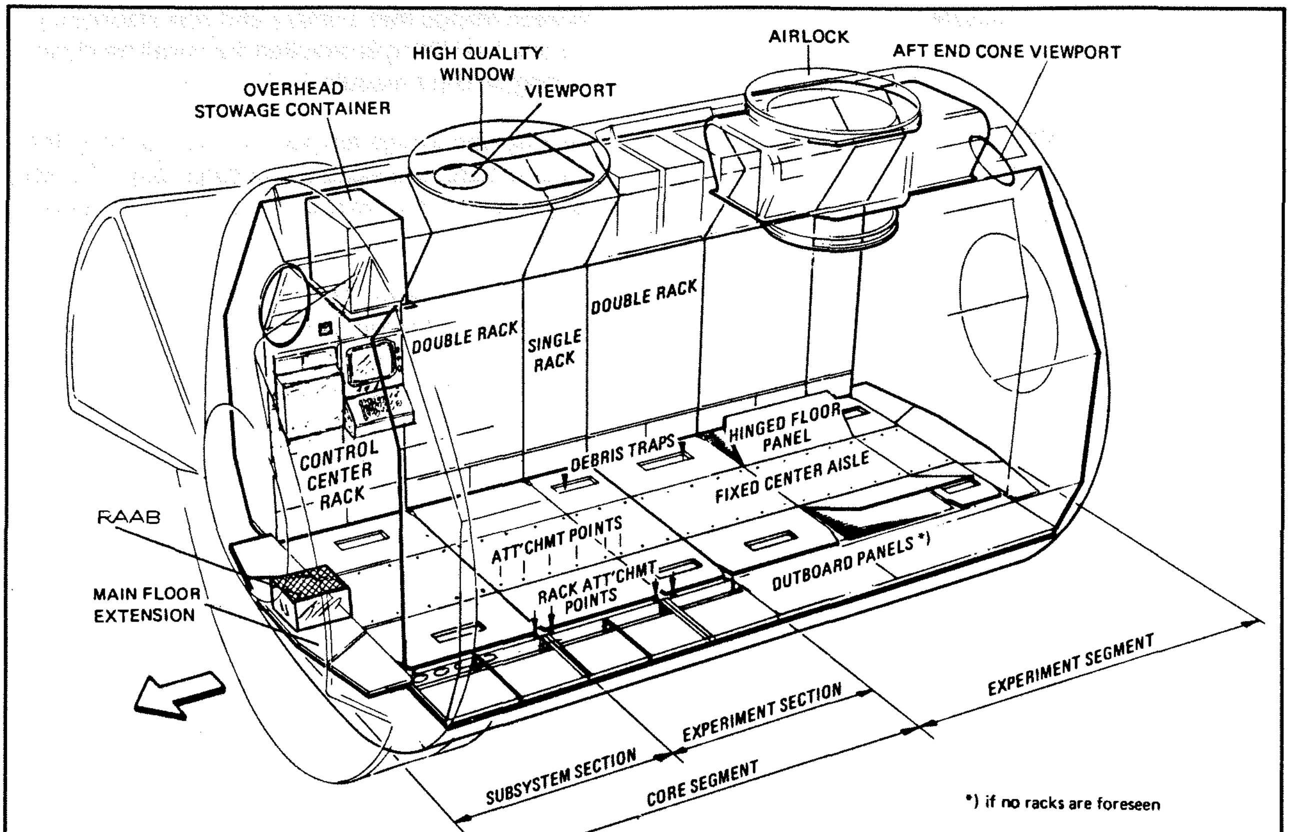
The fittings are attached to the rolled ring forgings of the module cylinder assemblies. The primary fittings are attached to the aft ring of either the short or long module, and the stabilizing fitting is attached to the forward ring of the module. The keel fitting, which is similar to the stabilizing fitting, is attached to the aft ring of the core segment.

The fittings consist of two common diagonal struts and a center post, all of which attach to the module. The physical interface with the orbiter is through an 8.25 cm (3.25 in.) diameter pin attached to the center post.

The fitting struts and center parts are machined from rough titanium forgings. The pin is chrome-plated Inconel. The various parts of the attachment fittings are joined with pins machined from stainless steel bars.



ORBITER ATTACHMENT FITTINGS



INTERNAL ACCOMMODATION LAYOUT

3.1.1.2 Secondary Structure

The module secondary structure is composed of the subfloor, the main floor and the racks.

Subfloor

The subfloor is situated beneath the main floor in both the core and experiment segments of the module. In the core segment, the subfloor provides structural support for Spacelab Environmental Control Subsystem and Electrical Power Distribution Subsystem components, which can be mounted to it. The subfloor in the experiment segment provides structural support for storage and for experiments that do not require Spacelab subsystem support.

The subfloor in each segment consists of three panels made of 5052 aluminum honeycomb core material with 2024-T81 aluminum face sheets bonded by adhesive. The panels are equipped with special inserts designed to accommodate screws for mounting subsystems and experiment equipment.

The subfloor is supported by the floor support structure beams and three longitudinal beams mounted to the segment shell. The subfloor panels are bolted to the beams.

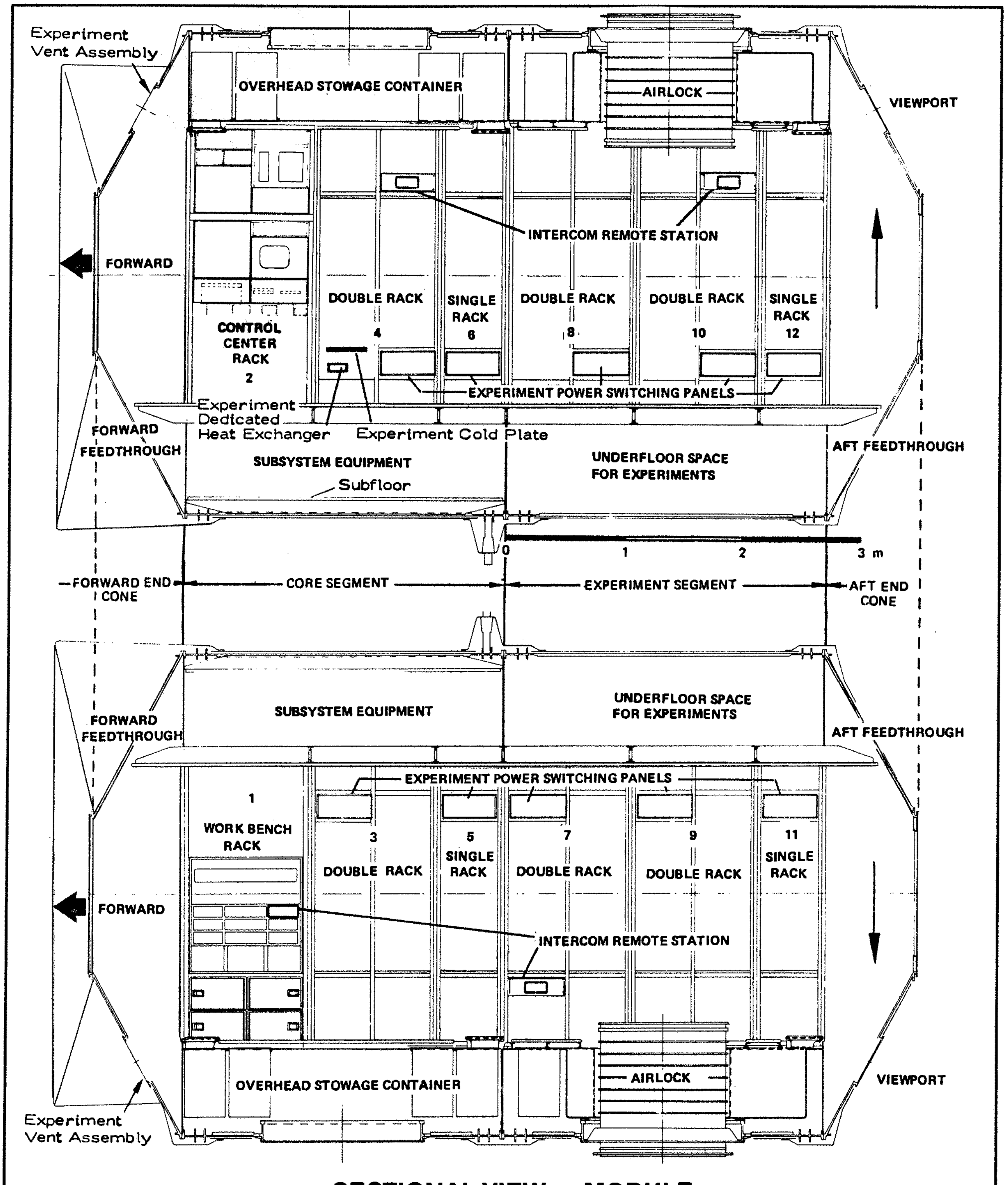
Main Floor

The main floor, which spans the width and extends the length of the module, provides support for experiment racks and non-rack mounted experiment equipment, a flat surface for crew activity on orbit, and a walking surface for technicians during ground processing. The floor also provides support for wire harnesses and subsystems equipment that may be mounted underneath it.

The main floor structure consists of a bolted framework of built-up aluminum beams covered by aluminum honeycomb core panels with anodized aluminum face sheets. Panels along the center of the module (the center aisle) are fixed, while the panels in front of the racks are hinged to allow access to the subfloor area. Side floor panels are also provided to cover openings left when experiment racks are not used. The floor provides rack attachment points and has provisions for mounting experiments on the center aisle panels.

The floor structure comes in short and long segments, which can be bolted together in different configurations for use in either the short or long module. The forward floor in the module core segment is called the subsystem floor. All other floor segments are called the experiment floor. Two short and two long floor segments are connected for use in the long module, and one short and one long segment are connected for use in the short module.

A tapering extension segment, designed to fit the shape of the end cones, is attached at each end of the floor. The floor structure is bolted to the floor support structure.



SECTIONAL VIEW — MODULE

Racks

Spacelab racks provide a universal support structure for experiments and Spacelab subsystems equipment. Racks come in either single or double widths. The single rack forms a framework for accepting laboratory-standard 48.3 cm (19 in.) panels on the front face of the rack. Double racks can accommodate payload equipment twice as wide. The double rack can be converted to the equivalent of two single racks by installing a rack center frame. The center frame is an open truss structure to facilitate direct cable routing between the two sections.

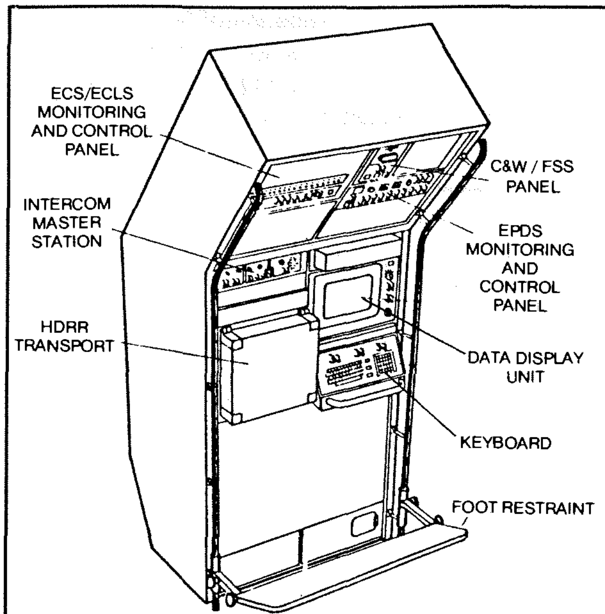
To accommodate experiments, up to two double racks and two single racks can be installed in the core segment of the module. Up to four double racks and two single racks can be installed in the experiment segment. Additionally, regardless of flight configuration, two double racks containing Spacelab subsystems equipment and controls and a general purpose workbench are installed in the forward portion of the core segment for each mission. Racks are always installed in "double-double-single" order from the forward end along each side of each segment.

The racks extend from the main floor to the overhead structure along each side of the module. They are bolted to the module structure at the floor, and attached by fittings to the overhead support structure. Each experiment rack is open at the front, has closed sides and removable back panels, and has a bottom panel with cooling duct cutouts. Each experiment rack has front panel attachment provisions as well as sets of standard hole patterns for attaching payloads to the rack structure at each corner post and at the rack sidewalls.

The racks are constructed from 7075-T73 aluminum and are assembled with rivets and threaded fasteners. The upper attachment fitting lugs are machined from 6AL4V titanium.

Control Center Rack

The Control Center Rack is a standard experiment double rack modified to accommodate subsystem controls. Several important components of the Command and Data Management Subsystem, including the High Data Rate Recorder, a Data Display Unit, keyboard, and Remote Acquisition Units, are located in the Control Center Rack. Standard Experiment Power Switching Panels, the electrical switches that deliver power to experiments, are found in the rack, as well as Environmental Control Subsystem equipment that monitors the atmospheric and thermal environment of the module. The Spacelab Caution and Warning/Fire Suppression System panel is also located in the Control Center Rack. The control center occupies the first forward rack on the starboard side of the module core segment.



CONTROL CENTER RACK

3.1.2 EXPERIMENT ACCOMMODATIONS

Within the Spacelab module, experiments can be accommodated in single and double experiment racks, in overhead and rack-mounted stowage containers, on the subfloor of the experiment segment, and along the center aisle of the main floor. Common Payload Support Equipment and additional experiment facilities can also be installed in the module to support scientific research.

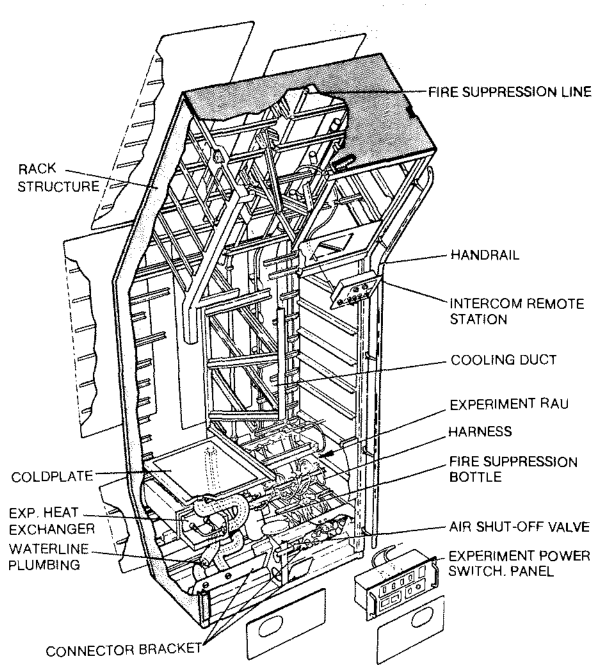
3.1.2.1 Experiment Racks

Experiment equipment can be mounted in standard single and double racks that can be installed along both sides of the Spacelab module.

Single racks have an available volume of .9 cubic meters (30 cubic feet) and can carry up to 290 kilograms (639.3 pounds). Double racks have an available volume of 1.75 cu. m (58.3 cu. ft.). They can carry up to 580 kg (1278.7 lb.) with the center frame inserted and 480 kg (1058.2 lb.) with the frame removed.

Rack-mounted experiments are served by Spacelab's Command and Data Management Subsystem, Electrical Power Distribution Subsystem, and Environmental Control Subsystem.

EXPERIMENT DOUBLE RACK



Experiments which cannot otherwise be accommodated may use module space provided for the racks. However, they must use the rack attachment points at both the floor and the overhead structure.

3.1.2.2 Center Aisle

The center portion of the Spacelab main floor (the center aisle) can accommodate experiment equipment mounted to the attachment points. Loading is permitted up to 300 kg/m (201 lb./ft.) of length over the .6 m (2 ft.) wide center aisle. Equipment mounted on the center aisle can be up to 1.5 m (59.05 in.) high at the rear end of the aisle, 64 cm (25.2 in.) high at the front end, and 60 cm (23.6 in.) wide.

Experiments mounted in the center aisle can be served by Spacelab's Command and Data Management Subsystem, Electrical Power Distribution Subsystem, and Environmental Control Subsystem. Cabin air may be used for cooling experiment equipment, but the necessary fans must be provided by the experimenter. Warm air from the experiments can be sucked through two round cutouts in the center aisle floor. Other cutouts provide access to the other Spacelab services.

3.1.2.3 Subfloor

Payloads may be accommodated under the main floor in the experiment section. Experiment equipment can be attached to the subfloor with screws.

The subfloor has a 300 kg/m (201 lb./ft.) loading capacity. A cross-section of the usable volume in the irregularly shaped area is 0.5 square meters (5.5 sq. ft.).

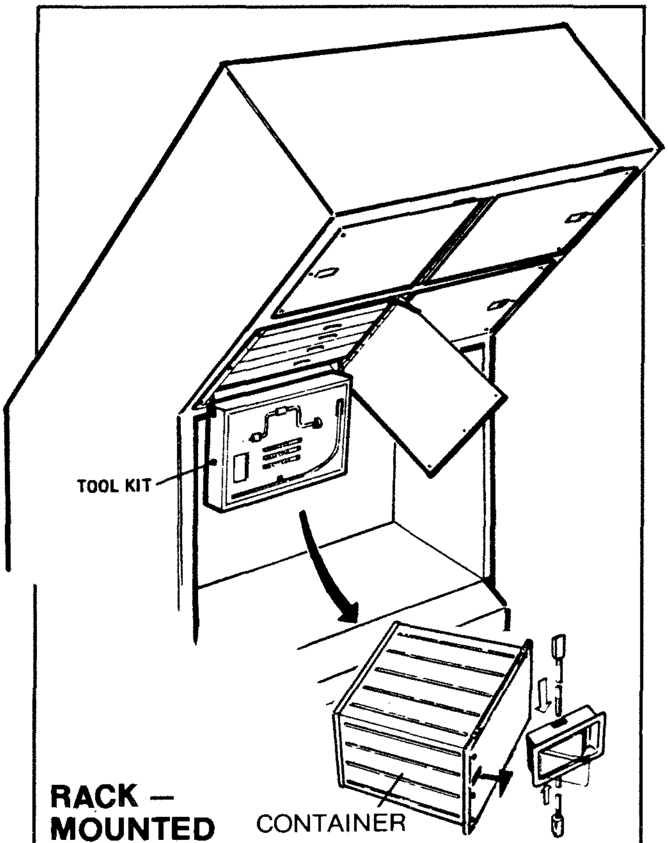
No Command and Data Management Subsystem or Electrical Power Distribution Subsystem services are available to these experiments. This area is primarily designed for storage.

3.1.2.4 Stowage Containers

Rack-mounted and overhead stowage containers are provided for experimenters' use.

Rack-Mounted Containers

Four rack-mounted containers are available. They are 28.4 cm (11.2 in.) tall, 39.9 cm (15.7 in.) wide, and 49.3 cm (19.4 in.) deep. They have a volume of .056 cu. m (1.97 cu. ft.) and can hold 25 kg (55.1 lb.) of equipment.



RACK – MOUNTED STOWAGE CONTAINER

Overhead Containers

Up to eight overhead stowage containers are available. There is space in each module segment for up to seven containers, though the number is reduced if Common Payload Support Equipment is installed. Overhead stowage containers are larger than the rack containers. They are 52.1 cm (20.5 in.) by 51.7 cm (20.35 in.) by 30.2 cm (11.9 in.), with a volume of .081 cu. m (2.9 cu. ft.). Each container can hold up to 33.5 kg (73.85 lb.).

Film Storage

Film can be stored in both the overhead and rack-mounted stowage containers. A film storage kit consisting of sheet metal separators can be installed in the containers. The kits contain sufficient separators to equip four overhead containers and four rack-mounted containers.

3.1.2.5 Common Payload Support Equipment (CPSE)

Common Payload Support Equipment consists of specific items that can be installed in the Spacelab module to meet the requirements of a particular mission. This equipment includes a Scientific Airlock, a Spacelab Window Adapter Assembly, and a Viewport Adapter Assembly.

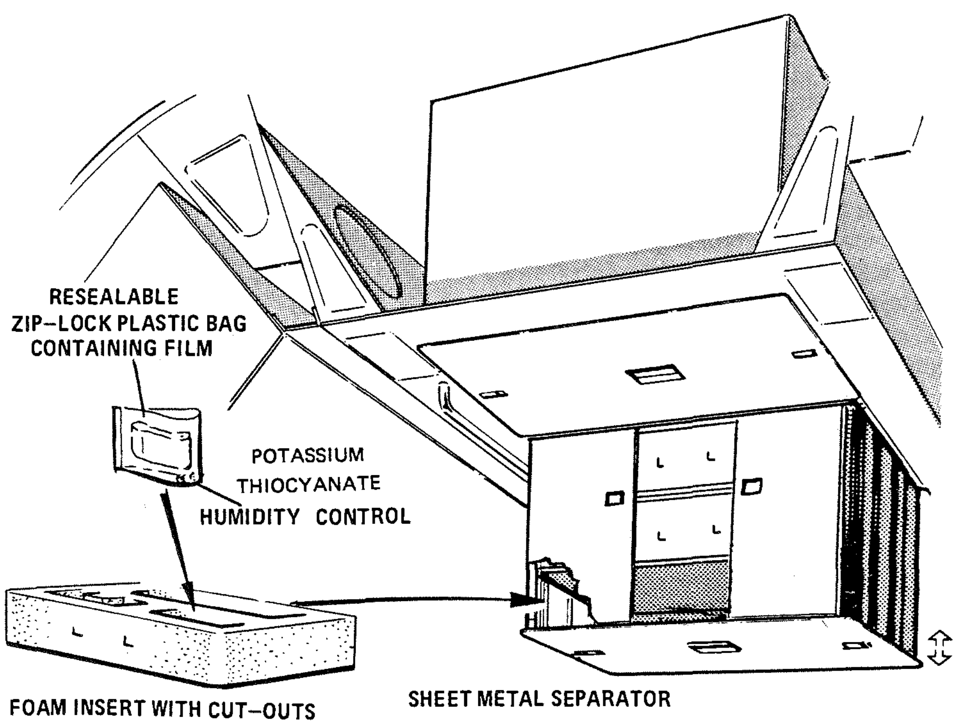
When used, the items are installed in the 1.3 m (51.2 in.) diameter flanged opening in the top of the appropriate module segment. The Spacelab Window Adapter Assembly and the Viewport Adapter Assembly can be used in either the core or experiment module segment. The Scientific Airlock can only be used in the experiment segment. When none of the equipment is used, the openings in the module are closed with cover plates.

Scientific Airlock (SAL)

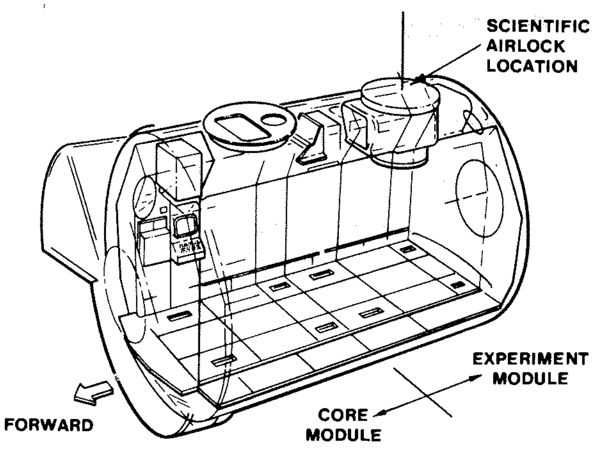
Some experiments carried inside the Spacelab module require direct exposure to space. This can be accomplished through the Scientific Airlock, which can extend an experiment package into space, provide it with power and data transmission while it is outside the module, and then retract it.

The airlock can accommodate an experiment up to 1 m (3.3 ft.) in length and .98 m (3.2 ft.) in diameter. The maximum weight that can be accommodated during orbital operations is 99 kg (218.25 lb.). Stowage of small experiments in the airlock is limited to 60 kg (132.3 lb.) at liftoff and 95 kg (209.4 lb.) on landing.

The airlock is a self-contained, manually operated unit designed to be mounted in the ceiling of the



FILM STORAGE KIT – OVERHEAD STOWAGE CONTAINER



SCIENTIFIC AIRLOCK

experiment segment of the module. It is a 1 m (3.3 ft.) long, 1.05 m (3.4 ft.) diameter cylindrical shell, fabricated from two large aluminum roll ring forgings, machined to shape and welded together. The airlock is closed at each end by a honeycomb sandwich panel hatch. The edge of the hatch is a machined ring designed to interface with the sealing surface of the shell. The outer hatch is hinged and is opened by rotating a handle on the airlock shell. The inner hatch, which contains a viewport with an 18 cm (7.1 in.) viewing area, is completely removable. Because the viewport is placed off-center, rotation of the hatch allows viewing any desired area inside the airlock.

Experiments are mounted to an experiment table. With the outer hatch closed and the inner hatch removed, the table can be extended 68 cm (2.2 ft.) into the module, for ease of mounting and dismounting equipment. With the inner hatch installed and the outer hatch open, the experiment table can be extended up to 96 cm (3.2 ft.) into space. The table is extended and retracted by a manual crank located on the airlock shell. Electrical and mechanical interlocks prevent the opening of both hatches simultaneously. Seven microswitches indicate the status of airlock components.

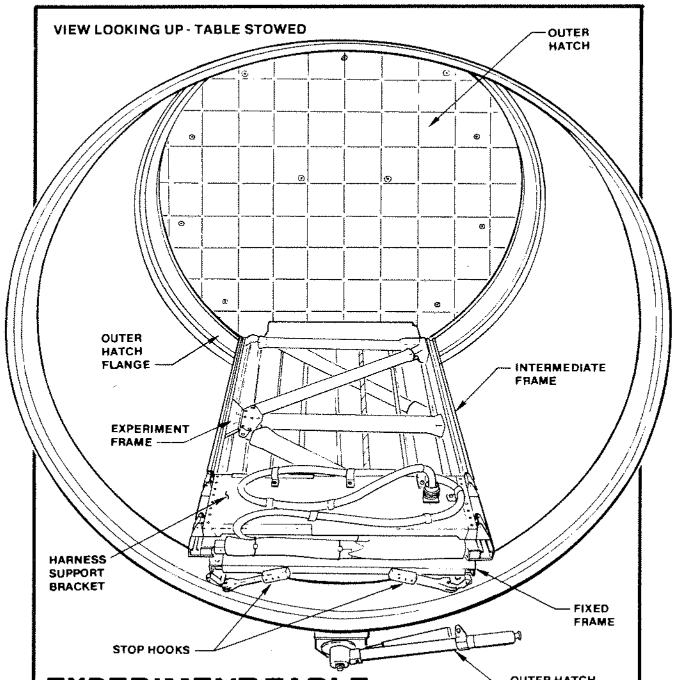
A manually operated, four-way selector valve is used for venting and filling the airlock and for equalizing the pressure inside the airlock with the pressure of the module. The fourth position is an off position. A pressure gauge located near the selector valve provides a direct readout of the airlock pressure relative to module pressure, and pressure transducers sense the absolute pressure in the airlock.

The airlock is depressurized by venting it to space and is repressurized with gaseous nitrogen from the Spacelab Environmental Control Subsystem. Sufficient nitrogen is available for at least seven repressurization cycles during a week-long mission. It takes approximately 16 minutes to depressurize the airlock to 10 mbar (.15 psi), and about 9 minutes to repressurize to 950 mbar (13.8 psi). While final pressure equalization may take only a minute or two, thermal reconditioning of the airlock and experiment may require several hours before the inner hatch can be opened.

Heaters, special surface coatings, thermal screens situated just inside the inner and outer hatches, and multi-layer insulation (MLI) blankets provide thermal control of the airlock. Six sensors measure the temperature of the shell, experiment table, and outer hatch.

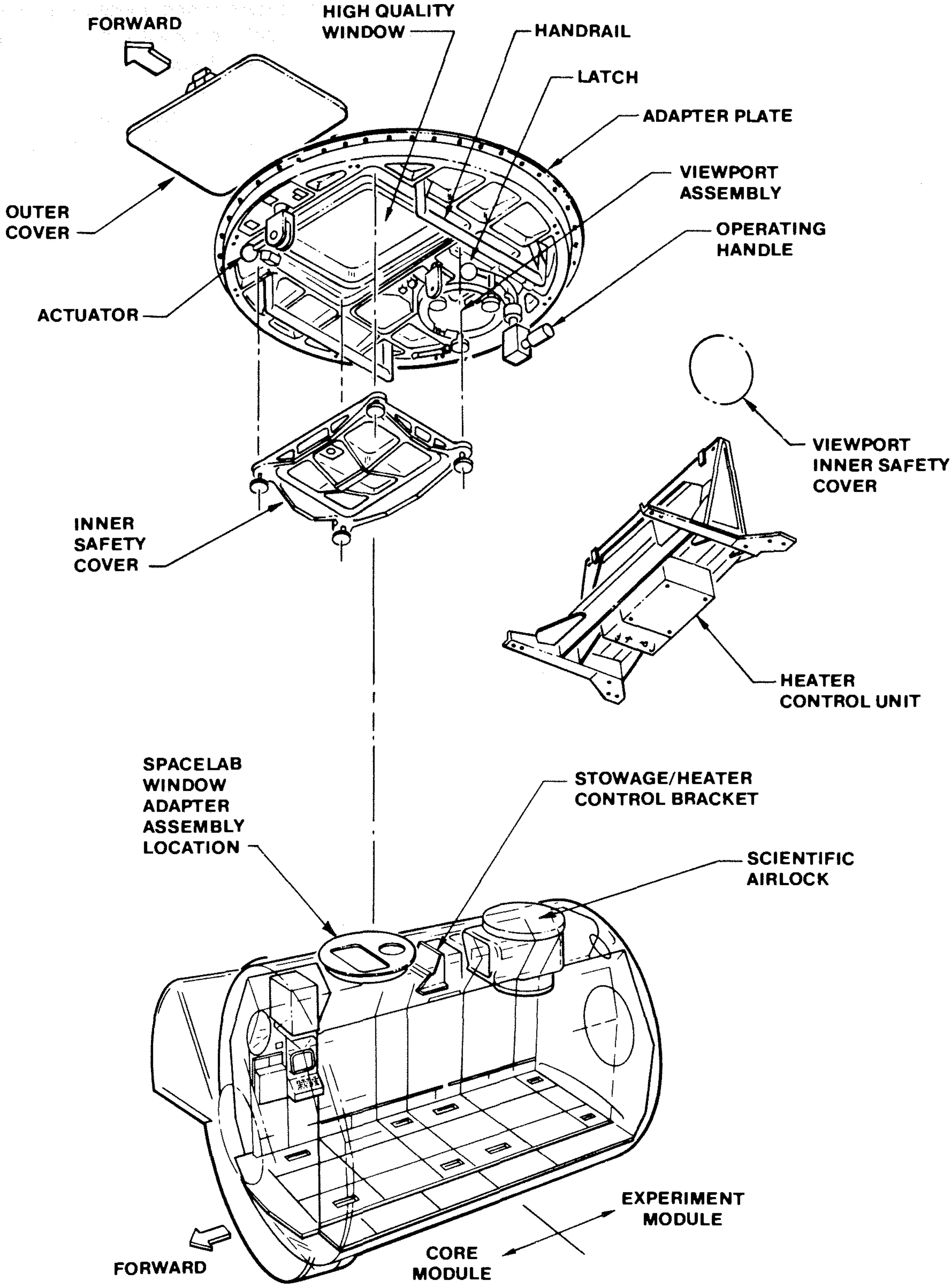
Flexible electrical harnesses running from the experiment table to the airlock shell feed-through carry power to the experiment and also transfer data between the experiment and subsystem computers. A lamp controlled from the airlock panel on the side of the shell lights the inside of the airlock.

If the experiment table fails to retract or the airlock hatch fails to close, closure of the cargo bay doors is obstructed. In these contingencies, the equipment can be jettisoned automatically or by a crew member on an extravehicular activity (EVA) spacewalk.



EXPERIMENT TABLE

SPACELAB WINDOW ADAPTER ASSEMBLY



Spacelab Window Adapter Assembly (SWAA)

The Spacelab Window Adapter Assembly, mounted in the ceiling of the Spacelab module, provides a high-quality window and a viewport. The high-quality window is for optical experiments and photography, and the viewport is for general observations of space and the earth.

The high-quality window consists of a single rectangular pane of BK-7 glass 4.1 cm (1.7 in.) thick with a viewing area of 40.9 cm (16.1 in.) by 55.2 cm (21.7 in.). The window has an anti-reflection coating on the inner surface of the glass and is equipped with a heater system to control temperatures and condensation and thereby maintain optical performance. (Temperature gradients deform glass and moisture obscures the view.) The window design includes temperature sensors and leads permanently bonded to the outside surface of the glass. The high-quality window is spare Skylab hardware returned to service.

The heater control unit contains two switches and two lights that are used to operate and indicate status of the window and frame heaters. The outer surface of the window glass has a 40 watt electroconductive film heater and two temperature sensors. In addition, there are two 100 watt heater elements mounted in the frame surrounding the glass. The window and frame heaters operate automatically to equalize temperature across the window.

An aluminum outer cover protects the glass from radiation, contamination and micrometeoroid impact. This cover must be closed except during data-taking periods, and it must be locked during ascent and descent. The cover can be rotated out of the field-of-view by manually operated controls located on the inside of the window adapter. The external shield is covered with a thermal blanket of multilayer insulation.

HIGH-QUALITY WINDOW CHARACTERISTICS

Optical Characteristics	Window Performance
Spectral Range	80/transmission, 500-900 nm
Parallelism	2 arc sec
Reflectance	2/on inside 4/on outside
Seeds and bubbles	total area 0.1 square mm/100 cubic cm of glass (.00015 sq. in./6.1 cu. in.) maximum dimension of single imperfection: .08 cm (.03 in.)
Surface quality	60-40 or better

A removable aluminum cover bolted to the window frame protects the internal surface from impacts and provides a redundant pressure seal when the window is not in use. During payload operations, the inner shield is removed and stowed in a nearby bracket.

A Spacelab window adapter plate serves as the interface between the two windows and the Common Payload Support Equipment opening in the Spacelab module core segment. Experiment hardware is mounted on the window adapter by using any combination of eight pairs of attachment holes spaced along the periphery of the plate. Handrails on the window adapter assist crew mobility and stability during observations and operation of the heater control switches. A special support structure is located aft of the common payload support equipment opening to provide the support for the high-quality window heater control unit and temporary on-orbit storage of the high-quality window inner safety cover.

Viewports

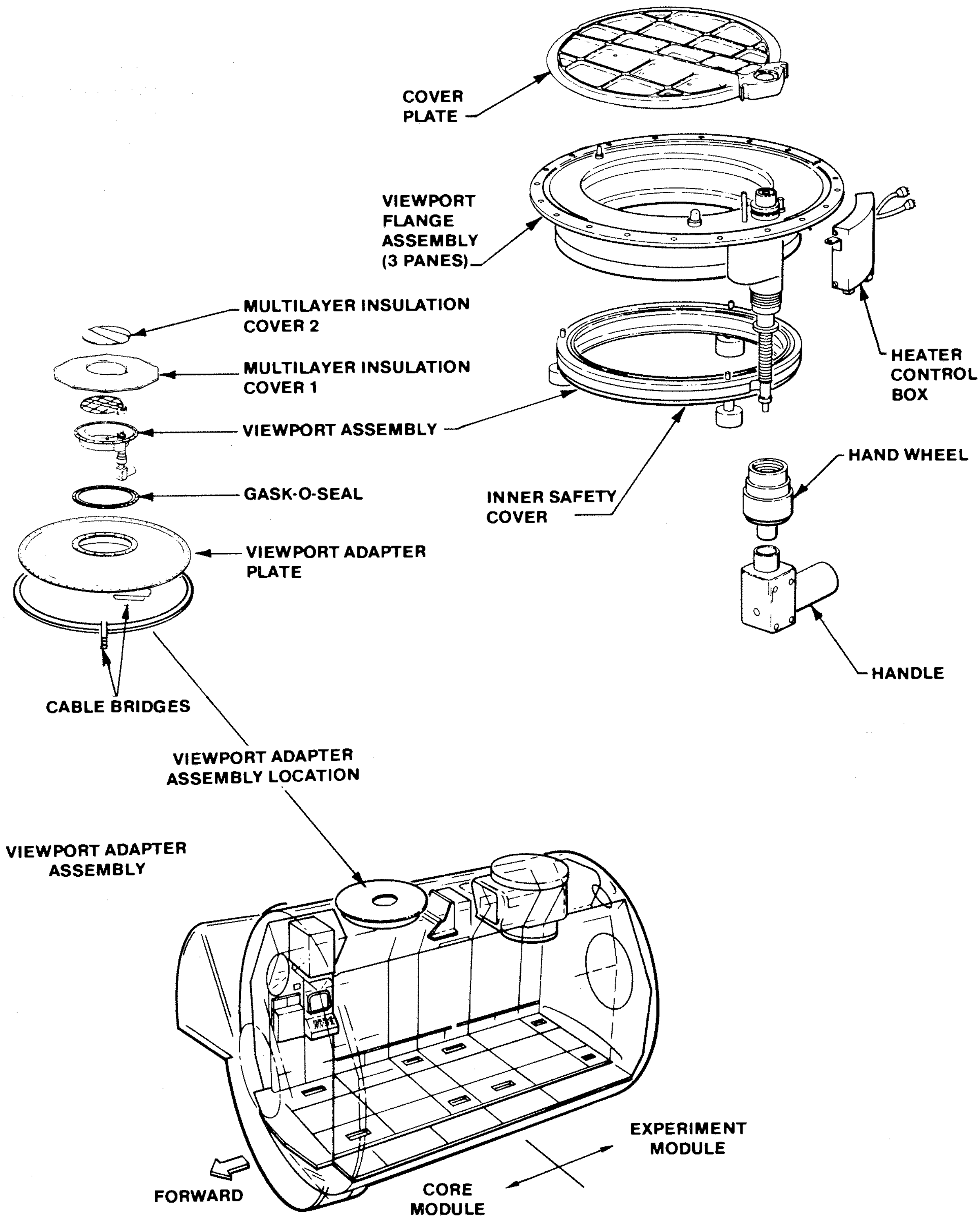
A space and earth viewing capability from viewports in the module is available for crew members and photographic experiments. One viewport is permanently located in the aft end cone of the module. Another viewport can be mounted as required on top of either the core segment or the experiment segment in a Viewport Adapter Assembly (VAA) that fits the 1.3 m (51.2 in.) opening, or it can be used in the high-quality window assembly.

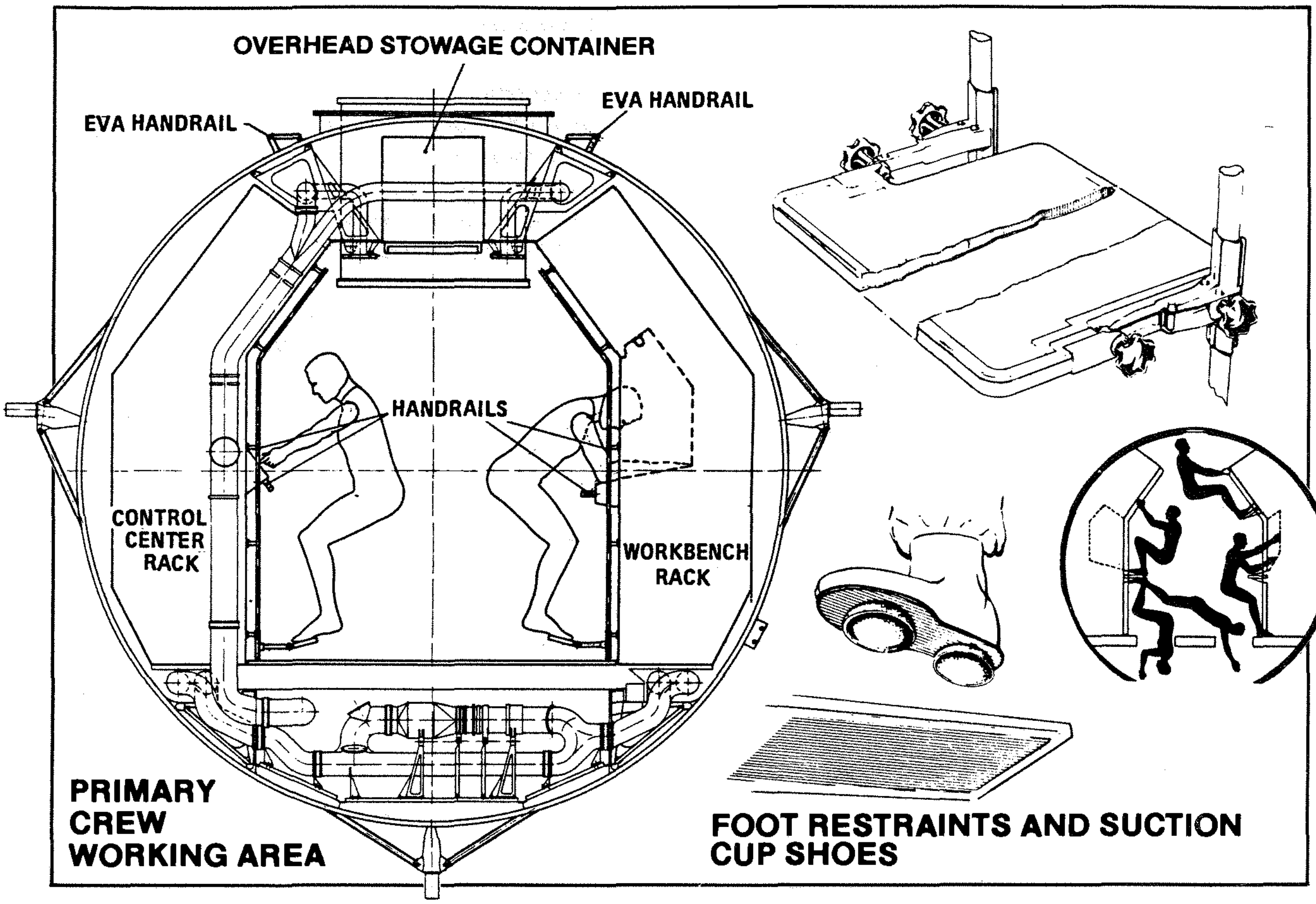
Each circular viewport consists of three laminated panes of Triplex glass. The total thickness is 2.6 cm (1.02 in.). The clear viewing area of Spacelab viewports is 30 cm (12 in.) in diameter. The viewport glass contains a heater film coating, called "hyviz," a metal substance through which a current is passed to prevent condensation.

Experiments with a mass of 25 kg (55.1 lb.) can be bolted directly to the viewport flange. Equipment with a mass up to 50 kg (110.2 lb.) can be mounted on a curved adapter plate with a cutout in the middle.

The outer aluminum protective cover of the viewport flips open or shut when operated by a handwheel. There are two inner covers: a transparent safety cover and a dark thermal cover that shades the viewport when the outer cover is open.

VIEWPORT ADAPTER ASSEMBLY





3.1.3 CREW ACCOMMODATIONS AND EQUIPMENT

The Spacelab module is designed as a working area much like a science laboratory on earth. Since the laboratory is carried in the Space Shuttle, the science crew lives in the orbiter and travels to and from work through the Spacelab Transfer Tunnel.

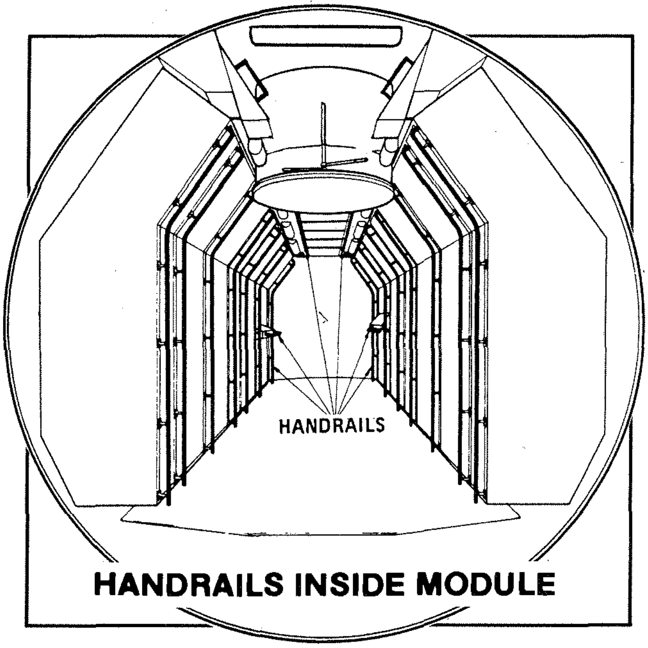
The natural body posture of a person working in the absence of gravity is different from the natural posture for a person working in an earth-based laboratory. Likewise, there is no actual "up" or "down" in space to give a person the normal sense of bodily orientation.Therefore, the Spacelab module was designed with a definite floor and ceiling to provide visual orientation and with adjustable angled work platforms to fit the weightless body posture and enable the crew to work effectively in micro-gravity. Spacelab was also designed with many of the same human accommodations of an earth-based lab.

3.1.3.1 Crew Restraints And Mobility Aids

Various crew restraints and aids situated throughout the module are designed to help the crew members safely perform their assigned tasks.

Foot Restraints

Adjustable aluminum honeycomb sandwich platforms 98 cm x 28 cm (38.6 in. x 11 in.) can be mounted to the double rack and aft end cone handrails. The crew members may anchor themselves to these platforms or to the module floor with porta-



ble adhesive-backed straps or suction cup shoes. A Skylab triangular grid structure and special shoes can be provided in selected locations where strenuous activity or very stable positioning is required.

Handrails

Fixed aluminum handrails are located throughout the habitable area to assist the crew in moving through the module and also to provide a means of body stabilization while they work. Vertical handrails are attached to the face of the Spacelab racks and horizontal handrails are attached along the overhead support structure. Other handrails are located at the inboard edge of the data display console, work bench, near the airlock and viewports, at the Spacelab Transfer Tunnel entrance, and inside the tunnel.

EVA Mobility Aids

Aluminum extravehicular activity (EVA) handrails are installed on Spacelab to allow a pressure suited crew member to move from the EVA hatch, up the end cone of the module, over the module, down the aft end cone, and along the pallet if it were necessary.

3.1.3.2 Work Bench

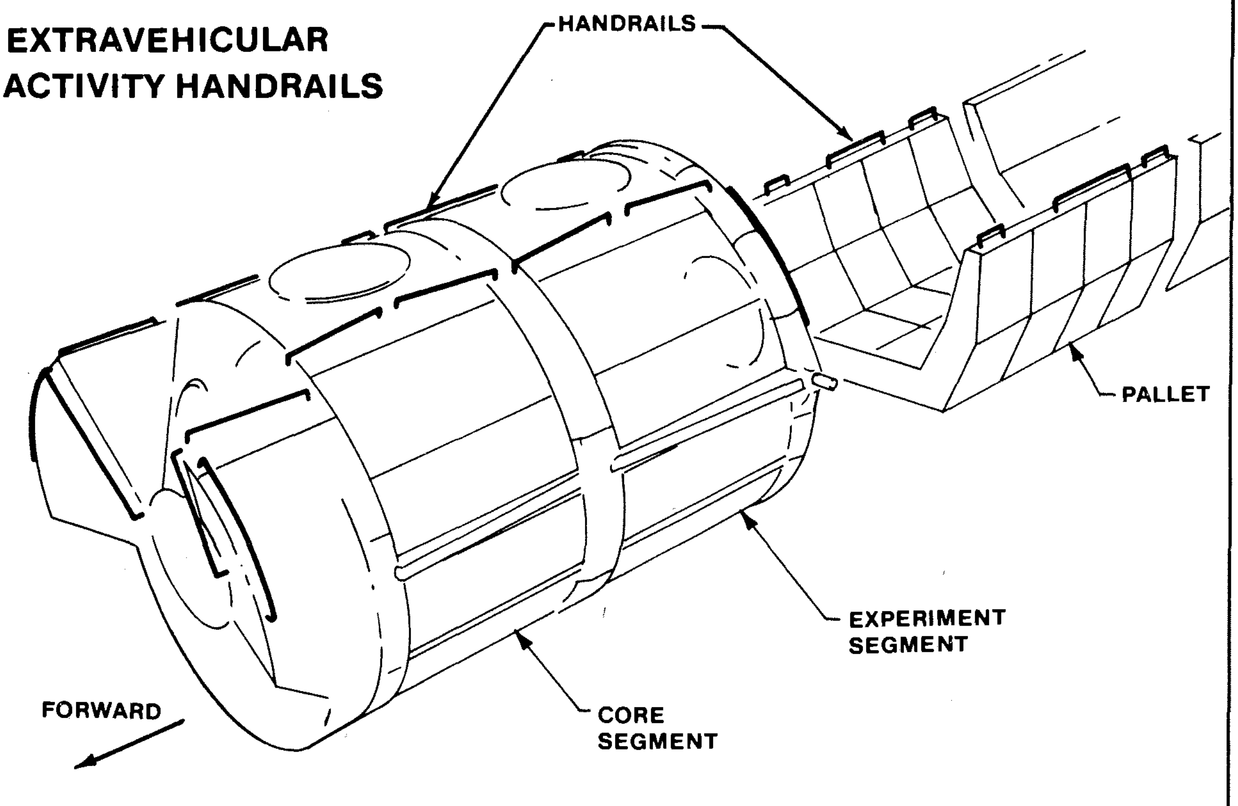
Like laboratories on earth, Spacelab comes equipped with a work bench. The work bench is installed in a double rack mounted on the forward port side of the module core segment. The work bench rack, a general purpose work station, is standard equipment in all Spacelab module configurations.

The rack includes an inclined work bench that provides a general purpose work surface for the science crew. In zero-gravity, elastic cords can be hooked into holes in the surface to anchor equipment and papers to the work surface. A horizontal handrail is mounted to the front of the work bench.

High intensity lighting is installed in a recessed area above the angled working surface. An electrical outlet provides 28V DC, 110W for science crew use. An intercom station provides for communications with the orbiter crew and the ground.

The rack contains six drawers (.056 cu. m/2 cu. ft. each), filing cabinets, a tissue dispenser, and four storage compartments (.081 cu. m/2.9 cu. ft. each). Writing utensils, tools for contingency maintenance,

EXTRAVEHICULAR ACTIVITY HANDRAILS



and other items are stored in this rack. The Spacelab computers are housed in the rack beneath the inclined work surface.

3.1.3.3 Lighting

Lighting within the Spacelab module is equivalent to lighting in a modern office (200-300 lumens/sq. m 18-27 lumens/sq. ft. overall) with about double that intensity at the work bench. Fluorescent lights are located on the module overhead structure, in the Scientific Airlock, at the work bench, and in the Spacelab Transfer Tunnel. Lights can be individually controlled by an on/off switch at each fixture. The fluorescent tubes are embedded in a special shrink hose designed to hold splinters and keep the light operational for a limited time in case the tube breaks. Emergency power and lighting are provided in the event of a power failure.

3.1.3.4 Caution & Warning System (C&W)

The Spacelab Caution & Warning System alerts the crew to emergency or hazardous conditions detected by sensors located within Spacelab. The system is integrated into the orbiter caution and warning system. Emergency signals are routed to various orbiter and Spacelab software systems.

Spacelab emergency signals are generated only by the detection of fire or rapid depressurization in the module. Pressure sensors and smoke sensors are available to detect the conditions. Information from pressure sensors is relayed to the orbiter Caution & Warning Electronic Assembly (CWEA). If a hazardous change in pressure is detected, this generates an emergency tone.

There are three pairs of Spacelab smoke sensors; one is located in the cabin air loop in the subfloor, and the other two are on the left and right sides of the avionics loop in the racks. Smoke sensor information is routed to the Spacelab subsystem computer, the orbiter Fire and Smoke Annunciator Panel, the orbiter Caution & Warning Electronic Assembly and the orbiter system management General Purpose Computer. Emergency conditions are then signaled at both the orbiter Caution & Warning panel and at the Spacelab Caution & Warning/Fire Suppression System panel in the Control Center Rack in the module. The orbiter Caution & Warning Electronic Assembly also generates an emergency siren when a fire/smoke signal is detected.

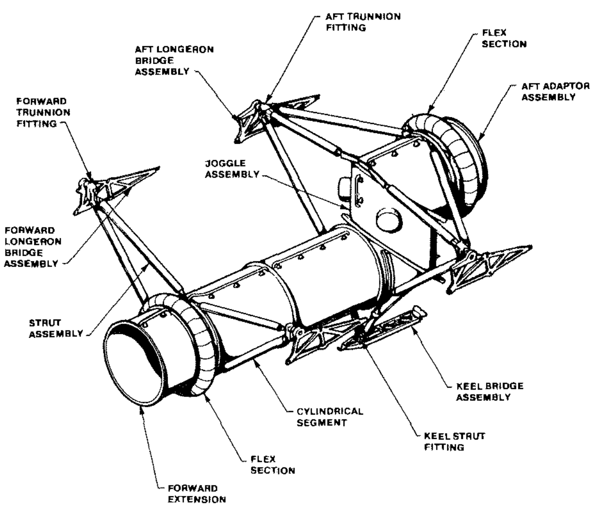
3.1.3.5 Fire Suppression

A crew-activated fire suppression system using HALON 1301 is built into three separate module areas. It can be turned on by the crew from the R7 panel in the orbiter aft flight deck or from the Caution & Warning/Fire Suppression panel in the Control Center Rack in the module. Additionally, portable fire extinguishers are located at the forward and aft end cones of the module.

3.2 Spacelab Transfer Tunnel (STT)

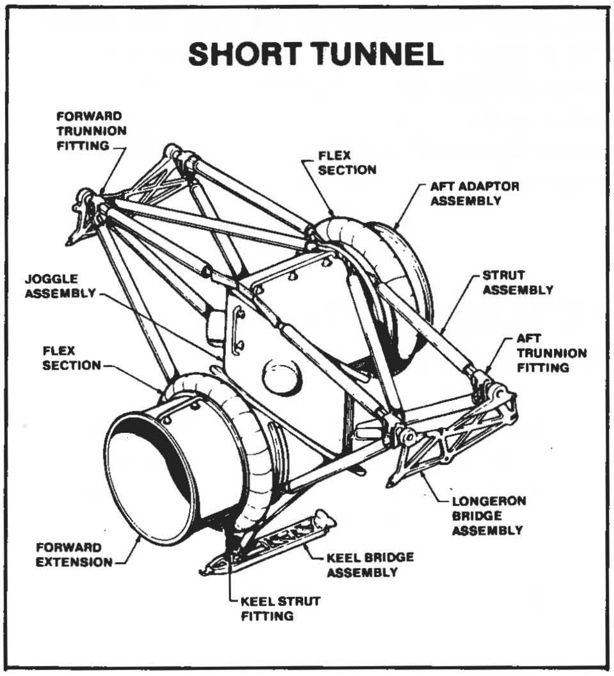
The Spacelab Transfer Tunnel is a pressurized passageway for personnel and equipment transfer between the orbiter crew cabin and the Spacelab module in the payload bay. The environmentally controlled tunnel is a modular structure. Six segments can be combined to form a long tunnel (5.75 m/18.8 ft.), or a short five-segment tunnel (2.66 m/8.7 ft.) can be formed, depending on the location of the Spacelab module in the payload bay. The internal diameter of the tunnel is 1.02 m (40 in.), allowing passage of crew members in shirt-sleeves or spacesuits, with or without packages.

LONG TUNNEL



3.2.1 TUNNEL STRUCTURE

The Spacelab Transfer Tunnel consists of rigid and flexible segments. Hard sections made of formed and welded 6061 aluminum sheet and machined



forgings are mated to flexible rubber and cord composite sections that minimize stress loads during installation and flight maneuvers. Both Spacelab main power and emergency power sources are provided to the tunnel. The six tunnel segments are described below.

3.2.1.1 Forward Adapter Section

The forward adapter (64 cm/25 in. long) is bolted to the orbiter tunnel adapter and sealed by double O-rings.

3.2.1.2 Flexible Sections

Two identical non-rigid sections, made of Viton-coated Nomex fabric, absorb loads transmitted through the structure during flight and also provide necessary flexibility for "drop-in" installation after the Spacelab module is placed in the payload bay. Each 23 cm (9 in.) flexible section is capable of a 7.6 cm (3 in.) adjustment. The flexible sections attach to the forward and aft adapters and to either the cylindrical or joggle section.

3.2.1.3 Cylindrical Section

The 3 m (10 ft.) cylindrical section is an extender used only in the long tunnel configuration.

3.2.1.4 Joggle Section

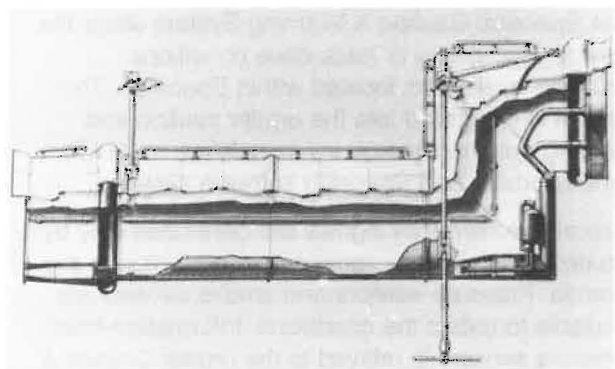
Direct access between the orbiter and the Spacelab module is impossible because the openings of the two compartments are vertically offset by 1.07 m (42.1 in.). The joggle section compensates for this difference in levels.

3.2.1.5 Aft Adapter Section

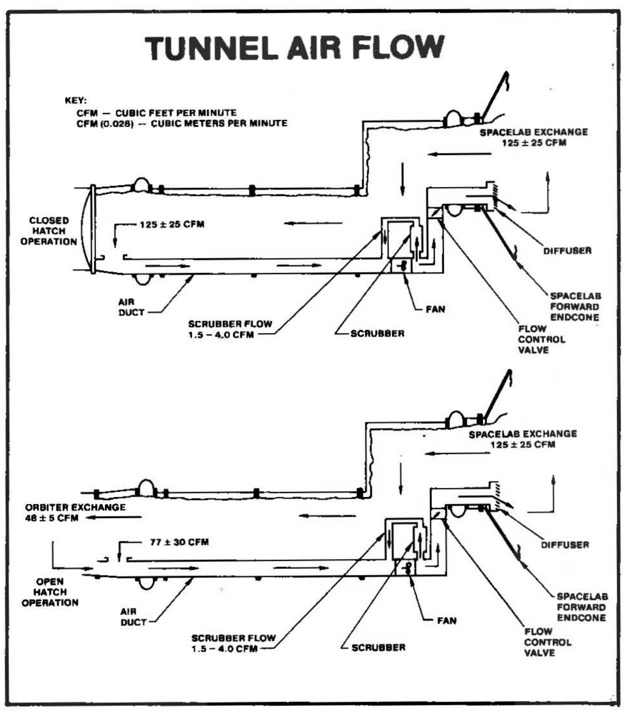
The aft adapter (20 cm / 8 in. long) is sealed to the aft flexible section by double O-rings and to the Spacelab module by a standard Spacelab Gask-O-Seal.

3.2.2 TUNNEL SYSTEMS

The tunnel air ventilation and negative pressure regulation systems are housed in the joggle section and provide atmospheric conditions similar to those in the module. These systems serve both the tunnel and the Spacelab module to maintain a habitable environment, prevent condensation on the tunnel walls, remove trace contaminants from the air, and prevent an excessive negative pressure differential. Air temperature between 17.8° and 27.2° C (64° and 81° F) is maintained. The joggle section contains the following hardware:



Tunnel systems — cutaway view



- Air flow duct, fan, switch, circuit breaker, and control valve – for circulation of air supplied by the Spacelab module and the orbiter. The fan is spare Skylab hardware returned to service. Design flow of the fan, located on the floor of the joggle section, is 2.6 ± .7 cubic meters per minute (100 ± 25 cubic feet per minute). The fan can be replaced on orbit. An air flow duct extends the full length of the tunnel and terminates at the Spacelab opening in a diffuser that prevents undesirable airflow patterns in the module. The diffuser is capped with a perforated screen to protect it from floating objects. At the orbiter end, a plenum and a port to the tunnel adapter ensure air exchange with the orbiter even when the hatch is closed.

- Atmospheric scrubber – a charcoal filter system that cleanses the air, converting carbon monoxide to carbon dioxide and removing other trace contaminants. The scrubber flow rate is .04 to .1 cu. m per minute (1.5 to 4.0 cu. ft. per minute). Air taken in downstream of the ventilation fan flows through the scrubber canister and is exhausted into the air duct upstream. The scrubber can be replaced on-orbit.

- Pressure sensor – checks transfer tunnel air flow pressure across the atmospheric scrubber as part of the performance measuring system.

- Two negative pressure relief valves – to prevent excessive negative differential pressure that could develop during reentry and cause structural damage. These valves are located 45° to each side of the tunnel centerline on the forward upper vertical surface of the joggle section. The valves on the tunnel operate in parallel with identical valves on the forward end cone of the module. Maximum negative differential pressure on the tunnel is limited to 0.5 psi.

- A fluorescent light and two switches, one in each adapter section for control from both ends of the tunnel. The light provides approximately 50 lumens per square meter (4.5 lumens per sq. ft.) throughout the tunnel.

Passive thermal control is provided by blankets of multilayer insulation (MLI) covering the entire outer surface of the tunnel. Thirty-six blankets are required for the long tunnel and 33 blankets for the short tunnel. The tunnel insulation is identical to the Spacelab insulation design except that aluminized rather than goldized Kapton is used in the blanket. Active thermal control is provided by air circulation between the tunnel and the Spacelab module (with the orbiter tunnel adapter hatch closed) or between the module and the orbiter (with the hatch open). The hatch, which opens into the orbiter tunnel adapter, normally remains open during use of the tunnel and module. However, when the tunnel adapter and extravehicular activity airlock are in use, the habitable area can be isolated by closing the hatch. There is no hatch at the Spacelab module opening.

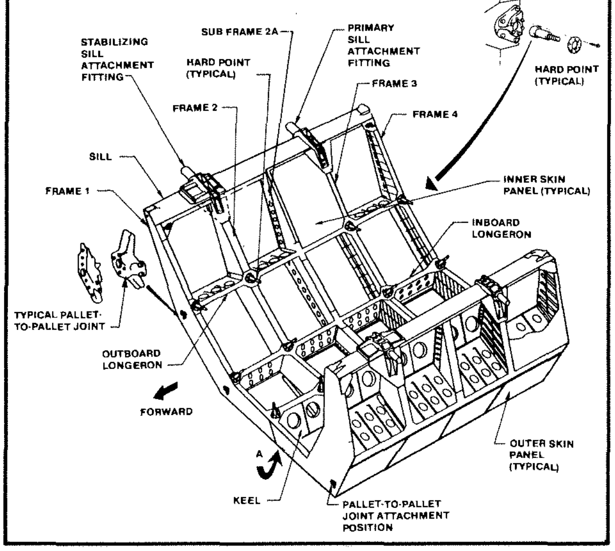
The transfer tunnel attaches to the keel and side walls of the orbiter by support struts and bridge fittings. Handrails placed along the top mid-line of the tunnel exterior provide a secondary EVA path to the Spacelab module. (The primary EVA pathway is along the payload bay sill.) Inside the tunnel, two sets of handrails positioned on opposite walls provide passage paths for two crew members travelling in opposite directions.

3.3 Pallet

Spacelab pallets are large, uncovered, unpressurized platforms designed to support scientific instruments that require direct exposure to space. Telescopes, large cameras, large antennas, and sensing devices are among the categories of experiment equipment carried on the pallets.

Pallets can be flown individually or hooked together to form a train of up to three pallets. Up to five individual pallets can be accommodated in the cargo bay of the Space Shuttle on a single mission. Pallets can be flown with or without the Spacelab module. When flown without the module, a pressurized container called the Igloo carries necessary subsystems support equipment.

PALLET



3.3.1 Pallet Structure

Pallets are 3 m (10 ft.) long, 4 m (13 ft.) wide, U-shaped structures that consist of an aluminum frame covered by aluminum skin panels.

3.3.1.1 Basic Structure

The basic pallet structure is made up of five parallel U-shaped frames (four primary and one subframe) which are connected axially by a keel member, four longerons, and two sill members. The longitudinal members are welded to the frames.

The primary frames, which are .25 cm (.1 in.) thick, are machined from aluminum alloy 2124-T851 plates. The subframe is chemically milled from .09 cm to .05 cm (.04 in. to .02 in.) aluminum alloy.

3.3.1.2 Pallet Surface

The inner and outer face of the pallet structure is covered by load-bearing skin panels of varying sizes. There are 24 inner skin panels and 24 outer skin panels.

Panels consist of an aluminum alloy closed cell honeycomb core covered by aluminum alloy face sheets. The panels are attached to the main structure of the pallet along their rim by .5 cm (.19 in.) titanium bolts.

Experiments and light-weight Spacelab subsystems equipment can be mounted directly to the inner surface skin panels. Threaded inserts arranged in a 14 cm by 14 cm (5.5 sq. in.) grid pattern provide the means for anchoring the equipment. Each panel is capable of supporting a uniformly distributed total load of up to 50 kg/sq. m (10.2 lb./sq. ft.).

3.3.1.3 Hardpoints

To mount large or heavy payloads, standard hardpoint assemblies can be fastened to the intersections of the frames and longerons of the main pallet structure. Twenty-four hardpoints are provided for each pallet.

The hardpoints consist of a bolt with a ball end that is mated to a bracket and held in place by a retaining ring. The bracket is bolted to the pallet structure. The payload is attached to the ball end bolt by a nut.

The brackets and ball fittings are machined from titanium. The retainer ring is titanium-brushed aluminum bronze.

If required by a particular payload, standard hardpoints can be replaced by custom installation fittings.

3.3.1.4 Orbiter Attachment Fittings

The Spacelab pallet is carried in the cargo bay of the orbiter and is held in place by a set of five attachment fittings. A single set of four (two primary and two stabilizing) sill fittings and one keel fitting is required for installing a single pallet or a pallet train.

The sill fittings anchor the pallet or pallets along the top port and starboard sides of the cargo bay. The keel fitting anchors the pallet or pallets along the bottom centerline of the cargo bay.

The primary sill fittings are located on the port and starboard pallet sill where it is joined by the second primary frame. The stabilizing fittings are located on the sill at the intersection of the third primary frame.

The sill fittings are forged and machined from titanium. They are attached to the sill with Inconel bolts. The physical interface with the orbiter is through an 8.25 cm (3.25 in.) diameter chrome plated titanium pin.

The keel fitting is attached to the pallet by a bracket at the intersection of the keel member and the second primary frame. The fitting is braced by a longitudinal strut and two lateral struts which are also attached to the pallet structure by brackets.

The main fitting is a titanium forging. The lateral struts are aluminum alloy tubes with titanium fittings, and the longitudinal strut is a titanium forging. The titanium brackets are bolted to the pallet. Like the sill fittings, physical interface with the orbiter is through an 8.25 cm (3.25 in.) diameter chrome-plated titanium pin which is attached to the main fitting.

3.3.1.5 Pallet-to-Pallet Joints

Pallet-to-pallet joints are used to connect two or more Spacelab pallets to form a single rigid structure called a train. Twelve pallet-to-pallet joints are used to connect two pallets together. The joints are mounted on the exterior pallet frames at the intersection of the longitudinal structural members.

The joint hardware comes in two parts. Long fittings, which include a tapered spigot or pin, are bolted to the aft frame of one pallet. Short fittings, which provide the receptacle for the spigot, are bolted to the forward frame of the adjoining pallet. Once the pallets have been mated, the fittings are locked together with a reversible keeper plate.

The joints are machined from aluminum alloy L93 and attached to the pallet with Inconel bolts. The spigot is made from Inconel.

3.3.1.6 Cable Ducts

Cable ducts and cable support trays can be bolted to the forward and aft pallet frames when needed to support and route electrical cables to and from experiment and subsystems equipment mounted on the pallet. All ducts mounted to the starboard side of the pallet are used to route subsystems cables, and all port side ducts carry experiment utilities cables. The ducts and cable trays are made of aluminum alloy sheet metal.

3.3.2 EXPERIMENT ACCOMMODATIONS

In addition to basic Spacelab utilities service, some special accommodations are available for pallet-mounted experiments.

3.3.2.1 Structural Accommodation

Experiments weighing 50 kg/sq. m (10.2 lb./sq. ft.) or less can be accommodated directly on the pallet skin panels. Heavier experiments can be mounted to hardpoints on the basic pallet structure, or they can be grouped on mission peculiar equipment support structures, which in turn can be mounted to pallet hardpoints.

3.3.2.2 Instrument Pointing Subsystem (IPS)

Some research to be accomplished on Spacelab missions requires that instruments be pointed with very high accuracy and stability at stars, the sun, the earth, or other targets of observation. The Instrument Pointing Subsystem provides precision pointing capability for a wide range of payloads, including large single instruments or a cluster of instruments or a single small rocket class instrument. The pointing mechanism can accommodate instruments of diverse sizes and weights up to 7000 kg (15,432 lb.) and can point them to within 2 arc seconds and hold them on target to within 1.2 arc seconds.

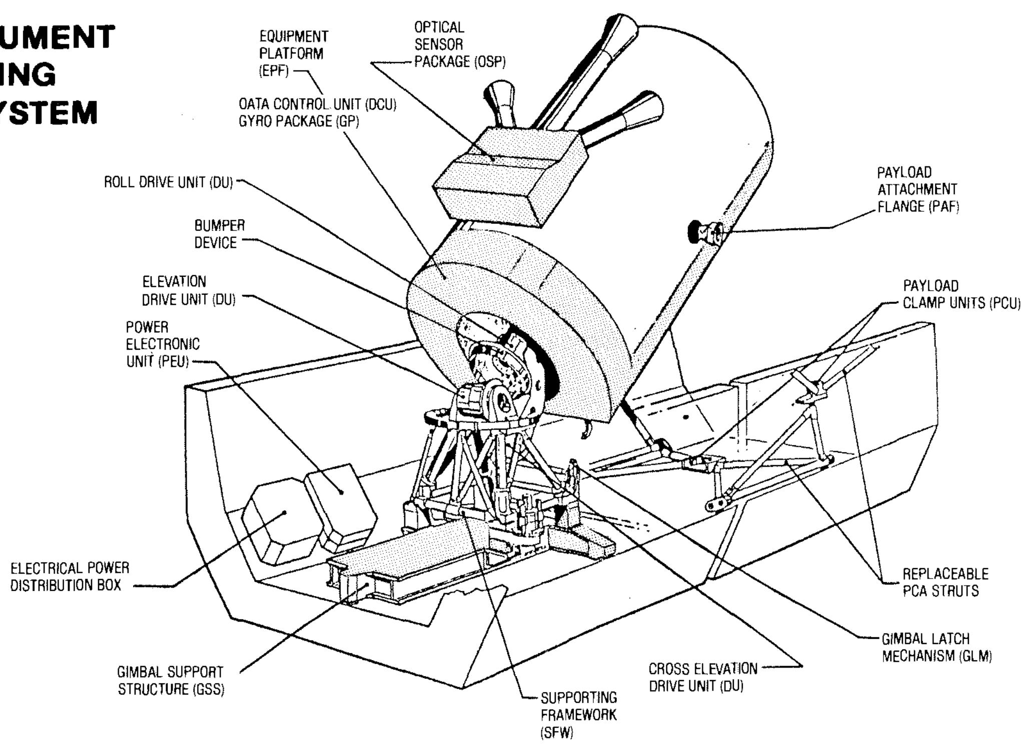
PERFORMANCE REQUIREMENTS OF THE INSTRUMENT POINTING SUBSYSTEM

Performance Requirements	In the 2 axes perpendicular to the experiment line-of-sight	About the roll axis
Pointing accuracy of the experiment line-of-sight	= 2 arc-sec	= 20 arc-sec
Quiescent stability error	= 1.2 arc-sec	= 3 arc-sec
Man-Motion disturbance	= 4 arc-sec	= 15 arc-sec
Stability rate	=60 arc-sec/sec	= 130 arc-sec/sec

Values based on a 2000 kg (4,409 lb.) payload with center of rotation directly above orbiter.

The Instrument Pointing Subsystem is a three-axis gimbal system mounted on a gimbal support struc-

INSTRUMENT POINTING SUBSYSTEM



ture connected to the pallet at one end and to the aft end of a payload at the other, a payload clamping system for support of the mounted experiment elements during launch and landing, and a control system based on the inertial reference of a three-axis gyro package and operated by a gimbal-mounted minicomputer.

The basic structural hardware is the gimbal system, which includes three bearing/drive units, a payload/gimbal separation mechanism, replaceable extension column, emergency jettisoning device, support structure and rails, and a thermal control system. The gimbal structure itself is minimal, consisting only of a yoke, an inner gimbal and an outer gimbal to which the payload is attached by the payload-mounted integration ring.

The three identical drive units are so arranged that their axes intersect at one point. From pallet to payload, the order of the axes is elevation, cross-elevation and azimuth. Each drive assembly includes three wet-lubricated ball bearings, two brushless DC-torquers, and two single speed/multi-speed resolvers.

The gimbal/payload separation mechanism is included between the outer gimbal and the payload integration ring. This device prevents the payload and the pointing mechanism from exerting excessive loads on each other during launch and landing. For orbital operations, the outer gimbal and integration ring are pulled together and locked.

The operating modes of the different scientific investigations vary considerably. Some require manual control capability, others long periods of pointing at a single object, others slow scan mapping, still others high angular rates and accelerations. Performance in all these modes requires flexibility achieved with computer software. The Instrument Pointing Subsystem is controlled through the Spacelab subsystem computer and a data display unit and keyboard. It can be operated either automatically or by the Spacelab crew from the module and also from the payload station in the orbiter aft flight deck.

The Instrument Pointing Subsystem has two operating modes, depending on whether the gimbal resolver or gyro is used for feedback control of the attitude. An optical sensor package consisting of one boresighted fixed head star tracker and two skewed fixed head star trackers is used for attitude correction and also for configuring the Instrument Pointing Subsystem for solar, stellar, or earth viewing.

3.3.2.3 Utilities

Pallet-mounted experiments can be served by Spacelab's Command and Data Management Subsystem, Electrical Power Distribution Subsystem, and Environmental Control Subsystem.

3.3.3 Crew Accommodations

Experiments on the pallet that require crew interaction are controlled remotely from either the Spacelab habitable module if it is flown or from the aft flight deck of the orbiter.

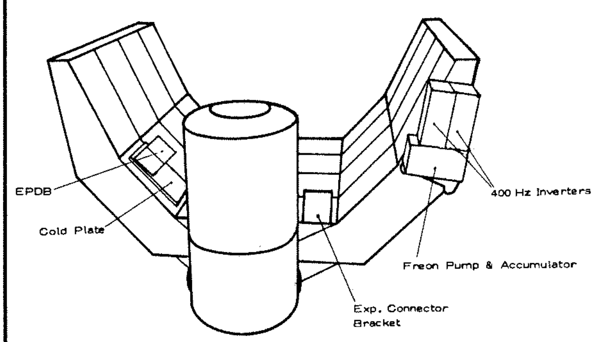
Three extravehicular activity (EVA) handrails are provided along each pallet sill should it become necessary for a pressure-suited crew member to work in the pallet area.

3.4 Igloo

Normally Spacelab subsystem equipment is housed in the core segment of the module. In pallet-only configurations when the module is not flown, it is necessary to house the subsystems elsewhere. As the subsystems are designed for a pressurized environment, a pressurized compartment called the Igloo was developed to house the Spacelab subsystem equipment in a dry air environment at normal earth atmospheric pressure. The Igloo is designed for seven-day missions but it is possible to extend the limit to 30-day missions.

The Igloo is always attached vertically to the forward end frame of the first pallet in the pallet-only mode.

IGLOO



The primary structure is a cylindrical, locally stiffened shell, made of aluminum alloy forged rings and closed at one end. The other end has a mounting flange for the cover. A seal is inserted when the two structures are joined together mechanically to form a pressure tight assembly.

Externally the primary structure has fittings for fastening it to the pallet, for handling and transportation on the ground and for the passive thermal control insulation. Two feedthrough plates accommodate utility lines and a pressure relief valve. Inside, there are mounting facilities for subsystem equipment and the Igloo secondary structure. The Igloo has 2.2 cu. m (77.7 cu. ft.) of available space for subsystems.

The cover is also a cylindrical shell made of welded aluminum alloy and closed at one end. Adapters for the positive relief valve and the burst disc are sited on top of the cover. The cover is removable for full access to the interior.

Subsystem equipment is mounted on the secondary structure, which also acts as a guide for the removal or replacement of the cover. The secondary structure is hinge-fastened to the primary structure, allowing access to the bottom of the secondary structure and to equipment mounted within the primary structure.

The Igloo is mounted on the pallet by a cross beam and two adjustable link fittings. The outer dimensions of the Igloo cylinder are approximately 2.4 m (7.9 ft.) height and 1.1 m (3.6 ft.) diameter.

Due to the low leak rate, the Igloo atmosphere can be maintained at approximately 1 bar without any active repressurization for a maximum of 12 days. The Igloo is covered with multi-layer insulation.

3.5 Command and Data Management Subsystem (CDMS)

Many Spacelab components and experiments are computer controlled through the Command and Data Management Subsystem. The subsystem serves three primary purposes: to control operations automatically by pre-programmed commands; to receive and execute real-time commands from the ground or from the Spacelab crew within the orbiter or Spacelab; and to process, display, store, and transmit data from Spacelab subsystems and experiments. The subsystem uses the orbiter's telecommunications service to transmit data, receive commands, and maintain audio and video contact with the Payload Operations Control Center (POCC) at Johnson Space Center.

The Command and Data Management Subsystem includes three identical computers and assorted peripherals. One computer is dedicated to Spacelab experiments and one to Spacelab subsystems, with the third serving as a backup. Crew members monitor and operate Spacelab subsystems and payload experiments via data display and keyboard units.

Data generated by the payload experiments in the module racks or on the pallets are acquired by the Spacelab Command and Data Management Subsystem and digitized in low-rate housekeeping and high-rate scientific data streams for transmission by the orbiter. The orbiter can communicate at S-band through the Space Tracking and Data Network (STDN), and at S-band or Ku-band with the geostationary satellites of the Tracking and Data Relay Satellite System (TDRSS). These satellites communicate with the TDRSS ground station at White Sands, New Mexico. Communication through TDRSS with the orbiter and Spacelab passes through this one ground station. The TDRSS ground station then communicates data through a domestic satellite (DOMSAT) to Johnson and Goddard. The capture of data and subsequent processing are done at Goddard. At Johnson, the payload data are routed to the Payload Operations Control Center (POCC) and the orbiter/Spacelab data are routed to the Mission Control Center (MCC).

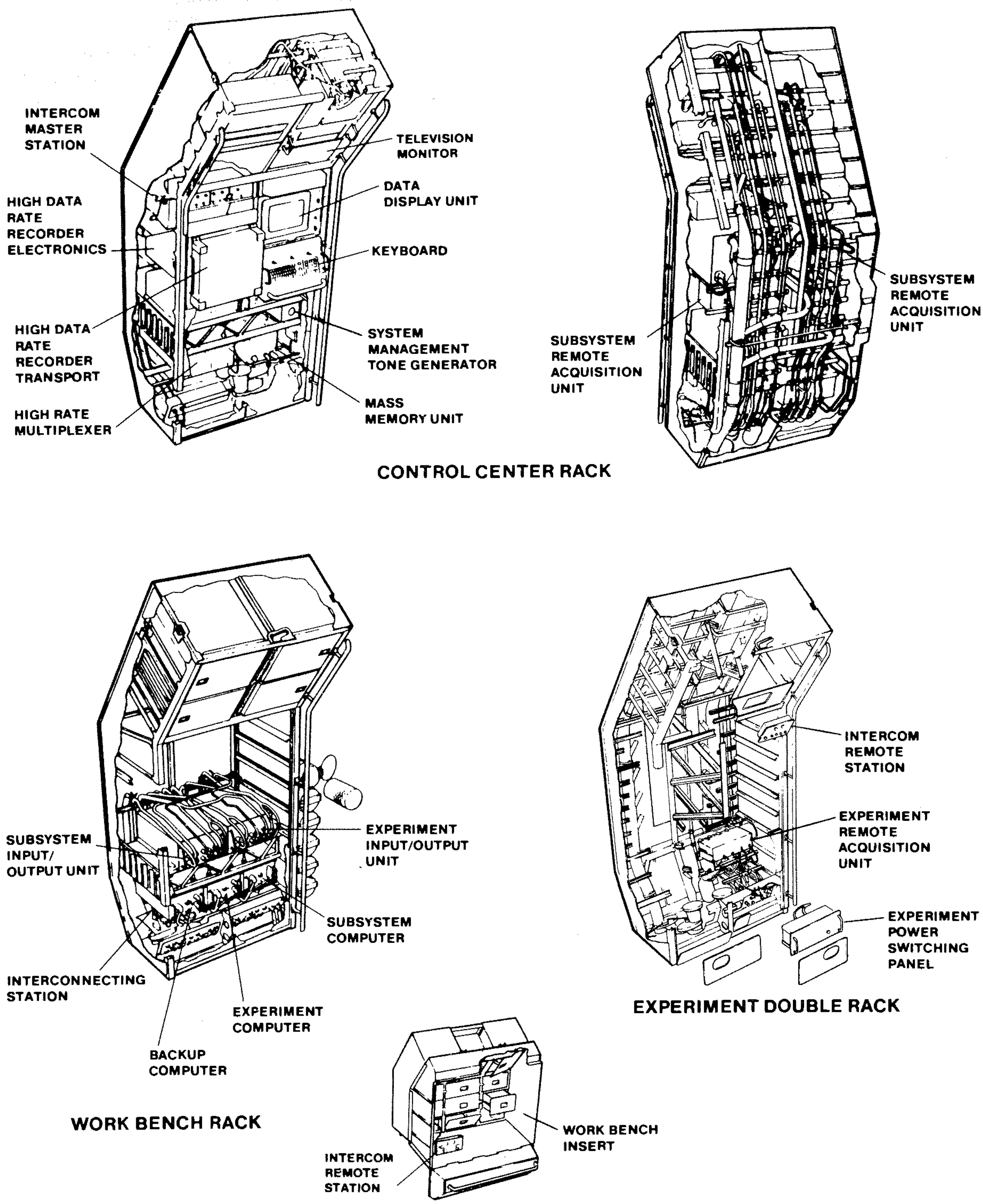
From the Payload Operations Control Center, ground-based scientific personnel are directly involved in the flight payload operations. The center provides recording and computing capability to deal with the large amounts of data that arrive during mission operations. It also offers further communication links to other remote centers either by land-lines or by satellite links.

Due to the earth's geometry and beam blockage by the orbiter and Spacelab payload structure, coverage with a two-TDRS system will be between 30 and 85 percent over a 24 hour period. To bridge "blackout" periods with no downlink capability, a digital recorder and one or more video/analog recorders are included in Spacelab with provisions to add the playback data into the data stream when communication with the ground is restored.

The uplink command capability consists of 2 kbits from the Mission Control Center to the Spacelab avionics via the TDRSS and the orbiter communications and avionics systems.

The following sections describe the major hardware and software components of the Command and Data Management Subsystem, and the command/data acquisition path between Spacelab and the ground.

LOCATION OF PRIMARY COMMAND AND DATA MANAGEMENT SUBSYSTEM EQUIPMENT IN THE SPACELAB MODULE



3.5.1 DATA PROCESSING ASSEMBLY (DPA)

The Spacelab Command and Data Management Subsystem includes three Data Processing Assemblies, each of which consists of a computer, an input/output unit, and remote acquisition units.

Three identical MITRA 125/MS computers are used in Spacelab. Each has a main memory capacity of 64K 16-bit words.

The Experiment Computer (EC) activates, controls, and monitors payload operations and provides experiment data acquisition and data handling. The Subsystem Computer (SC) provides control and data management of the basic Spacelab services that are available to support experiments, such as electrical power distribution, equipment cooling, and scientific airlock operations. The Backup Computer (BUC) can function in the place of either computer.

Each computer has an Input/Output Unit (IOU) that buffers all communications between the computer and the rest of the subsystem. The experiment computer also has at least one (and as many as eight, depending on the payload) Remote Acquisition Unit (RAU), which is the interface between the experiments and the subsystem. The subsystem computer may have as many as nine acquisition units, depending on the Spacelab configuration being flown.

For module-only and module-pallet flight configurations, the experiment and subsystem computers and their associated data processing units, as well as the shared mass memory unit and backup computer, are located in the work bench rack of the module core segment. In pallet-only flight configurations, these components are located in the Igloo, a structure specifically designed to accommodate the components of the Command and Data Management Subsystem, mounted at the front of the first pallet.

Mass Memory Unit (MMU)

The Mass Memory Unit is a tape recorder that contains all of the operating system and applications software for the subsystem and experiment computers. The memory unit provides the initial program load for the Spacelab subsystem, experiment, and backup computers and can be used to completely reload computer memory if required.

The Mass Memory Unit stores various files, timelines, and displays. Writing onto the unit during flight is possible. Approximately half of the unit's storage capability is available for software and data supporting Spacelab experiments.

Data Display Systems (DDS)

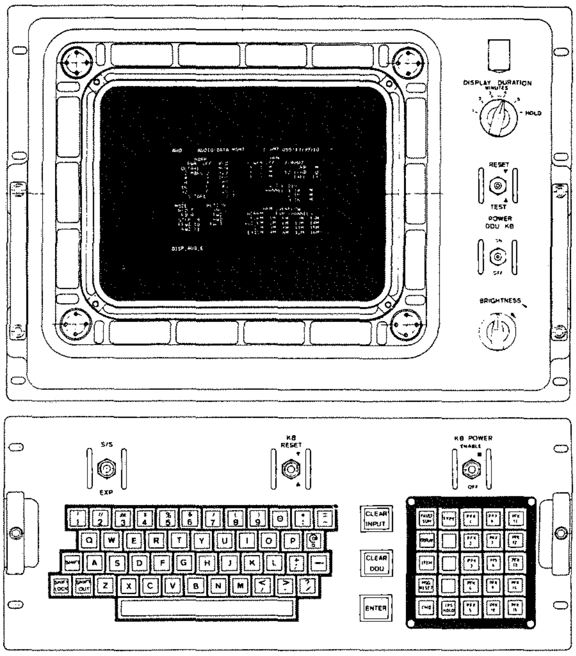
The Data Display Systems are the primary onboard interface between the Command and Data Management Subsystem and Spacelab crew. Each display system consists of a keyboard and a cathode ray tube data display unit (DDU). Up to three Data Display Systems may be used on a mission. One is mounted in the control center rack, another in the orbiter aft flight deck, and a third may be mounted in an experiment rack.

The keyboard consists of 43 alphabetic, numeric, punctuation and symbol keys of the familiar standard typewriter keyboard, as well as the standard typewriter action keys, such as "space" and "backspace," and 25 function keys.

The data display unit is a 30.5 cm (12 in.) diagonal cathode ray tube (CRT) screen providing a 22-line display (47 characters per line) in three colors (green, yellow, and red). In addition to 128 alphanumeric symbols, the unit can also display vector graphics (1,024 different lengths and 4,096 angles). A high-intensity green flashing mode is provided.

The display units are connected to the experiment and subsystem input/output units. Each data display unit can display information from both computers simultaneously, and each keyboard can communicate with either computer. Crew members can call up various displays via the keyboard onto the screen for experiment evaluation and control.

DATA DISPLAY UNIT AND KEYBOARD



3.5.2 SOFTWARE

Command and Data Management Subsystem software consists of experiment computer software and subsystem computer software, each of which includes operating systems software and applications software.

Within the experiment computer, both the operating system (ECOS) and the applications software (ECAS) are wholly dedicated to the direct support of Spacelab payload experiments. The operating system provides such general services as activation, control, monitoring and deactivation of experiments as well as experiment data acquisition, display and formatting for transmission. Some experiments have data handling requirements beyond the capabilities of the operating system. For these experiments, applications software is developed.

The subsystem computer functions mainly to monitor and control other Spacelab subsystems and equipment, such as the Electrical Power Distribution Subsystem and the Environmental Control Subsystem. These functions are performed by the Subsystem Computer Operating Software (SCOS).

Software to support the Instrument Pointing Subsystem (which generates and issues pointing and mode commands based on experiment-specific pointing data contained in the experiment computer software) and the subsystem-related fixed format displays for the Data Display Units is provided by Subsystem Computer Applications Software (SCAS). Thus, operating and applications software interface only indirectly with payload experiments.

3.5.3 DATA TRANSMISSION

Command and Data Management high frequency communications involve data transfer from the experiments to the orbiter. The role of the High Data Rate Acquisition Assembly (HDRA) is to acquire data directly from the experiments and to multiplex these data into a composite data stream of up to 48 Mbit/s. The data stream interfaces with the orbiter Ku-band communication system and is subsequently transmitted to the ground via the Tracking and Data Relay Satellite System (TDRSS). On the ground, a demultiplexer decodes the original experiment inputs. The acquisition assembly consists of a High Rate Multiplexer (HRM), a High Data Rate Recorder (HDRR), the orbiter's Payload Recorder, and a High Rate Demultiplexer (HRDM) on the ground.

3.5.3.1 High Rate Multiplexer (HRM)

The High Rate Multiplexer collects serial data from different sources, performs a time division multiplexing based on 16-bit time intervals, and, finally, delivers a high speed downlink output of one composite serial data stream containing all the input data. This multiplexer is located in the control center rack or, on a pallet-only mission, in the Igloo.

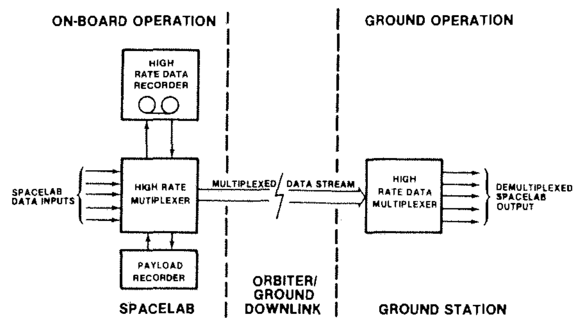
3.5.3.2 High Data Rate Recorder (HDRR)

The High Data Rate Recorder stores data at rates of up to 32 Mbits/s during mission periods of degraded or no downlink capabilities when TDRSS transmission is interrupted. The recorder can operate for periods of 20 minutes to more than 10 hours. The storage buffer is emptied during the next TDRSS transmission period by interleaving and multiplexing the recorded data with new real-time user data.

Data recording for onboard storage without transmission to the ground is allowed only in periods when the recorder is not used as a buffer device in the ground link. Experiment and voice data may also be recorded for onboard storage. The payload recorder of the orbiter is used in the event of a failure by the High Data Rate Recorder. The recorder and High Rate Multiplexer form an integrated system. Both are controlled by the subsystem computer in a coordinated manner.

In the module configurations, the recorder is located in the control center rack next to the Data Display System, with easy access for the crew. In pallet-only configurations, it is enclosed by an environmentally conditioned box and mounted on the pallet.

HIGH DATA RATE ACQUISITION ASSEMBLY – OPERATIONS SCHEMATIC



3.5.3.3 Payload Recorder

The orbiter-mounted payload recorder is essentially a low data rate complement to the High Data Rate Recorder used when the latter is not required or not flown. The payload recorder has a storage capacity of 3,440 Mbits and a selectable input rate range from 64 to 1,024 kbits/s. Recording is accomplished by serial track sequencing of 14 available tracks; record time per track ranges from 4 to 32 minutes.

3.5.3.4 High Rate Demultiplexer (HRDM)

The High Rate Demultiplexer decodes the composite data stream received on the ground via the TDRSS link and recovers the original inputs for delivery to the investigators.

3.5.4 SPACELAB CLOSED CIRCUIT TELEVISION

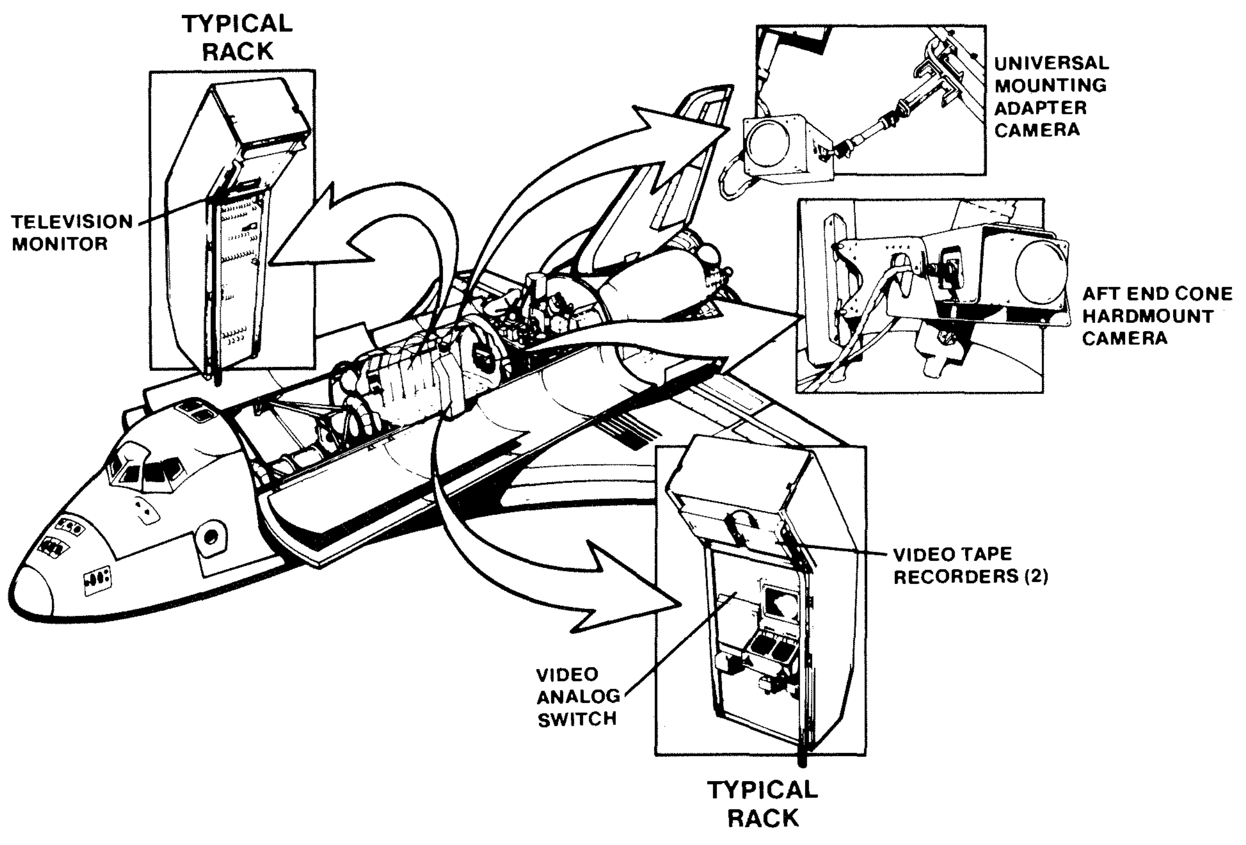
The Spacelab closed circuit television system (CCTV) is associated with the orbiter closed circuit television system. Two orbiter type television cameras are used in the Spacelab module, and provisions exist for other payload television cameras that are part of the investigators' experiment equipment. For pallet-only missions, from one to three payload television cameras can be accommodated.

Video images can be displayed on television monitors onboard Spacelab and in the Payload Operations Control Center on the ground for monitoring experiment operations. Closed circuit television permits real-time participation by engineers and scientists in payload operations and problem solving. The system also can be used for live broadcast coverage of mission operations.

3.5.4.1 Video Analog Switch (VAS)

The control unit of the Spacelab closed circuit television system is the Video Analog Switch, which is controlled through the data display units of the Command and Data Management Subsystem. This switch accommodates 14 video/analog inputs and 9

CLOSED CIRCUIT TELEVISION ASSEMBLY EQUIPMENT LOCATIONS



video analog outputs, including one video signal from the orbiter and three video channels to the orbiter. In addition to the Spacelab cameras, it handles the video instrumentation tape recorders. The switch distributes each of the video or analog sources to any of the video or analog output destinations. It also has an audio input from the intercom system, and it can add audio signals as well as GMT information to video signals generated by the Spacelab cameras.

The video analog switch interfaces with the orbiter switching unit and Ku-band signal processor. The switch is located in an experiment rack with the intercom remote station and two video instrumentation recorders or on the first pallet during pallet-only missions using payload cameras. An 8-inch diagonal orbiter television monitor can be provided in either the control center rack or an experiment rack.

3.5.4.2 Video Instrumentation Tape Recorder (VITR)

Two Video Instrumentation Tape Recorders are available as mission dependent equipment. They must be mounted in an experiment rack in the module because they are not designed for the pallet environment. Each recorder can record 55 minutes of data. Many hours of data may be recorded if the tapes are played back for transmission to the ground. Each recorder can record and play one channel of video or instrumentation data and one audio channel. Crew members can change tapes on orbit. The 4.5 mHz video analog recorders measure 48.2 cm x 27.9 cm x 25.4 cm (19x11x10 in.) and weigh no more than 27.2 kg (60 lbs.).

3.5.5 ORBITER INTERFACES WITH THE COMMAND AND DATA MANAGEMENT SUBSYSTEM

Four communications paths exist for data transfer between Spacelab and the orbiter:

- between the Remote Amplifier and Advisory Box and the Multiplexer/Demultiplexer to permit dialogue between the Spacelab computers and the orbiter's General Purpose Computer;
- between the Input/Output Units and the orbiter's Pulse Code Modulation Master Unit for the transfer of engineering and telemetry data via the orbiter to the ground;
- between the Command and Data Management Subsystem and the orbiter's Master Timing Unit to provide time reference; and
- between the High Rate Multiplexer and the Ku-band Signal Processor for the transfer of high rate data to the ground.

These links are used mainly for sending ground-to-orbiter commands to Spacelab and transferring Spacelab-mounted attitude sensor data to the orbiter for vehicle attitude control. Orbiter position and pointing data also can be transferred to the subsystem computer for use by the Instrument Pointing Subsystem (IPS).

The following nine components, provided by the orbiter, interface with the Command and Data Management Subsystem.

3.5.5.1 Master Timing Unit (MTU)

The Master Timing Unit generates and distributes central onboard time. For experiments that require precision reference timing information, a range of time services is available.

Two separate time signals are available to experiments from the Master Timing Unit via the Remote Amplifier and Advisory Box: the Greenwich Mean Time (GMT) signal and the User Clock Signal (UCS). The GMT signal provides "macroscopic" time information with a time resolution of 10 microseconds. The User Clock Signal provides "microscopic" time information with a time resolution of 1 microsecond.

Experiments may also interface directly with the orbiter Master Timing Unit to receive GMT signals or a mission elapsed time (MET) signal. The Spacelab time distribution system provides experiments with time services having a minimum accuracy of better than 10 microseconds.

3.5.5.2 Multiplexer/Demultiplexer (MDM)

This orbiter component serves as the primary link for the transfer of low rate command and control data from the orbiter General Purpose Computer or from the ground to Spacelab.

3.5.5.3 Remote Amplifier and Advisory Box (RAAB)

The remote Amplifier and Advisory Box interfaces with the experiment computer peripherals of the Command and Data Management Subsystem and with the Master Timing Unit to provide time management services to experiments. The box also amplifies and conditions the commands going from the Multiplexer/Demultiplexer to Spacelab subsystems. This box is located on the module floor below the tunnel opening.

3.5.5.4 Orbiter General Purpose Computer (GPC)

The General Purpose Computer controls the flow of command data to Spacelab via the Multiplexer/Demultiplexer link. General Purpose Computer software generates orbiter state vector and corollary data and transmits the data to Spacelab. These data may be routed to experiments via the remote acquisition units. They may also be accessed by Experiment Computer Applications Software (ECAS) for use in experiment control.

3.5.5.5 Pulse Code Modulation Master Unit (PCMMU)

The Pulse Code Modulation Master Unit is an interface device between the Spacelab subsystem computer and experiment computer, the orbiter General Purpose Computer, and the downlink (telemetry) system. This unit is a low data rate link device that accesses data from the Spacelab computers, provides data to and accepts data from the General Purpose Computer, stores Spacelab and General Purpose Computer data, and provides downlink of the stored data.

3.5.5.6 Audio Central Control Unit (ACCU)

Audio communication capability is provided to experimenters by interfacing the Spacelab master intercom station and up to four remote terminals with the Audio Central Control Unit of the orbiter. Voice and signal communication are possible through the following channels:

- Two air-to-ground circuits;
- Two intercom circuits;
- One air-to-air circuit; and
- One page circuit.

For all module flight configurations, an intercom master station and an intercom remote station form the basic Spacelab intercom assembly, and up to three additional remote stations can be placed in experiment racks as required. The Spacelab intercom assembly interfaces with the orbiter caution and warning system for annunciation of alarm signals.

In addition to providing onboard voice communication, the Spacelab intercom assembly also interfaces directly with experiment data. The three voice channels from the intercom master station are routed to the High Rate Multiplexer and closed circuit television, where the combined "talk" and "listen" lines are digitized and multiplexed into the downlink for direct communication with ground stations and for voice annotation of scientific data.

In pallet-only flight configurations, a "listen" line is provided from the Audio Central Control Unit to the High Rate Multiplexer, and voice data are demultiplexed on the ground for post-flight analysis.

3.5.5.7 Video Control Unit (VCU)

Video and analog data from Spacelab are provided to the orbiter closed-circuit television system by the Spacelab closed circuit television system via the Video Analog Switch (VAS). The orbiter Video Control Unit can receive up to three video data outputs from Spacelab for viewing onboard or for transmission via the Ku-band Signal Processor to the ground. This downlink permits real-time participation by engineers and scientists on the ground in experiment operations, engineering tests, and on-orbit problem solving. The orbiter/Spacelab television system is compatible with standard United States commercial broadcast rates and quality.

The central control unit of the orbiter closed circuit television system is the Video Control Unit, which permits switching and distribution of each of the video signals originating onboard, including those from experiment sources, to any of the video output destinations.

3.5.5.8 Network Signal Processor

The Network Signal Processor is the relay control unit that receives housekeeping and low-rate scientific data and transmits them to the ground on either of two channels:

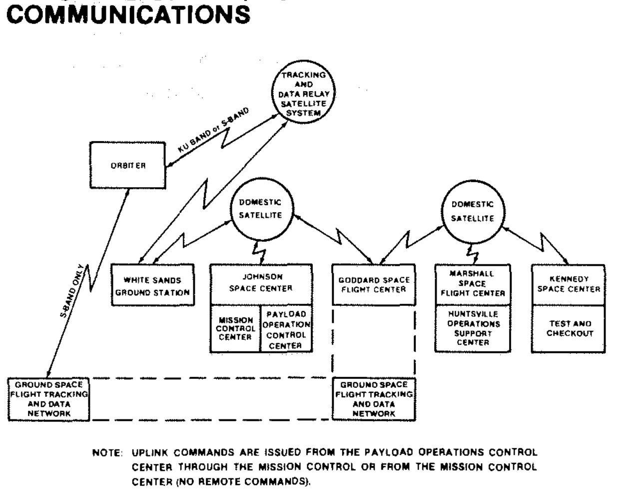
- The Space Tracking and Data Network (STDN) which links the orbiter directly to various ground stations via S-band.
- The Tracking and Data Relay Satellite System (TDRSS), which has two relay satellites and one ground station. The TDRSS/orbiter link normally uses the Ku-band, except during initial antenna adjustment procedures, when it also transmits via the S-band.

3.5.5.9 Ku-band Signal Processor (KUSP)

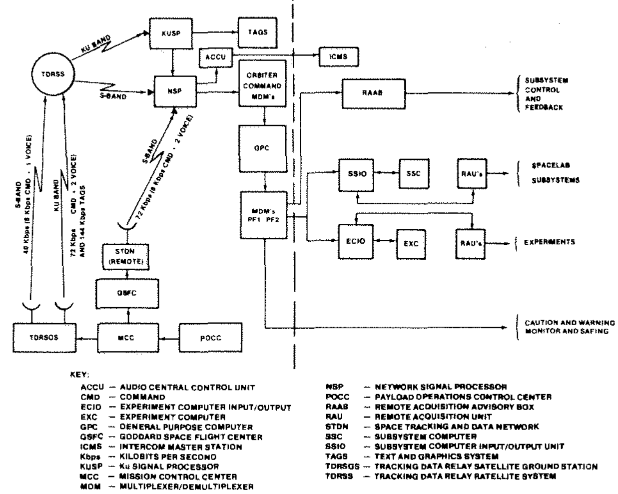
The Ku-band Signal Processor sends and receives data on the Ku-band via the Tracking and Data Relay Satellite System. The processor receives experiment-related and other data over the housekeeping and low-rate scientific data channel, which is routed from the network signal processor, and over the wideband scientific data channel, which it receives directly from the High Rate Multiplexer and video channels. Both kinds of data are converted to a Ku-band signal for downlink via satellite relay.

The Ku-band Signal Processor transmits to the TDRSS ground station at White Sands, New Mexico, from which it is relayed by DOMSAT or ground lines or communications satellite to the Mission Control Center, Payload Operations Control Center, and Spacelab Data Processing Facility. Experiment command data uplinked on the Ku-band channel from the Payload Operations Control Center at Johnson Space Center are routed primarily to the orbiter General Purpose Computer and forwarded to the experiment computer on a 10 kbit/s channel.

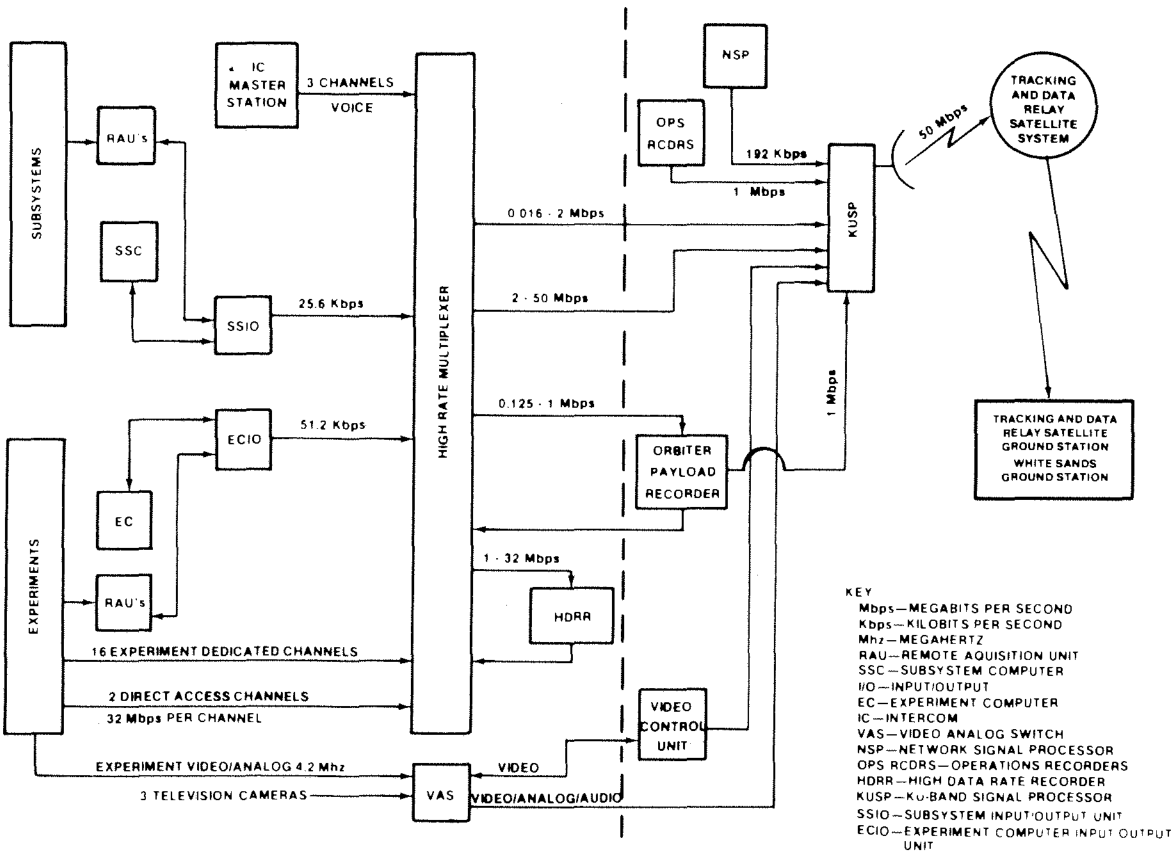
SPACELAB UPLINK/DOWNLINK COMMUNICATIONS



UPLINK DATA FLOW



DOWNLINK DATA FLOW VIA KU-BAND



3.6 Electrical Power Distribution Subsystem (EPDS)

Spacelab depends on the orbiter for electrical power to operate the various Spacelab subsystems and many of the payload experiments. The Electrical Power Distribution Subsystem supplies electricity to the module and pallets for this purpose.

The electrical power available to Spacelab originates from the orbiter's fuel cells. The power delivered to Spacelab is 28V, 7kW, DC; the 7kW limit is set by the orbiter's heat rejection capability. Peaks of 12kW are possible for 15 minutes in a three-hour period.

Power is received through the orbiter bus system which is connected to the Spacelab Power Control Box (PCB) and Spacelab Emergency Box. The AC power is generated from the DC main power by the Spacelab 400 Hz inverters. The Electrical Power Distribution Subsystem also distributes orbiter DC and 400 Hz AC power in the orbiter aft flight deck.

This system distributes power to other Spacelab subsystems and to experiments on separated bus systems through Electrical Power Distribution Boxes (EPDBs). When only the pallets are flown, the distribution boxes interface directly with the pallets. When the module is flown, the interfaces at the rack level are Experiment Power Switching Panels (EPSPs), located downstream of the distribution boxes.

3.6.1 POWER CONTROL BOX (PCB)

The main power conditioning, distribution, and control of the power from orbiter fuel cell generators are performed in the Power Control Box. A shunt regulator limits the main bus voltage to 32V- 2 percent. Melting fuses are provided against short circuits on the feeders. The Power Control Box is installed in the subfloor of the core segment of the module and in the Igloo for pallet-only configurations.

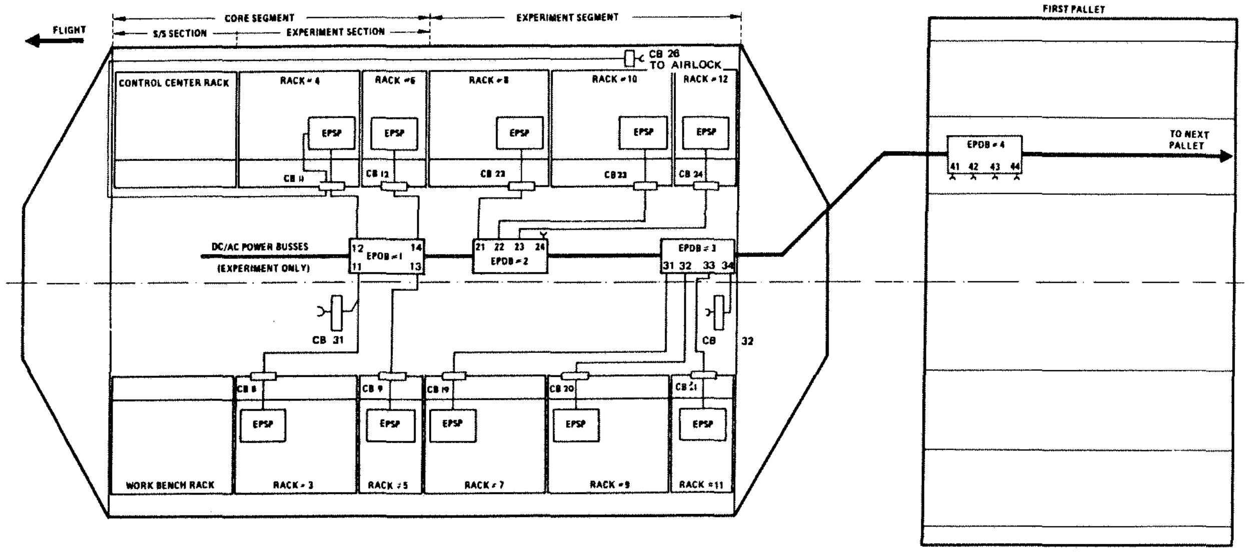
3.6.2 EMERGENCY BOX (EB)

The Spacelab Emergency Box is fed by two independent auxiliary DC power lines from the orbiter. The Emergency Box supplies 28V DC power, referred to as emergency or essential power, to Spacelab subsystem equipment. The outputs are protected by melting fuses. One separately fused outlet, an experiment essential bus, is dedicated to experiments. The Emergency Box is installed in the subfloor of the core segment of the module, or in the Igloo for pallet-only configurations.

3.6.3 400 Hz INVERTER

In all Spacelab configurations, two inverters are installed, one normally dedicated to subsystems and

LOCATION OF ELECTRICAL POWER DISTRIBUTION SYSTEM COMPONENTS



Legend

EPDB: Experiment Power Distribution Box
EPSP: Experiment Power Switching Panel
CB : Connector Bracket

the other to experiments, although they are interchangeable. Each inverter generates 3-phase AC power 117/203V, 400 Hz. Built-in control and regulation circuits protect the inverter, and consumers, against overvoltage and overcurrent. The inverters are mounted on coldplates.

In the pallet-only configuration, both inverter panels with attached coldplates and guide rails are mounted on the first frame bracket. Thermal conductance on the pallet is improved by the application of filler material between the coldplate and the inverter. In module configurations, both inverters are located in the control center rack.

3.6.4 AFT FLIGHT DECK POWER DISTRIBUTION BOX

The Aft Flight Deck Power Distribution Box is normally installed in the orbiter aft flight deck Payload Station area within the payload equipment rack. This box provides 28V DC and 3-phase, 115/220V, 400 Hz AC power for Spacelab subsystems equipment and experiments.

3.6.5 SUBSYSTEM POWER DISTRIBUTION BOX (SPDB)

The Subsystem Power Distribution Box distributes the subsystem DC bus and AC bus power into subsystem dedicated feeders. All outputs are remotely switched using latching relays except for the Tunnel, Environmental Control Subsystem AC and experiment AC outputs.

Melting fuses ensure that the protection in the box is slower than protective devices downstream. Power protection circuits and command activation are powered from the Remote Amplifier and Advisory Box (RAAB).

Two AC switches are installed for switch-over capability of AC power coming from the two inverters to the subsystem AC bus or the experiment AC bus.

3.6.6 EXPERIMENT POWER DISTRIBUTION BOX (EPDB)

The Experiment Power Distribution Box provides distribution, control, and monitoring facilities for the experiment electrical power distribution system, which consists of a nominal redundant 28V DC experiment main DC supply and a 115V, 400 Hz 3-phase experiment AC supply.

ELECTRICAL POWER CHARACTERISTICS AT EXPERIMENT POWER DISTRIBUTION BOX

DC power	**AC power**
Voltage 28± 4V	**Output** 3 phases plus neutral line
Output Current 2 outputs max 60 A each 2 outputs max 60 A	**Voltage** 115/200V rms ± 5% in totalline to neutral
	Max continuous power: 4 outputs, 2.7 KVA in total **Peak power:** 3.5 KVA for 120 seconds **Frequency:** 400 Hz ± 1 Hz

One distribution box (EPDB 1) is installed under the core segment floor on a support structure. For the long module configuration, two additional units (EPDB 2 and 3) are installed. For pallet-only configurations, the unit is mounted with other assemblies via an adapter plate on a coldplate that is fitted on a support structure and attached to the pallet.

3.6.7 EXPERIMENT POWER SWITCHING PANEL (EPSP)

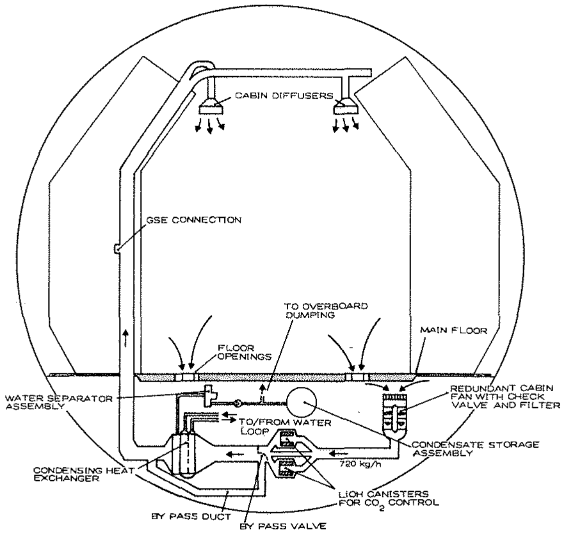
The Experiment Power Switching Panel provides facilities for the branching and switching of DC and AC power, delivered by a dedicated experiment power control box. . The DC and AC output is distributed to experiments and experiment supporting remote acquisition units (DC only). The number of switching panels and their location depends on the mission, but they are always mounted in the experiment racks.

3.7 The Environmental Control Subsystem (ECS)

The Environmental Control Subsystem protects both the crew members and the payload equipment. When the module is flown, this subsystem provides a breathable atmosphere, safe pressure levels, and comfortable working temperatures for crew members. It also provides thermal control of experiments and subsystems within the module and those flown on pallets. Environmental control, including module pressure and atmosphere levels, and thermal control of Spacelab are accomplished through various cooling loops, heat exchangers and insulation blankets. Different combinations of these systems are used according to the module-pallet configuration flown.

3.7.1 MODULE ENVIRONMENT

The module environmental control provides a shirt-sleeve, one atmosphere environment for up to four crew members (maximum 52 work-hours a day) during a seven day mission. The air temperature is kept between 18 and 27degrees C (64.4degrees and 80.6degrees F), with 30 to 70 percent humidity. The air is circulated at a speed of 5 to 12 m (16.4 to 39.4 ft.) a minute. To maintain the atmosphere within proper limits, an atmosphere revitalization system and an atmosphere storage and control system are in operation.



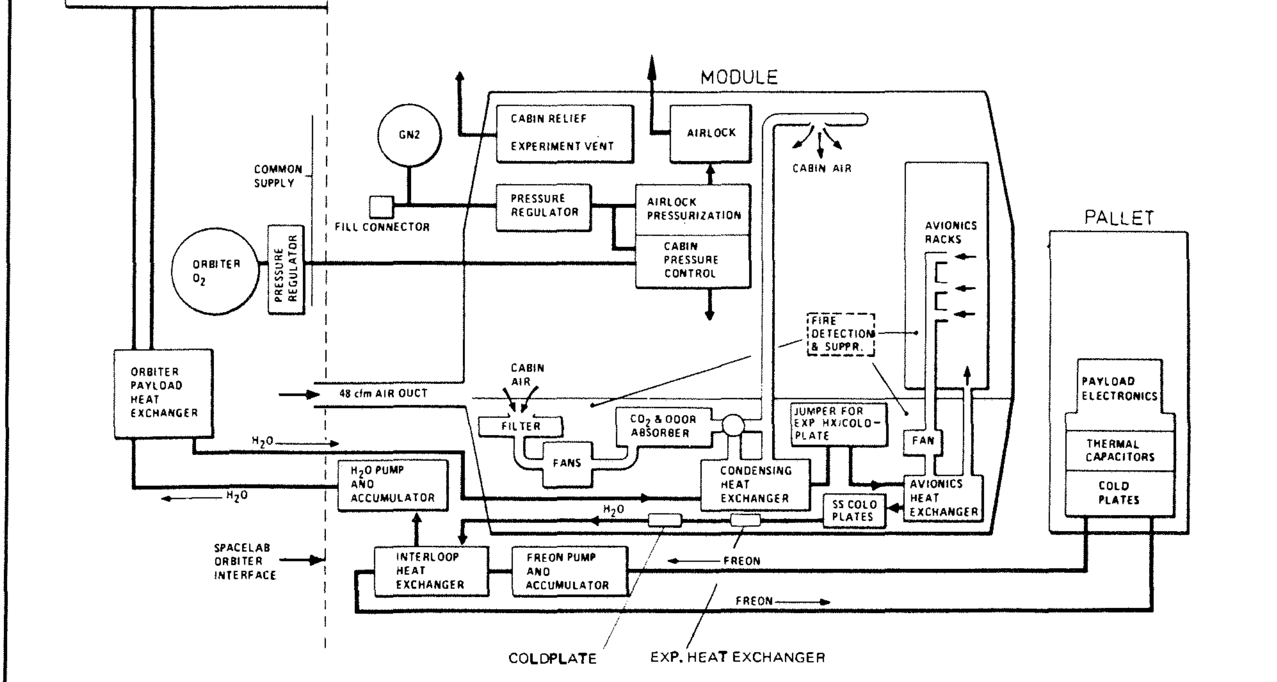
CABIN AIR LOOP

3.7.1.1. Cabin Air Loop

Atmosphere revitalization is achieved through the cabin air loop. Two cabin fans are mounted on the subfloor, though only one fan operates at a time. The air in the cabin is sucked in by the fan through openings in the main floor, and any debris is discarded at the inlet filter. The carbon dioxide is kept within safe limits by lithium hydroxide cartridges which also contain activated charcoal to remove any trace contaminants in the carbon dioxide control assembly located in the floor of the module. A condensing heat exchanger, also in the floor structure, cools the air below the dew point; the resulting moisture is removed and stored. Sensors in the air ducts control the cabin temperature by activating an air bypass valve that modulates the flow of air through the heat exchanger. The cabin distribution system releases the air into the cabin through adjustable air diffusers located in the overhead structure of each module segment.

Another atmospheric system operates in the transfer tunnel. The tunnel fan draws cabin air into the tunnel and recirculates it to the module. The

ENVIRONMENTAL CONTROL SUBSYSTEM SCHEMATIC



system can also be used to exchange air between the orbiter and the Spacelab cabin.

The atmosphere storage and control system consists of one high-pressure nitrogen storage tank mounted on the front end cone, a high-pressure regulator, and an atmospheric pressure regulator. Oxygen is supplied through a line connected with the orbiter oxygen supply. Oxygen partial pressure transducers regulate the gases in the cabin by signaling to activate a solenoid valve. Nitrogen flows until the sensors signal that the oxygen partial pressure has decreased. The valve then closes and the oxygen flow is resumed as necessary.

The cabin total pressure is automatically controlled within the range of 1.013 - 0.013 bar, with an oxygen partial pressure of 0.220 - 0.017 bar, by a nitrogen/oxygen control panel. As a backup, the panel can also be used manually for nitrogen repressurization of the airlock or for supplying oxygen to the module.

Pressure relief valves mounted on a plate attached to the forward end cone protect the module structure against excessive pressure differentials, depressurize or evacuate the cabin, and vent experiment chambers.

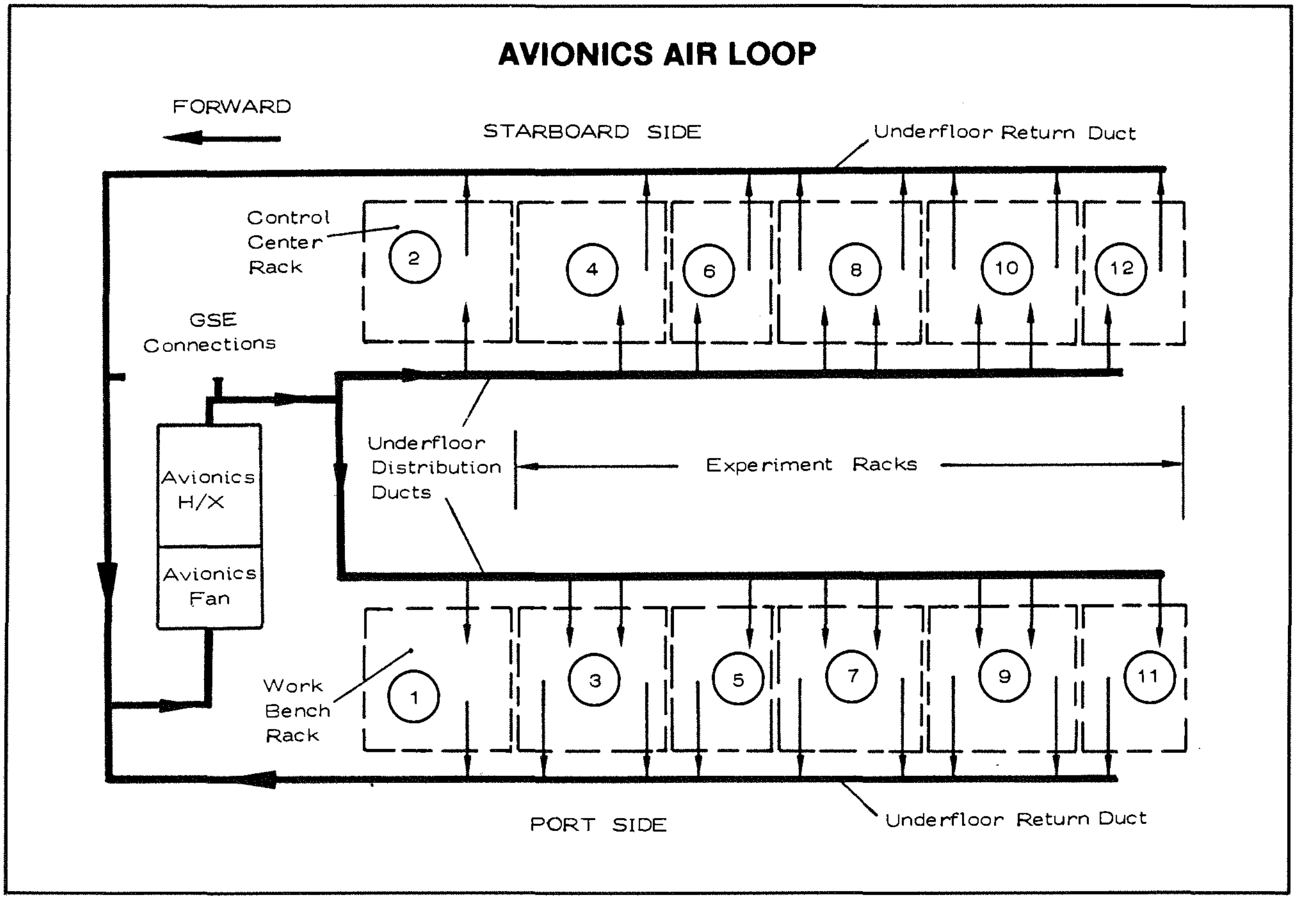
Environmental Control Subsystem Design Characteristics

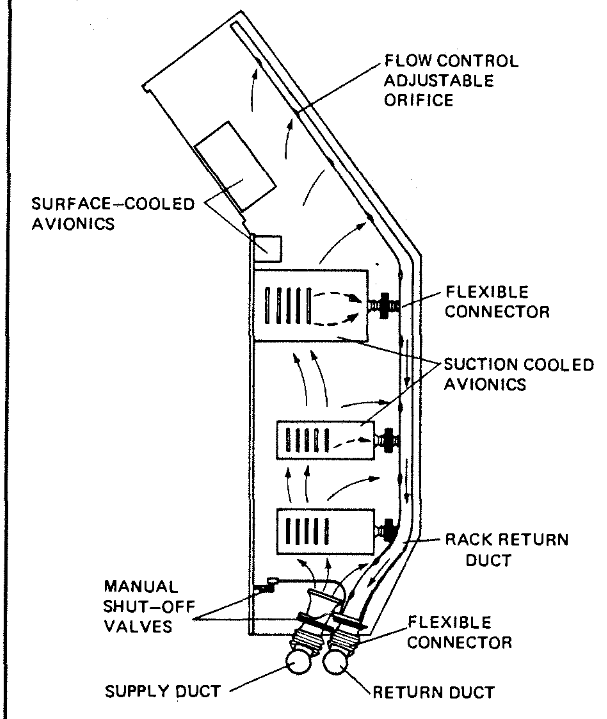
Mean Radiant Temperature	max 30°C
Max Touch Temperature	max 45°C
Air Atmosphere Leakage	1.35 kg/day
CO_2 Control	Nom 0.0067 bar or less Max 0.0101 bar
Air Filtration	280 micron Filter nominal 300 micron absolute
Airlock Repressurization	0.87 m³, nominal 7 times for a 7 day mission

3.7.1.2. Avionics Air Loop

Subsystem and experiment avionics equipment mounted in the module racks generate heat which needs to be removed to keep the equipment within its operating temperature range.

The avionics air loop is similar to the cabin air loop. Air cooled by the water cooling loop enters under the racks through supply ducts, where it is blown upwards to cool the experiment equipment. The air





RACK EQUIPMENT COOLING

is sucked back into return ducts located at the back of the racks for recycling.

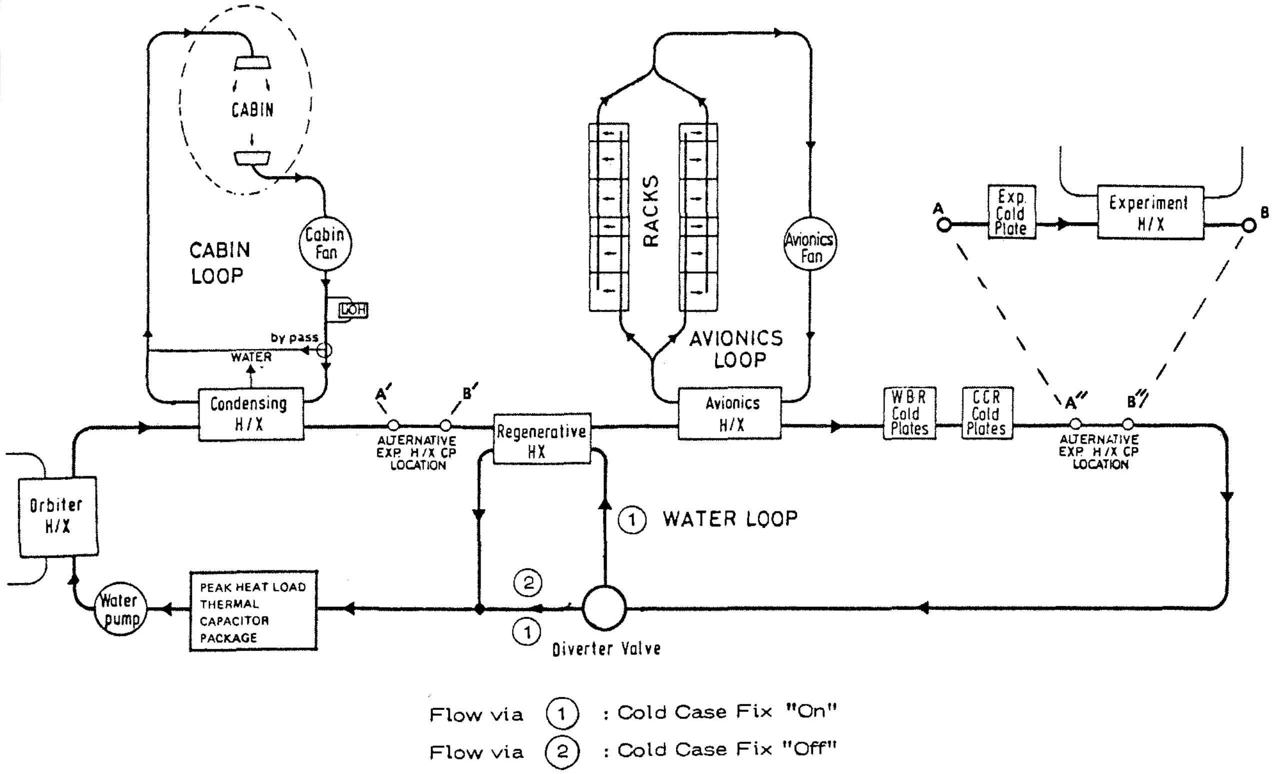
A maximum of 12 racks are serviced by the avionics loop in the long module and six racks in the short module. The most forward rack on each side of the module is a subsystem rack. One of these racks, the work bench rack does not require air for cooling, since it is cooled by coldplates serviced by the water loop. The control center rack is similarly cooled. However, a certain amount of air flow is provided in this rack for smoke and fire detection.

3.7.1.3. Water Cooling Loop

The module water coolant loop collects all module heat loads and transports them via the orbiter interface to the orbiter payload heat exchanger for final rejection during all mission phases. A regenerative heat exchanger is available to preheat the water loop should the mission demand it.

To transfer experiment heat loads into the loop, an experiment dedicated heat exchanger and/or coldplates may be connected to the loop downstream of the condensing heat exchanger or downstream to the subsystem coldplates. Heat is transmitted from subsystem equipment to the coldplate surface,

WATER COOLING LOOP



where the heat is then conducted away by the liquid in the cooling loop. In the module, coldplates are mounted on support structures within the racks. The heat load is transported via a thermal capacitor/coldplate stack and the pump package to the orbiter interface for final rejection.

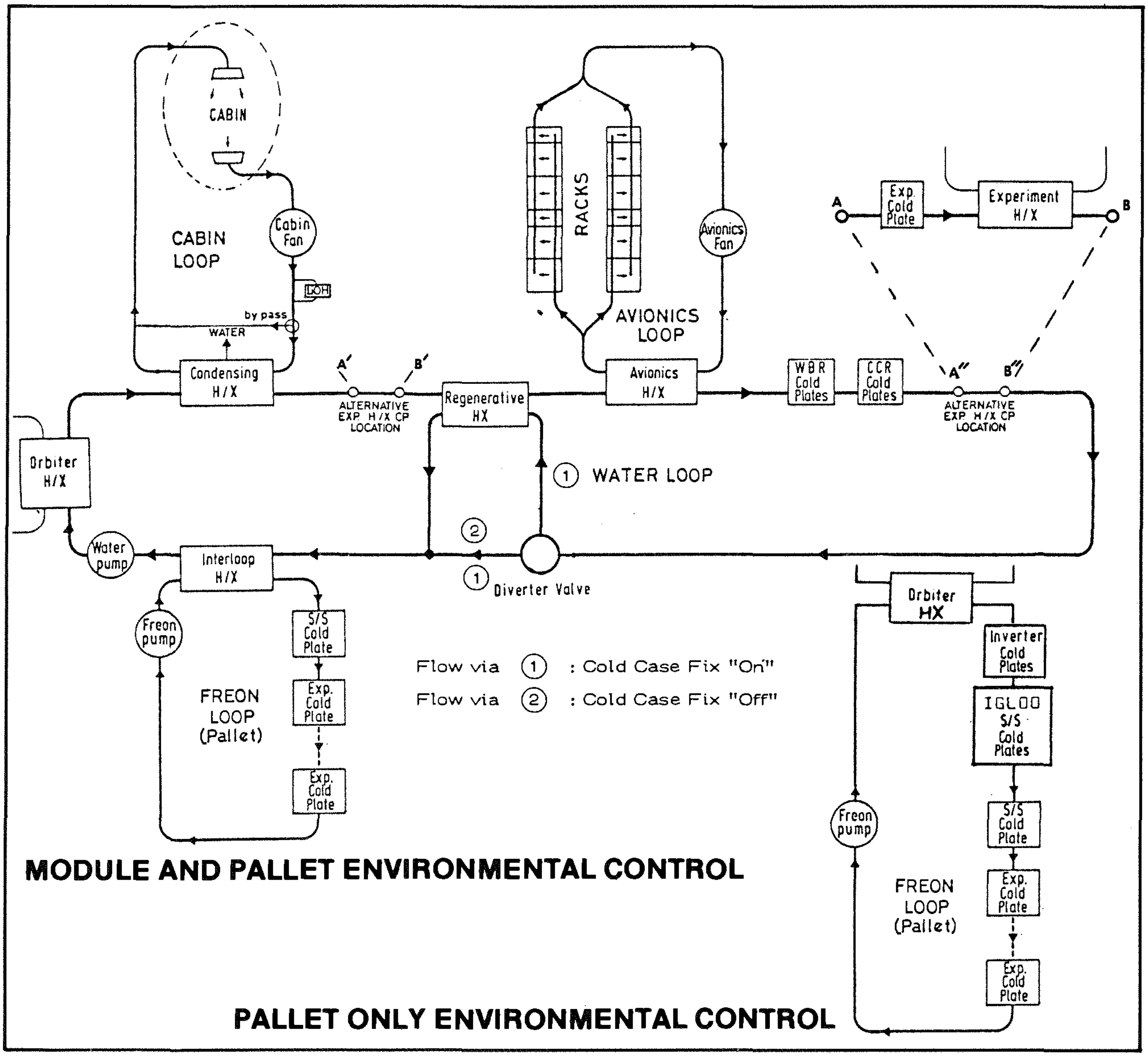
The water pump contains two pumps and an accumulator. Only one pump works at a time. The accumulator regulates the inlet pressure to accommodate thermal expansion and compensate for liquid leakage rates. The pump package is mounted with the thermal capacitor/coldplate stack on the external surface of the front end cone.

3.7.1.4. Module Insulation

The Spacelab module is insulated from the extreme orbital thermal environment with high-performance multilayer insulation (MLI) blankets. The insulation minimizes radiative heat exchange between the module and space.

The insulation blankets consist of 19 layers of double goldized kapton (kapton sheets with a thin layer of vacuum-deposited gold) and 20 layers of dacron net that alternate with the kapton sheets. The blankets are covered externally by teflon coated beta cloth and inboard by a double goldized polyamide nomex reinforced sheet.

The blankets are attached by plastic ball fasteners that fit into stainless steel sockets bonded or riveted to the module. This attachment allows for adequate venting of the enclosed air between the structure and insulation during ascent and repressurization of the enclosed vacuum during descent.



3.7.2 MODULE-PALLET AND PALLET ENVIRONMENTAL CONTROL

When the pallets are flown, either with or without the module, a freon cooling loop is used specifically to service pallet systems. As with the other loops, the primary purpose of the loop is to collect heat dissipated by subsystem and experiment equipment. Freon 21 was selected as a coolant having adequate thermal properties for the extreme orbital thermal environment.

The freon loop collects heat from the pallet-mounted subsystems and experiments through coldplates, some of which have thermal capacitors to store peak heat loads. The coldplates used in the freon loop are bolted to an intermediate support structure which is then attached to the pallet. A maximum of eight coldplates can be used on the pallets on a particular mission. In the pallet-only mode, the subsystem equipment mounted in the Igloo is also serviced by the freon loop.

When module and pallets are flown in combination, the freon loop interfaces with the water loop via the interloop heat exchanger, located in the forward end cone. In the pallet-only mode, the loop interfaces directly with the orbiter payload heat exchanger.

The freon pump package is mounted either externally on the forward end of the module cone or on the front frame of the first pallet in the pallet-only mode.

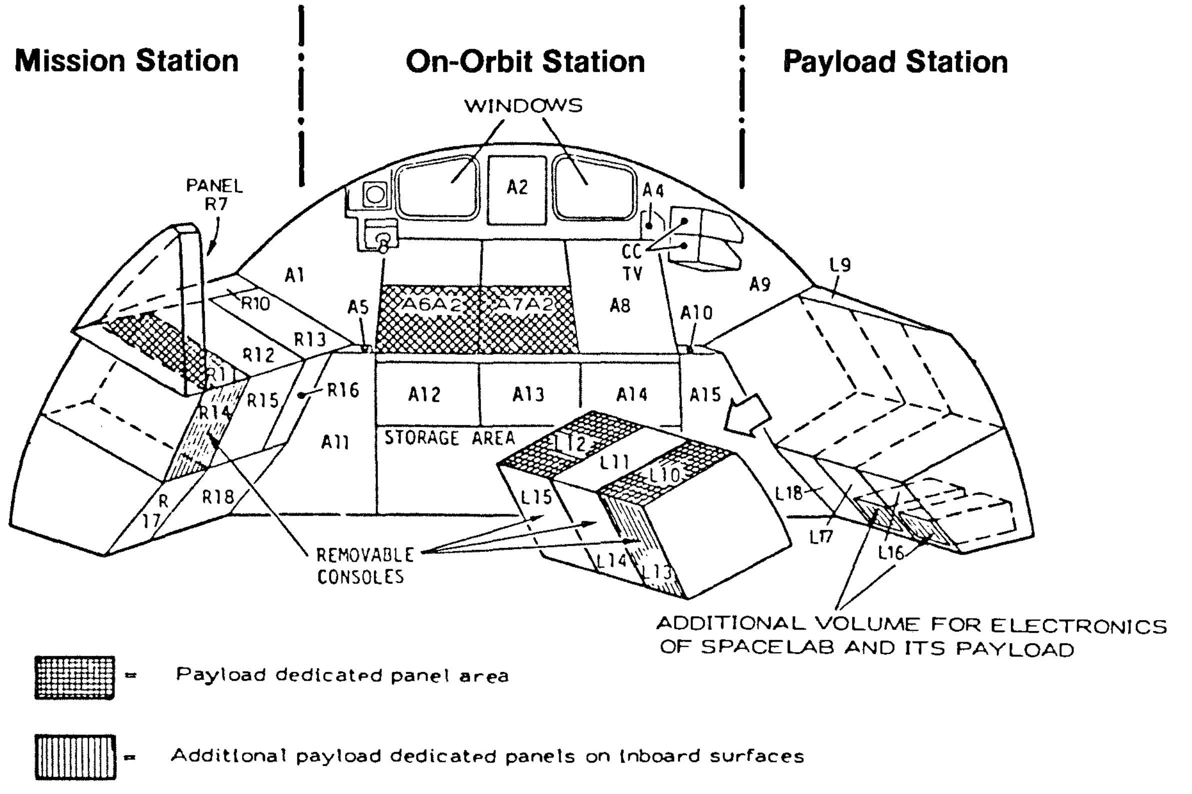
In the pallet-only configuration, thermal coatings are applied to minimize heat leakage and effects of solar radiation. A special paint is used to reduce the hot case temperature of the pallet structure itself. An insulated shield installed between the pallet-mounted coldplates and the pallet structure reduces radiation exchange between these items.

Multilayer insulation thermal tents are also provided for pallet-mounted subsystems; any unused tents are available for experiments.

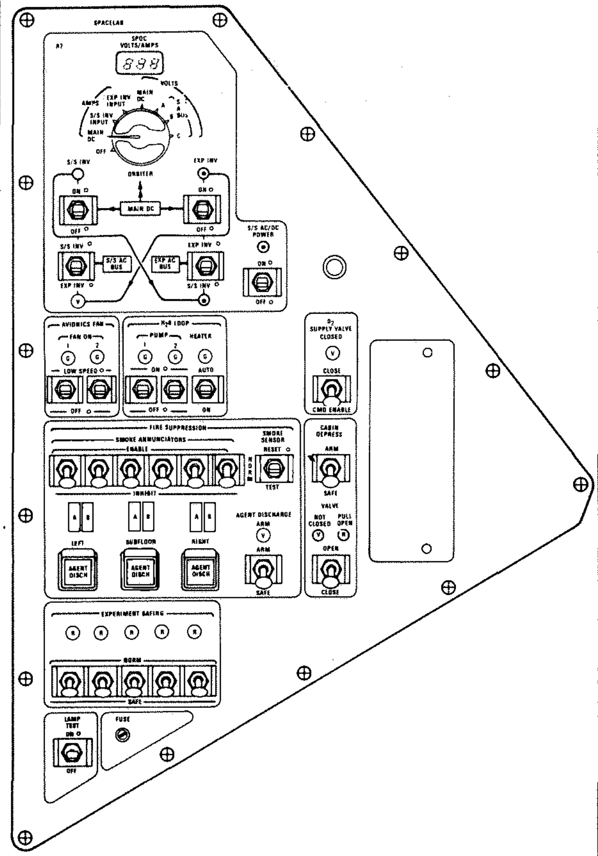
3.8 Orbiter Aft Flight Deck/Mid-deck

Some panel area and volume in the orbiter aft flight deck are available to support Spacelab payload operations. The aft flight deck is divided into three

AFT FLIGHT DECK LAYOUT



SPACELAB CONTROL PANEL R7



work stations: the Mission Station, the On-Orbit Station, and Payload Station. The Payload Station and part of the On-Orbit Station are dedicated to experiment operation. The table below summarizes the physical parameters of payload accommodations in the aft flight deck.

The entire R11, L10, and L12 panels, with their associated volumes, are available to Spacelab payloads. A Standard Switch Panel (SSP) can be accommodated in panel L10. Panel area available on inboard surfaces of consoles L13 and R14 may be used for payload controls and displays. Panels A6-A2 and A7-A2 are reserved for payload, but the resources (cooling, etc.) available here are limited.

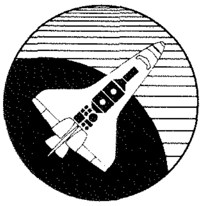
Panels R7 and L11 can be fully dedicated to Spacelab hardware. A Spacelab Data Display System (DDS) with a keyboard can be accommodated in L11 and the associated volume. Additional Spacelab hardware (aft flight deck power distribution box, remote acquisition unit, etc.) is located in the "additional volume for electronics" at the Payload Station. A second data display system for the Spacelab payload can be installed in the Mission Station at panel R11.

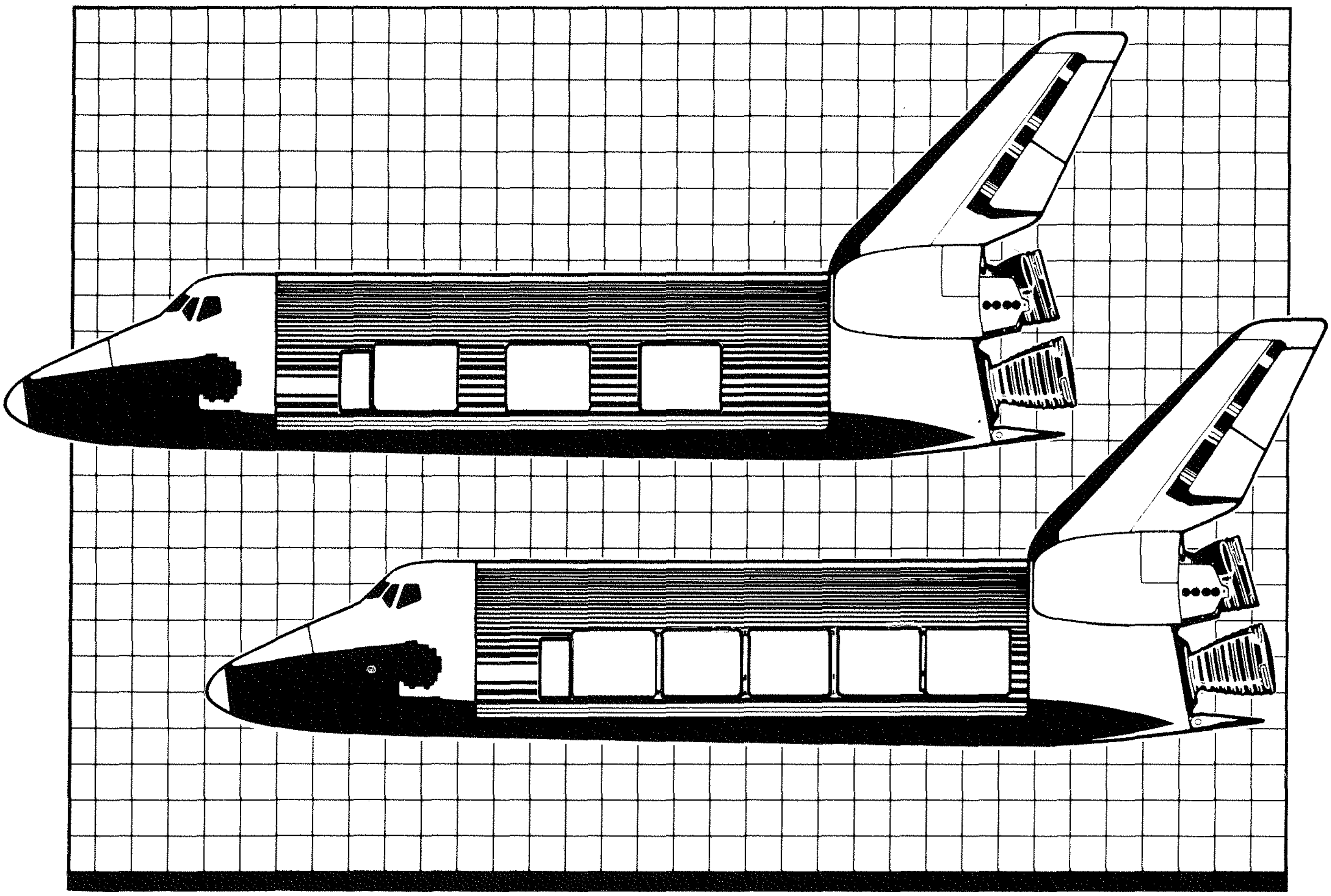
Consoles in the Mission and Payload Stations are removable to permit equipment integration off-line from the turn-around cycle of the orbiter.

Stowage lockers for payload equipment are available in the orbiter mid-deck. These lockers are used for "late-on" / "early-off" items such as plant and animal specimens and blood samples. During flight these perishables are transferred to the module for experiment operations and then returned to the mid-deck for quick recovery after landing. Some experiments may be performed in the mid-deck.

4. SPACELAB AND PAYLOAD SUPPORT OPERATIONS

Support operations for Spacelab and its payload fall into two classes: ground operations and mission operations. In general, ground operations involve handling the Spacelab and experiment hardware through preflight assembly, integration, checkout, launch preparation, and post-flight disassembly and processing. Mission operations involve mission planning, training, simulations, actual flight operations, and delivery of the data after the mission. Teams of management and technical personnel from various NASA centers, as well as contractors and (for the first three missions) ESA personnel, work together to support Spacelab and payload operations. For each mission, NASA designates a mission manager responsible for planning and directing all payload integration and operations activities. The mission management organization ensures that investigators' research needs are satisfied and that Shuttle/Spacelab capabilities are used efficiently.





4. SPACELAB AND PAYLOAD SUPPORT OPERATIONS

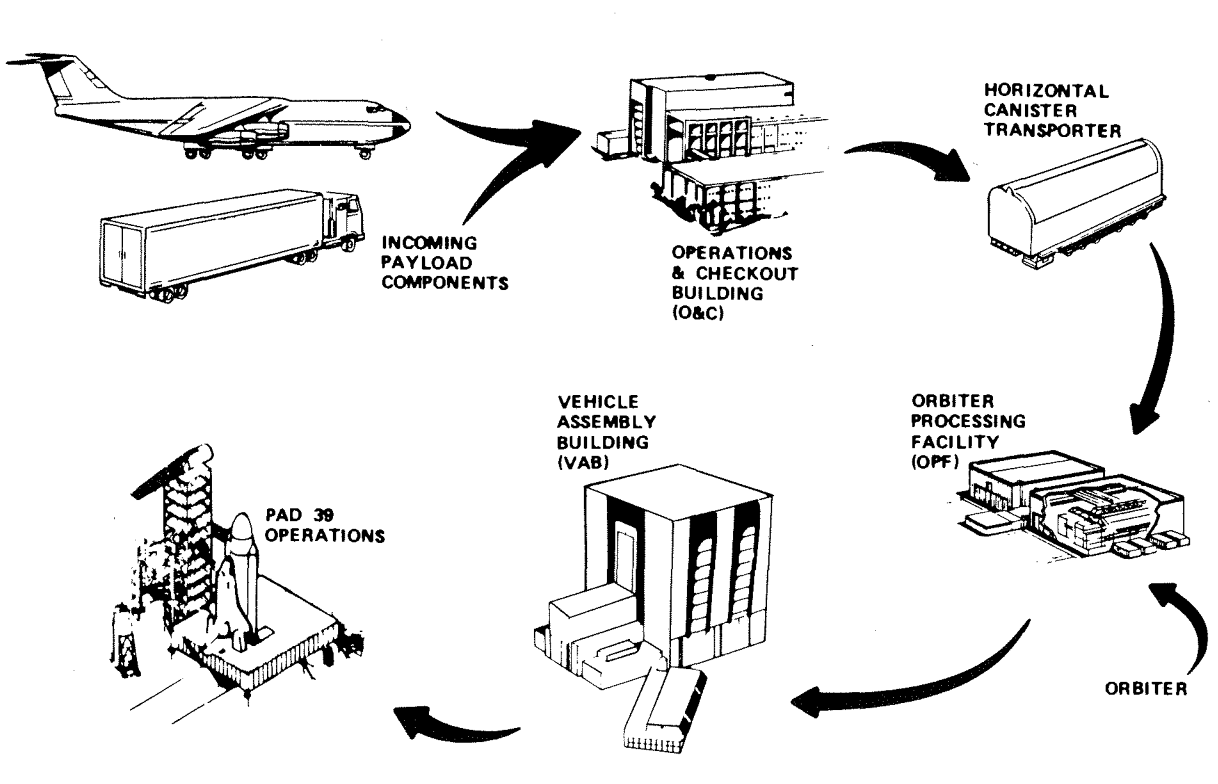
This section describes the typical ground operations required to process a Spacelab and its payload for a mission in the Space Shuttle. Most of these activities occur in the Operations and Checkout (O&C) Building at the Kennedy Space Center in Florida. Spacelab is generally integrated with the Shuttle orbiter in the Orbiter Processing Facility (OPF), also at Kennedy. On-site support is provided by NASA personnel and contractors and also (for the first three missions) by ESA personnel. Remote support of test activities is provided through the Huntsville Operations Support Center (HOSC) at NASA's Marshall Space Flight Center in Alabama.

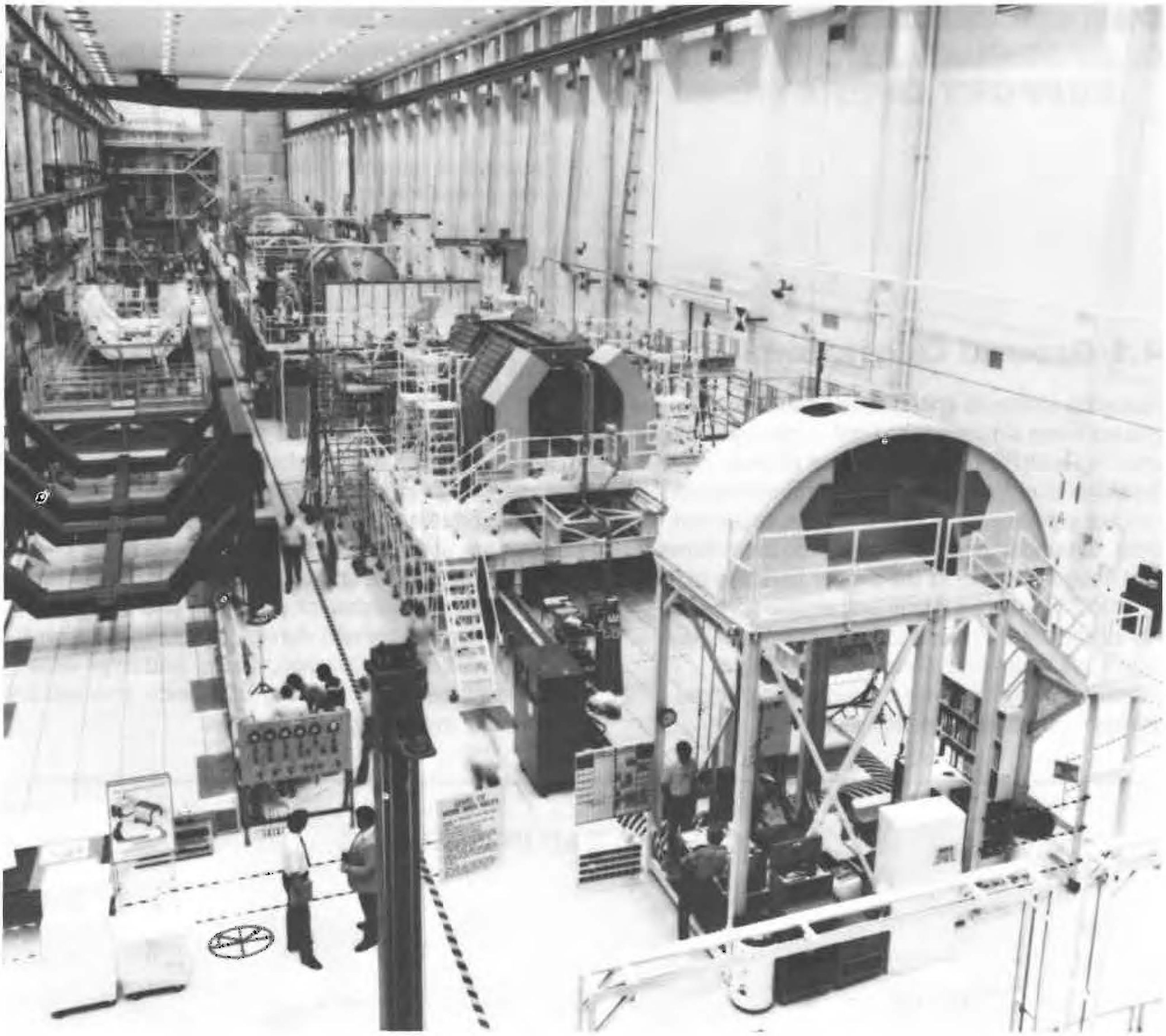
4.1 Ground Operations

Spacelab elements spend most of their time on the ground being prepared for flight or disassembled after flight. During the turn-around phases of the mission cycle, they are handled and moved as individual pieces of equipment and as integrated units. Ground support requirements, procedures and equipment ensure the proper handling of Spacelab and its payloads and enable a host of checks and verifications to be performed. NASA managers base their decisions about flight readiness in part on status information derived through ground support activities.

The assembly of Spacelab and payload hardware is accomplished through a four-phase integration process. Bridge cranes, handling fixtures, special slings, and transportation ground support equipment are used to transfer Spacelab elements between work areas and test stands. Laboratory facilities are available for preparing and maintaining experiment equipment during payload integration. Data links, communication, power, and other essential resources for supporting integration activities are available in Payload User Rooms.

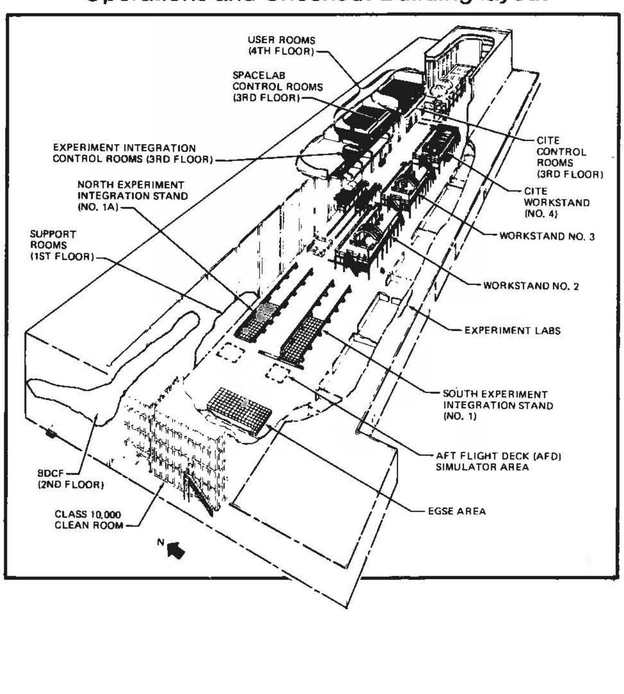
TYPICAL PAYLOAD PROCESSING





Operations and Checkout Building

Operations and Checkout Building layout



4.1.1 STAGING

The first step in the integration process is putting Spacelab components such as pallets and racks into the required configuration for a given mission. Examples of staging activity are the placement of air ducts into racks, the assembly of pallet segments into pallet trains or the placement of the instrument pointing subsystem or igloo onto a pallet. Staging takes place in a holding area in the Operations and Checkout Building.

4.1.2 EXPERIMENT INTEGRATION (LEVEL IV)

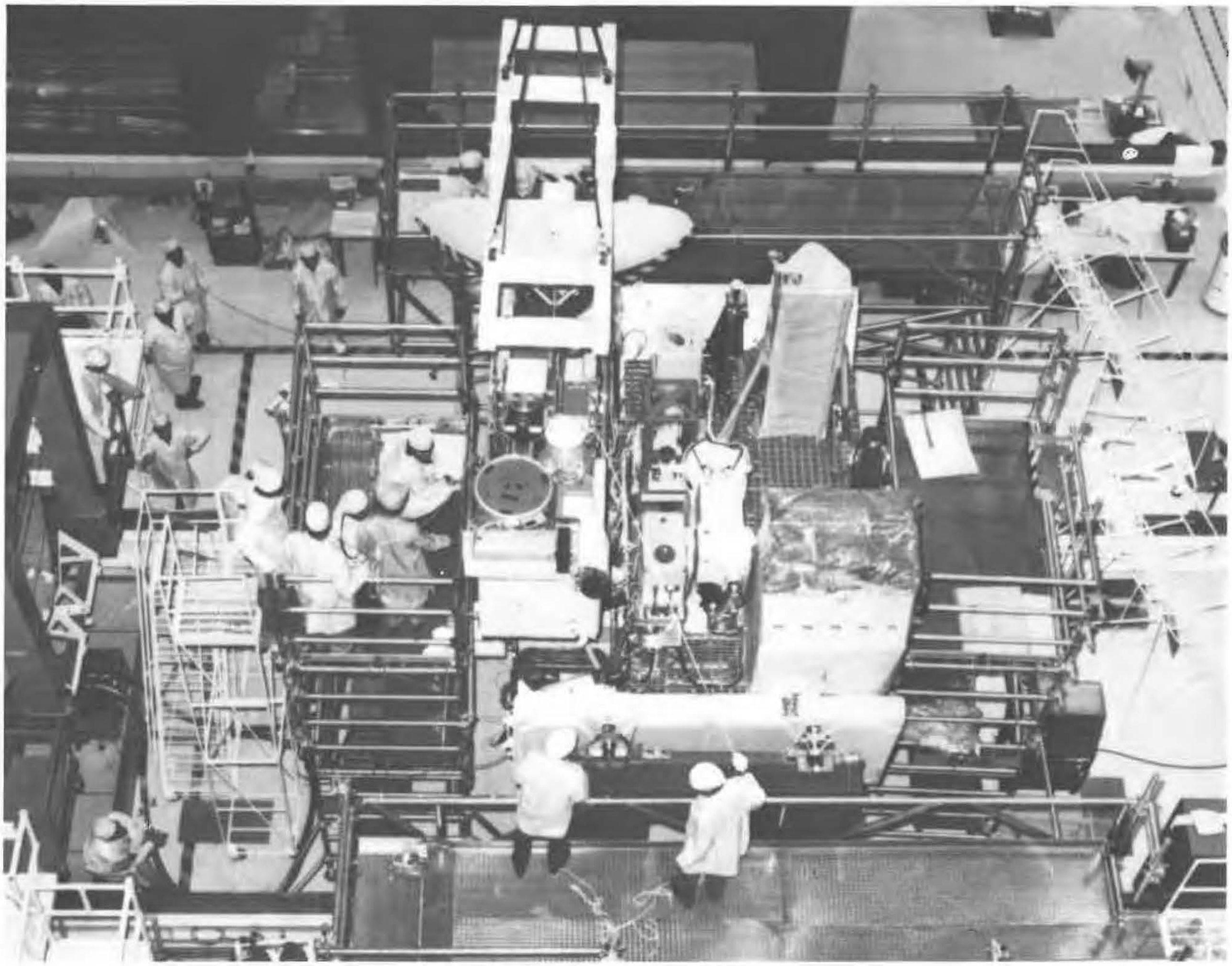
Experiment integration takes place under the auspices of the NASA mission management organization and is not, properly speaking, a Spacelab activity. This phase of ground operations takes place in one of the two Level IV stands in the

Integration of Racks and Floor (Level IV)

Operations and Checkout Building and is conducted by NASA employees with support from contractor technicians.

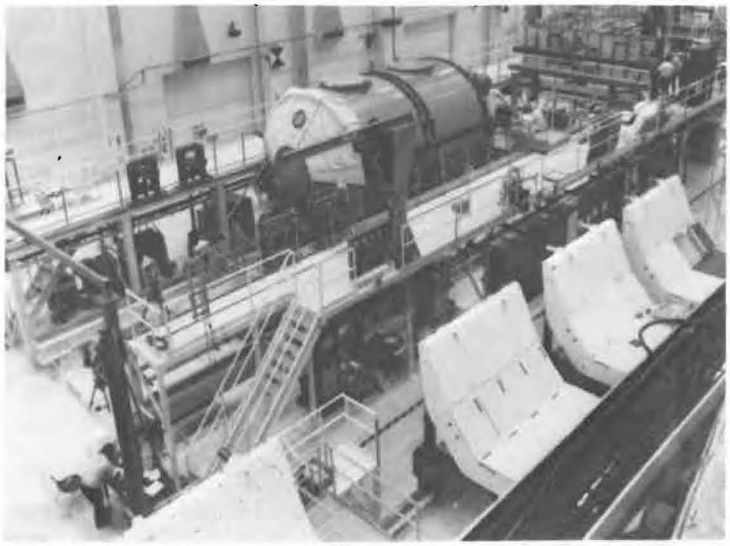
Upon arrival at Kennedy, experiment equipment is generally taken to an off-line laboratory area where it can be functionally tested by the developer prior to on-line activity. After this test, it is installed on pallets or in racks and checked out, and the racks are mounted on the Spacelab experiment floor. During this phase of integration, the experiments are connected to a Spacelab subsystem simulator, the Payload Checkout Unit (PCU), for functional testing.

The final authority on the proper operation of the experiment equipment during Level IV (and at all phases of integration) is the developer of the experiment. Experiment Ground Support Equipment (GSE) is placed in User Rooms on the third floor of the Operations and Checkout Building so that the developer can monitor test activity and report on the proper functioning of the experiment.



Experiment Integration (Level IV) on Pallet


Spacelab Integration (Levels III/II)


Module Close-out (Levels III/II)


Pallet to Module Integration (Levels III/II)

4.1.3 SPACELAB/EXPERIMENT INTEGRATION (LEVELS III/II)

After completion of Level IV, the rack/floor assembly, individual pallets, or pallet trains are moved to one of the two Spacelab integration stands in the Operations and Checkout Building. For a mission that includes a module, the experiment floors with racks attached are slid into the module, the aft end cone is installed on the module and flight connections are made with any pallet(s) included in the mission requirements. For missions using the igloo, all pallet/igloo connections are made. Items to be stowed in the module are generally put in place during Levels III/II. Mounted experiment elements are connected with actual Spacelab subsystems and with Spacelab and experiment flight software for further functional testing.

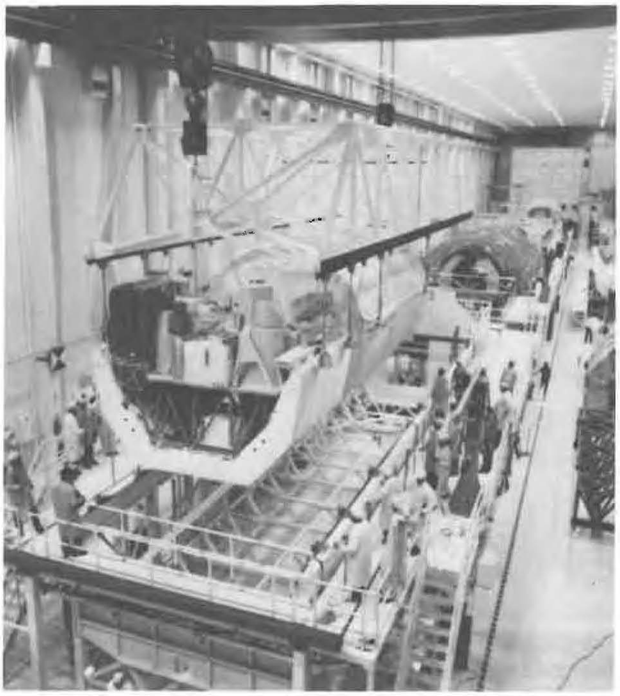
During integration Levels IV and III/II, a number of tests are performed to verify that all systems and interfaces are functioning properly and all Spacelab/payload elements are compatible. Checkout and verification activities are conducted in an integration test stand in the O&C Building. Experiment Ground Support Equipment is used to operate the payload and to monitor the status of experiments during testing. Tests and related data processing are controlled by Automatic Test Equipment (ATE) provided by ESA. Various simulators of Spacelab and orbiter resources are used in these tests.

Major events during the functional testing in Levels IV and III/II are the Mission Sequence Tests in which the payload is run in as close a simulation of actual flight operations as possible. Selected slices of the mission timeline are simulated to exercise Spacelab subsystems, experiment operations, software, and procedures. These tests primarily demonstrate that Spacelab/payload flight hardware and software function properly and compatibly.

4.1.4 CARGO INTEGRATION TEST EQUIPMENT (CITE)

Upon completion of Spacelab systems testing, Spacelab is ready for simulated orbiter-to-cargo testing in the Cargo Integration Test Equipment stand in the Operations and Checkout Building. The CITE stand provides a realistic simulation of the orbiter's mechanical and electrical interfaces for verifying Spacelab-to-orbiter compatibility. Spacelab is processed in this stand only for its first few missions.

Several integrated functional tests are performed at the CITE stand. An orbiter Integrated Test verifies orbiter-to-cargo connections and validates payload data via the orbiter data system as necessary.



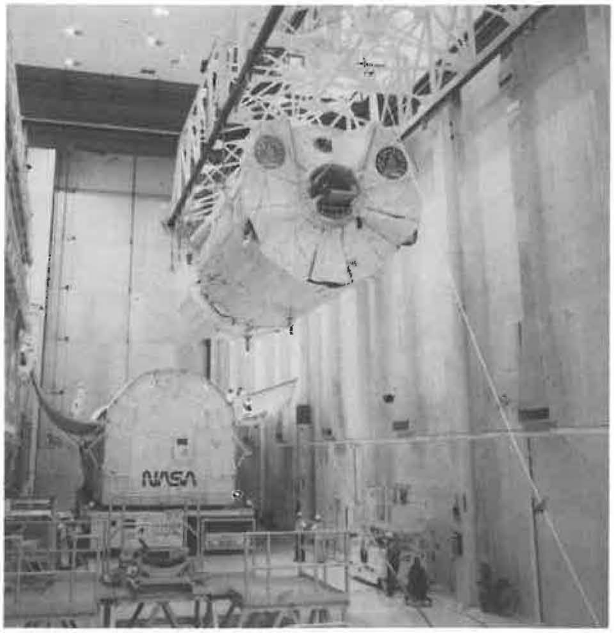
Spacelab Transfer into CITE Stand

For integrated command and data flow tests involving other NASA centers, the CITE stand Launch Processing System (LPS) has a data link with the Mission Control Center (MCC)/Payload Operations Control Center (POCC) at Johnson. This link provides the capability to verify Spacelab payload hardware and software with the two control centers and to send uplink commands to the payload.

4.1.5 SPACELAB/ORBITER INTEGRATION (LEVEL I)

Level I integration generally occurs in the Orbiter Processing Facility, where the assembled Spacelab and its integrated payloads are installed in the Shuttle orbiter and checked out. The Payload Strongback hoists Spacelab as a single assembled unit into the Payload Transportation Canister for transfer from the Operations and Checkout Building to the Orbiter Processing Facility. There, Spacelab is lifted out of the canister, lowered into place in the orbiter cargo bay, and secured. Orbiter-to-Spacelab flight connections are made and verified in a series of tests.

If the mission includes a module, the Spacelab Transfer Tunnel is installed and any inspection access platforms are removed. Final closeout of the payload includes such servicing as battery replacement, film/camera/tape installation, and removal of



Strongback Transfer of Spacelab into Payload Canister

temporary protective covers. Any Spacelab panels in the orbiter aft flight deck will have been installed before Spacelab arrives in the Orbiter Processing Facility. However, experiments to be operated in the mid-deck or items to be stowed in mid-deck lockers may be installed during Level I integration. The orbiter cargo bay doors are closed and the cargo bay environment is maintained by an air purge from processing facility systems until transfer to the Vehicle Assembly Building (VAB) is begun.

After orbiter closeout at the processing facility, the orbiter/Spacelab is transported to the VAB to be vertically mated with the solid rocket booster/external tank elements of the Shuttle. Since no Spacelab activities are planned for the Vehicle Assembly Building, no Spacelab unique facilities or ground support equipment are provided. After the lifting operation, the payload is protected by a purge of clean, cool air.

Payload Transportation Canister

Installation of Spacelab into Orbiter (Level I)

After these mating operations, the Shuttle loaded with Spacelab is transported to the launch pad on the crawler transporter. During the transport to the pad, the payload bay is purged with conditioned air. Only limited Spacelab activity occurs at the launch pad. A final test is run to verify the integrity and serviceability of the entire set of pad/Shuttle/Spacelab system connections. Except to load biological specimens and similar perishables in the orbiter mid-deck or module, no access to Spacelab is planned at the launch pad.

Some Spacelab payloads, such as certain life sciences experiments, can only be installed in Spacelab hours before launch. When it is necessary to install such items, the orbiter and the module can be entered through the Module Vertical Access Kit (MVAK), a special system of hardware for entering Spacelab when it is is a vertical orientation. The access kit is composed of five sets of hardware: the Orbiter Mid-deck Equipment Set, Tunnel Joggle Equipment Set, Module Platform Equipment Set, Utility Equipment Set, and a Hoist Sling Set. Configurations of this hardware provide access to the front side of all racks, the inside of both end cones, the underside of the hinged floor panels, the center aisle experiment dedicated volume and the overhead structure including the stowage containers and airlock.

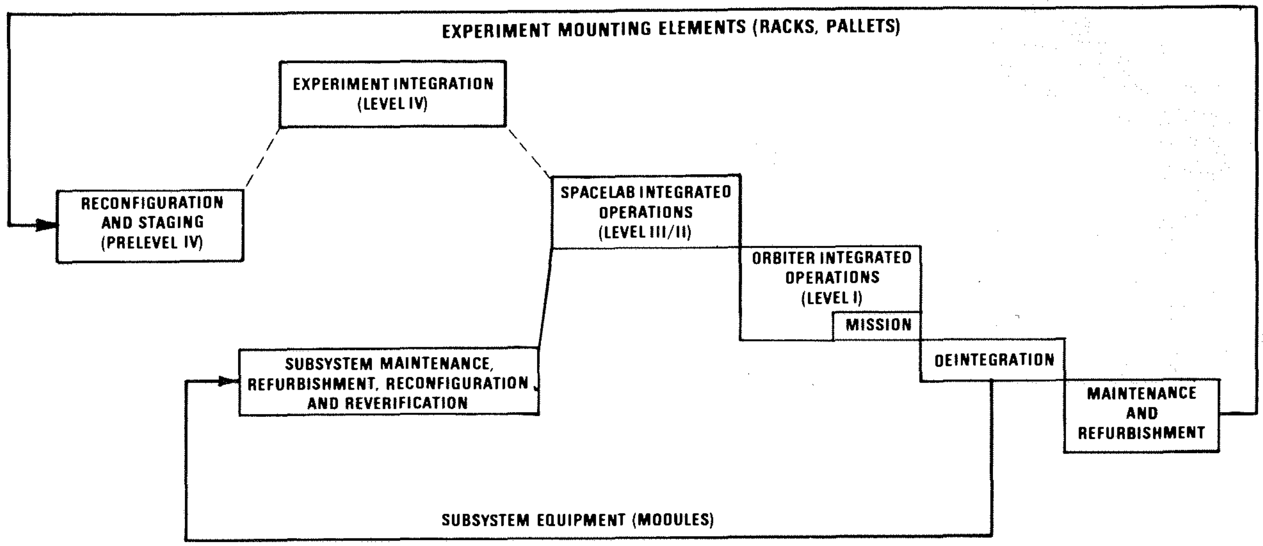
During integration and launch preparation, data pass from Spacelab flight hardware to monitoring equipment through a fiber optics communications network that links the key processing facilities at Kennedy. The system carries considerably more data than conventional wire cables, enabling more efficient Spacelab checkout and launch processing.

4.1.6 DEINTEGRATION

The deintegration process is essentially the reverse of the integration process. It begins on the landing strip where experiment items that must be removed quickly are taken out of the mid-deck and module. The earliest access to items on a pallet occurs when the orbiter is returned to the Orbiter Processing Facility for deservicing. In general, access to non-critical items does not occur until Spacelab is removed from the orbiter and returned to a workstand in the Operations and Checkout Building.

Experiment instruments, samples, film and data are removed and returned to respective principal investigators or sponsors. Standard Spacelab elements are checked, serviced and refurbished as needed before being reconfigured for another mission or placed in temporary storage. It is possible to design a Spacelab mission so the hardware can be reflown with only minimal refurbishment and without deintegration.

TYPICAL SPACELAB TURNAROUND FLOW



RECONFIGURATION AND STAGING (PRELEVEL IV)	EXPERIMENT INTEGRATION (LEVEL IV)	SUBSYSTEM MAINTENANCE, REFURBISHMENT RECONFIGURATION AND REVERIFICATION	SPACELAB INTEGRATED OPERATIONS (LEVEL III/II)	ORBITER INTEGRATED OPERATIONS (LEVEL I)	DEINTEGRATION	MAINTENANCE AND REFURBISHMENT
● REMOVE FROM STORAGE ● PREMISSION RECONFIGURATION ● PALLET STAGING ● RACK STAGING ● POST STAGING VERIFICATION TEST ● PREPARATION FOR SHIPMENT ● INSTALL IN SHIPPING CONTAINER	● EXPERIMENT INSTALLATIONS ● VERIFY INSTALLATIONS ● VERIFY INTERFACES ● FLOW BALANCE TEST ● EXPERIMENT FUNCTIONAL TEST ● PREPARATION FOR TRANSPORT	● MODULE RECONFIGURATION ● INSTALL MISSION DEPENDENT EQUIPMENT ● MODULE MAINTENANCE -SCHEDULED -UNSCHEDULED ● POST MAINTENANCE REVERIFICATION	● RACK/PALLET BUILDUP INSTRUMENT POINTING SYSTEM MATE ● REMOVE INTERNAL ACCESS GROUND SUPPORT EQUIPMENT ● INSTALL RACK AND FLOOR ASSEMBLY ● INSTALL PALLET(S) ● SERVICING ● INTERFACE VERIFICATIONS ● SIMULATED MISSION ● SPACELAB CLOSEOUT ● INSTALL SPACELAB IN CANISTER	● MOVE CANISTER TO ORBITER PROCESSING FACILITY ● INSTALL SPACELAB IN ORBITER ● ORBITER INTEGRATED TEST ● INSTALL TUNNEL ● ORBITER/SPACELAB CLOSEOUT ● VERTICAL ASSEMBLY BUILDING OPERATIONS ● PAD OPERATIONS ● LAUNCH-MISSIONS ● LANDING DESERVICING ● REMOVE SPACELAB FROM ORBITER	● MOVE CANISTER TO OPERATIONS AND CHECKOUT BUILDING ● INSTALL IN TEST STAND ● REMOVE PALLET FROM TEST STAND ● DEMATE AFT END-CONE ● REMOVE RACK AND FLOOR ASSEMBLY	● INSTALL RACK/PALLET STAND ● REMOVE EXPERIMENTS ● DEMATE RACKS FROM FLOORS ● DEMATE PALLETS ● RACK/PALLET MAINTENANCE -SCHEDULED -UNSCHEDULED

4.2 Mission Operations

Whereas ground operations are oriented toward flight hardware/software fit and function, mission operations focus on coordinated activities such as simulations, training, data flow, and real-time monitoring and replanning. Flight operations, from lift off to landing, are the major effort. Mission support activities involve various organizational units working in collaboration to ensure the operational success of a Spacelab mission.

4.2.1 SPACELAB FLIGHT OPERATIONS

Operation of the Spacelab system and subsystems is the responsibility of the Johnson Space Center from the moment of liftoff through landing. These operations are conducted to meet the specific mission requirements for that payload and are conducted from the Mission Control Center (MCC) under the authority of the flight director. Marshall Space Flight Center provides engineering support from the Huntsville Operations Support Center (HOSC).

4.2.2 PAYLOAD OPERATIONS

Payload operations are the responsibility of the mission management organization. These operations can be conducted entirely from the Payload Operations Control Center (POCC) at Johnson or major portions of the operations can be located at a remote POCC, as desired by the mission manager. The operational concept allows for real-time interaction between the individual principal investigator and the flight crew.

4.2.2.1. Payload Operations Control Center (POCC)

The Payload Operations Control Center at Johnson is the site for continual monitoring and control of Spacelab experiments and other attached payloads. It is a command post, communications center and data relay station for principal investigators, mission managers and their support staffs who are headquartered there throughout a mission. All decisions about payload operations are made and transmitted to the Spacelab crew from this control center.

The capabilities of the Payload Operations Control Center include both communications and data processing. Multiplexed Spacelab data are received at up to 48 Mbit/s and converted into separate channels in original input form. These channels are routed to recorders, to the principal investigators' ground support equipment, or to experiment consoles that can display up to 2,500 parameters, updated once per second. The principal investigators

Consoles in the Payload Operations Control Center

monitor their experiments by observing and analyzing the downlinked data. If investigators determine the need to reschedule or develop contingency timelines, real-time changes can be uplinked to the crew. These decisions can be relayed in voice, text or graphic form. In some situations; investigators can operate their experiments by remote control from the center. Thus, scientists and managers on the ground can exercise control over payload operations onboard Spacelab. They can also verify proper experiment configuration and readiness. Information can be transmitted to remote locations (e.g., scientists' laboratories) or information can be received from remote locations.

The Payload Operations Control Center is housed in a 4000 square foot area in a building adjacent to the Mission Control Center. The POCC is composed of a management room, a cadre support and mission replanning room and six user support rooms. Each user support room contains three work stations, each having a CRT terminal and keyboard, a floppy disk unit and a hard copy unit for the user's own payload monitoring. Three overhead monitors display information from Mission Control. Users can view the information displayed on the monitors directly on their own screens by operating a manual select keyboard located at their work stations. Voice communications keysets allow users direct voice communication within the Payload Operations Control Center, with Mission Control, and with Spacelab.

4.2.2.2 Huntsville Operations Support Center (HOSC)

The Huntsville Operations Support Center, a facility at the Marshall Space Flight Center in Alabama, is involved in virtually all phases of Spacelab ground operations and mission operations. It supports prelaunch integration and checkout, simulations and training activities, launch operations, flight operations and post-flight evaluation. The facility includes communications, data processing and display, and related capabilities required to monitor and support a Spacelab mission. Live data from Spacelab and its payloads are monitored at engineering consoles. The center can also support mission replanning, a Payload Operations Control Center function, during simulations and orbital operations.

The Huntsville Operations Support Center activities fall into two domains - Spacelab engineering support and payload operations team training and support. Spacelab support entails monitoring ESA- and NASA-developed Spacelab systems and hardware, working on any problems that arise, and recommending action to Kennedy and Johnson control centers. The nerve center of this facility is the Spacelab Action Center, manned by the Spacelab operations manager, chief engineer, and various team leaders supporting Spacelab operations. The Spacelab Action Center is the clearing house for all Spacelab-related decisions and recommendations to Mission Control Center.

Payload operations team training can occur in the Huntsville Operations Support Center when crew training simulations are held at Marshall. The center contains a simulated Payload Operations Control Center with consoles and physical arrangements identical to the real ones at Johnson. During integrated simulations the Huntsville center serves as the throughput between the Shuttle crew in the Shuttle simulator at Johnson and the Spacelab crew in the Payload Crew Training Complex at Marshall.

A Payload Action Center in the Marshall facility can be the focal point for coordination of Spacelab payload support to Johnson and Kennedy when staffed by the payload operations manager, payload chief engineer, experiments chief engineer, and support team leaders. The Payload Action Center can be used during simulations, pre-launch checkout, orbital operations, and post-flight evaluation.

4.2.3 MISSION PLANNING

The mission manager is responsible for the development of a mission timeline that will accomplish the requirements of the payload within the resource constraints of the Spacelab/orbiter system. When this mission timeline is delivered, Johnson develops an orbiter timeline that accommodates these activities. The mission manager can conduct simulations of these timelines independently. Integrated simulations with the Mission Control Center are conducted in the last three months before launch.

Activity in the Huntsville Operations Support Center

Crew Training/Simulation Activities in Spacelab

4.2.4 FLIGHT CREW

The flight crew for a Spacelab mission may include the commander, pilot, mission specialists, and payload specialists. The commander and pilot are responsible for the operation of the orbiter. The mission specialists are responsible for the operation of the Spacelab and may participate heavily in the payload operations. The payload specialists are dedicated to the operation of the experiments and are generally chosen to participate in only a single mission.

4.2.5 SPACELAB CREW TRAINING

Payload specialists receive intensive training in experiment operations in the laboratories of the principal investigators. In addition, Spacelab crew members undergo two categories of NASA-sponsored training: mission-independent and mission-dependent. The aim of mission-independent training is to develop an understanding of the operation of Spacelab and to develop certain skills for efficient operation in the space environment. Knowledge of the orbiter's living and working conditions and the effects of zero-gravity is gained through training under the auspices of Johnson Space Center.

The most important part of training, and the longest, is mission dependent experiment/payload operations. This involves familiarization with the particular objectives and techniques of the discipline, intimate knowledge of the experiment hardware, sound insight into the methodology involved, and experience in actually operating the experiment under near-flight conditions. For a complex instrument or payload it may be necessary to build a simulator. Payload mission dependent training is the responsibility of the mission management organization.

Mission dependent training in the operation of Spacelab subsystems occurs in the Spacelab Simulator at Johnson. For early Spacelab missions, training in experiment operations controlled through the Spacelab computer system occurs at the Payload Crew Training Complex at Marshall.

4.2.5.1 Spacelab Simulator

The Spacelab Simulator is located at the Johnson Space Center, adjacent to the two Space Shuttle Mission Simulators used to train Shuttle pilots. Its primary role is Spacelab crew training in the areas of command and data management, environmental control, electrical power management, and the caution and warning system.

The main elements of the simulator are the instructor/operator station, the computer complex, signal conditioning equipment, and the crew station module itself. In the module are located all the control subsystems, circuit breakers, fuses, valves, under-floor equipment, power panels, audio panels, and the scientific airlock.

The simulator can be used in three modes: by itself, with the Shuttle Mission Simulator, or in an integrated simulation with the Payload Operations Control Center and Marshall Space Flight Center's Payload Crew Training Complex.

4.2.5.2 Payload Crew Training Complex (PCTC)

The Payload Crew Training Complex at Marshall Space Flight Center is a simulation facility that provides a realistic physical and operation setting for training the Spacelab science crew in the operation of experiments controlled through the onboard computer Command and Data Management Subsystem. Training sessions in the complex simulate the command, control, data display, and communication functions of Spacelab payload operations, These sessions also train the crew to conduct simultaneous experiment operations.

High-fidelity mockups of the Spacelab module and orbiter cabin and lower-fidelity mockups of experiment hardware provide a realistic physical setting

Payload Crew Training Complex

for mission simulations. The training center's computer system creates a realistic operational environment using several different software models to simulate normal operations, problems, simultaneous experiment operations, flight environmental conditions such as vehicle attitude, and visual displays of the earth, sun, and sky.

The complex also contains a simulation control room from which the simulation team can control, monitor, and alter the training session in progress. Crew performance and errors are monitored via closed-circuit television, and faults can be inserted into the simulation to test the crew's problem solving abilities.

The simulation facility is designed to exercise all crew/experiment/computer interactions in a "hands on" training scenario. Simulations in this high-fidelity physical and operational setting prepare the crew for real-time problem solving and decision making.

4.2.6 COMMUNICATIONS

Communications to and from Spacelab flow through the orbiter and the Tracking and Data Relay Satellite System (TDRSS). Depending on orbiter attitude, TDRSS coverage can vary from approximately 30 to 85 percent. This variance is due to blockage of the line of sight from the orbiter Ku-band antenna to the TDRSS by the orbiter body. When communications are possible, voice, commands, and data flow through the TDRSS to the ground station at White Sands, New Mexico. From there, communications are retransmitted via satellite to other NASA centers.

4.2.7 SPACELAB DATA PROCESSING FACILITY (SLDPF)

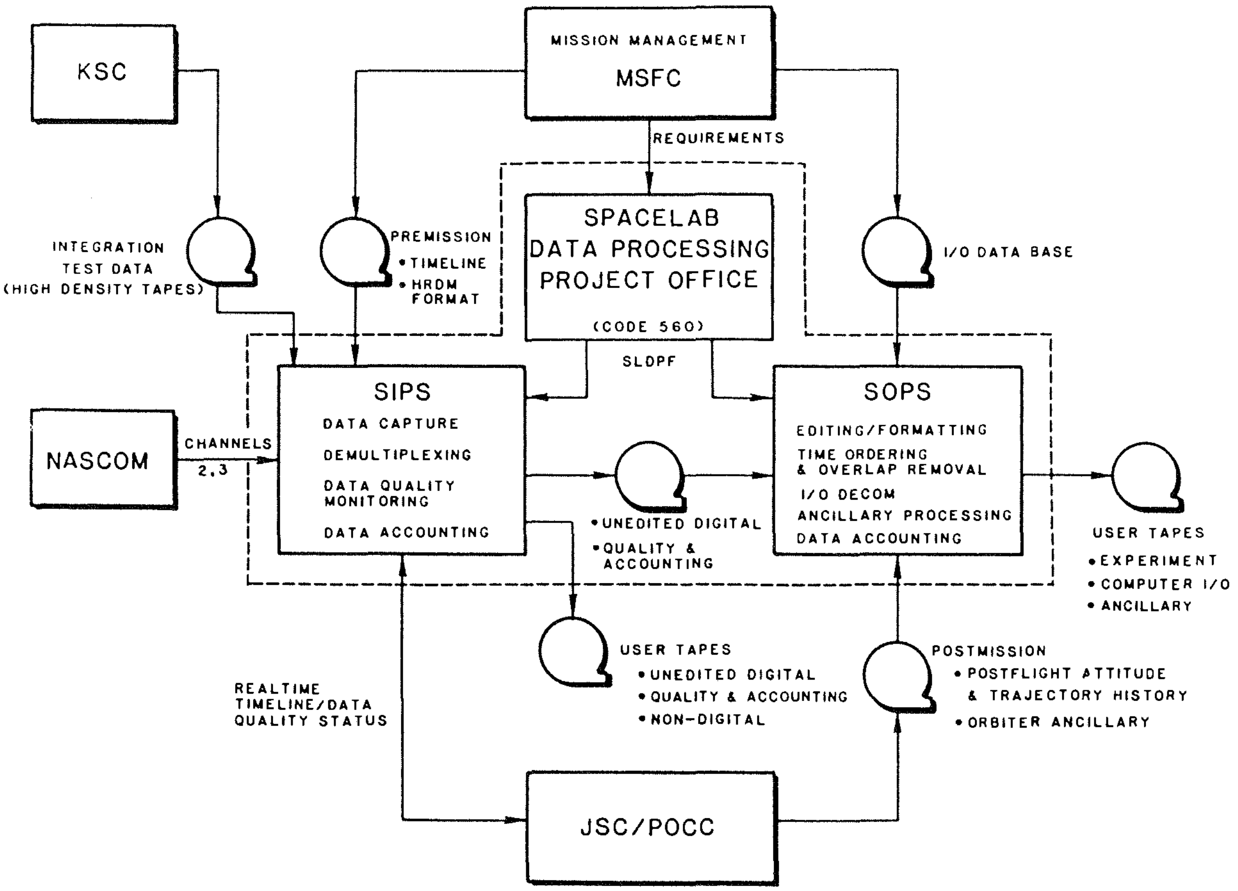
The Spacelab Data Processing Facility at Goddard Space Flight Center in Greenbelt, Maryland, was developed primarily to handle the voluminous streams of payload data from Spacelab experiments. The facility can also handle other attached Shuttle payloads.

During the flight, Spacelab data flow from the Shuttle orbiter to a TDR satellite for downlink to the TDRSS Ground Terminal at White Sands. From there, data are retransmitted to a domestic communications satellite (DOMSAT), then back to Goddard's Network Control Center (NCC), which manages the tracking system, and over to the Spacelab Data Processing Facility. This facility communicates with other NASA centers in the Spacelab data network via NASA's worldwide Communications Network (NASCOM) of voice and data links.

During the flight, all data are received not only at Goddard but at Johnson as well, flowing into the Payload Operations Control Center via the NASCOM-DOMSAT link to White Sands. The POCC can see only four data channels flowing from the orbiting spacecraft, so the data processing facility constantly monitors all 18 channels. If Goddard personnel spot any abnormal science or engineering data, the facility immediately notifies the POCC so that managers there can take action if necessary.

The facility is divided into two major functional elements - the Spacelab Input Processing System (SIPS) and the Spacelab Output Processing system (SOPS). After capturing the digital telemetry data stream, the input system demultiplexes, synchronizes, time tags, quality checks, accounts for the data, and formats the data onto computer-compatible tapes. Further processing of digital data is performed in the output system, where data are edited, time ordered, quality checked, blocked, formatted for distribution, accounted for, and recorded onto tapes for shipment to the user. Audio and analog data products, which are generated in the input system, are output directly to the users. When specifically requested by the users, selected digital tape products may also be obtained from the input system.

SPACELAB DATA PROCESSING FACILITY ACTIVITIES



APPENDIX A

Acronyms and Abbreviations

AC	alternating current
ACCU	audio central control unit
AFD	aft flight deck
ATE	automatic test equipment
BUC	backup computer
C&W	caution & warning system
CCTV	closed circuit television
CDMS	command and data management subsystem
CDR	Critical Design Review
CITE	cargo integration test equipment
CPSE	common payload support equipment
CRT	cathode ray tube
CWEA	caution & warning electronic assembly
DC	direct current
DCR	Design Certification Review
DDS	data display system
DDU	data display unit
DOMSAT	domestic satellite
DPA	data processing assembly
EB	emergency box
ECAS	experiment computer applications software
ECOS	experiment computer operating system
ECS	environmental control subsystem
EGSE	electrical ground support equipment
EPDB	electrical power distribution box
EPDS	electrical power distribution subsystem
EPSP	experiment power switching panel
ERNO	Entwicklungs Ring Nord
ESA	European Space Agency
ESRO	European Space Research Organization
ESTEC	European Space Technology Center
EVA	extravehicular activity
FAR	Final Acceptance Review
GMT	Greenwich mean time
GPC	general purpose computer
GSFC	NASA Goddard Space Flight Center
HDRR	high data rate recorder
HOSC	Huntsville Operations Support Center (MSFC)
HRDA	high rate data acquisition
HRDM	high rate demultiplexer
HRM	high rate multiplexer
IOU	input/output unit
IPS	instrument pointing subsystem
JSC	NASA Johnson Space Center
JSLWG	Joint Spacelab Working Group
JURG	Joint User Requirements Group
KSC	NASA Kennedy Space Center
KUSP	Ku-band signal processor
LPS	launch processing system
MCC	Mission Control Center (JSC)
MDM	multiplexer/demultiplexer
MET	mission elapsed time
MLI	multilayer insulation
MMU	mass memory unit
MSFC	NASA Marshall Space Flight Center
MTU	master timing unit
MVAK	module vertical access kit
NASA	National Aeronautics and Space Administration
NASCOM	NASA Communications Network
NCC	Network Control Center (GSFC)
O&C	Operations and Checkout Building (KSC)
OPF	Orbiter Processing Facility (KSC)
PCB	power control box
PCMMU	pulse code modulation master unit
PCTC	Payload Crew Training Complex (MSFC)
PCU	payload checkout unit
PDR	Preliminary Design Review
PI	principal investigator
POCC	Payload Operations Control Center (JSC)
PRR	Preliminary Requirements Review
RAAB	remote amplifier and advisory box
RAU	remote acquisition unit

SAL	scientific airlock
SCAS	subsystem computer applications software
SCOS	subsystem computer operating system
SIPS	Spacelab input processing system
SL	Spacelab
SLDPF	Spacelab Data Processing Facility (GSFC)
SOPS	Spacelab output processing system
SPDB	subsystem power distribution box
SRR	System Requirements Review
STDN	Space Tracking and Data Network
STS	Space Transportation System
STT	Spacelab transfer tunnel
SWAA	Spacelab window adapter assembly
TDRSS	Tracking and Data Relay Satellite System
UCS	user clock signal
UTC	user time clock
VAA	viewport adapter assembly
VAB	Vehicle Assembly Building (KSC)
VAS	video analog switch
VCU	video control unit
VFI	verification flight instrumentation
VFT	verification flight test
VITR	video instrumentation tape recorder

APPENDIX B

Contractors to ESA

Prime Contractor	Hardware or Service Provided
VFW-FOKKER ERNO Federal Republic of Germany	Project management, system engineering, product assurance, integration, test operations, crew habitability, igloo thermal control, miscellaneous Spacelab components and services
Co-Contractors	
AEG Telefunken Industries Federal Republic of Germany	Electrical power distribution subsystem
Aeritalia Italy	Module structure environmental and thermal control subsystem
Bell Telephone Manufacturing Co. Belgium	Electrical power distribution subsystem
Dornier Federal Republic of Germany	Instrument pointing subsystem, Environmental control/life support subsystem
Fokker Netherlands	Scientific airlock, common payload support equipment
Hawker Sidley Great Britain	Pallet structure
Kampsax Denmark	Computer software
MATRA France	Command and data management subsystem
SABCA Belgium	Igloo structure, utility bridge, common payload support equipment
Sener Spain	Mechanical ground support equipment
Subcontractors	
AEG–Ulm Federal Republic of Germany	ASCE, intercom system
Aeritalia Italy	Airlock manufacturing

Contractor	Hardware or Service Provided
Brunswick Lincoln United States	Nitrogen tanks
Carleton Control United States	Atmosphere storage and control system
Celesco United States	Fire detection and suppression
CII France	Computer
Compagnie Industrielle Radio Electronique Switzerland	Simulators, Orbiter interface adapter
Dornier Federal Republic of Germany	Subsystem computer operating system coding
Draeger Federal Republic of Germany	Ground support equipment
Elec. Zentr. Denmark	Pressure decay sensor
ERNO Federal Republic of Germany	Condensate storage assembly
ETCA Belgium	Measuring and stimuli equipment
Hamilton Standard United States	Pumps, cabin loop
Instituto Nacional de Technica Spain	Subsystem power distribution box, mechanical ground support equipment
Martin Marietta United States	Demultiplexer
Messerschmitt Bolkow Blohm (MBB) Federal Republic of Germany	Multiplexer
Microtecnica Italy	ATCS components, pump package
Nord Micro Elektronix Federal Republic of Germany	Avionics loop

Contractor	Hardware or Service Provided
Odetics United States	Recorder
OKG Austria	Mechanical ground support equipment, viewport adapter assembly, manifolds, nitrogen shut off valve control
Rovsing Denmark	Computer software
Standard Electric Lorenz Federal Republic of Germany	Remote acquisition units, caution & warning system
Terma Denmark	Normal and emergency lights
Thompson CSE France	CRT data display TV monitor
Vereinigte Flugtechnische Werke (VFW) Federal Republic of Germany	Real-time software support facility, mechanical ground support equipment

Consultants

McDonnell Douglas and TRW
United States

CONTRACTORS TO NASA

Contractor	Hardware or Service Provided
*McDonnell Douglas Technical Services Co. Huntsville, Alabama *prime contractor, all others listed are subcontractors to MDTSCO	Integration of Spacelab into Shuttle
Brunswick Aerospace Costa Mesa, California	Smoke detector assemblies
Carleton Group, MOOG, Inc. East Aurora, New York	Partial pressure oxygen sensors, oxygen-nitrogen control panel, various assemblies and spares
General Products Brownsboro, Alabama	Fabrication of various mechanical parts for NASA provided hardware (e.g., brackets on Module Vertical Access Kit)

Contractor	Hardware or Service Provided
Goodyear Aerospace Corp. Akron, Ohio	Flexible sections of Spacelab Transfer Tunnel
Hamilton Standard Windsor Locks Connecticut	Water and freon pump packages and spares for atmosphere revitalization system
HTL K-West Santa Ana, California	Verification Flight Instrumentation avionics hardware/signal conditioners
IBM Huntsville, Alabama	Software development and software integration for both experiment and subsystems computers
Intek, Inc. Columbus, Ohio	Water and freon flow meter
Intergraph Corp. Madison, Alabama	Avionics software
McDonnell Douglas Corp. Huntington Beach, California	Spacelab transfer tunnel
McDonnell Douglas Corp. St. Louis, Missouri	Fabrication of frame for window adapter assembly
MK Associates Huntsville, Alabama	Engineering/design support for NASA-provided hardware
O.C. Jean and Associates Huntsville, Alabama	Engineering support
Odetics Anaheim, California	High data rate recorder
Systron Donner Concord, California	Verification Flight Instrumentation avionics hardware, accelerometers
TRW, Huntsville, Alabama	Software
Wyle Laboratories Huntsville, Alabama	Test support for qualification of mechanical parts

APPENDIX C

Memorandum of Understanding Between the National Aeronautics and Space Administration and the European Space Research Organisation for a Cooperative Programme Concerning Development, Procurement and Use of a Space Laboratory in Conjunction with the Space Shuttle System

Preamble

Pursuant to the offer of the Government of the United States of America to Europe to participate in the major U.S. space programme which follows the Apollo programme, and in particular in the development of a new space transportation system (Space Shuttle), the execution of which has been entrusted by the Government of the United States of America to the National Aeronautics and Space Administration (NASA), European States, members of the European Space Research Organisation (ESRO), have manifested their desire to develop a Space Laboratory, hereinafter referred to as "SL", in the form of a Special Project within ESRO, for the purpose of participation in the Space Shuttle programme. These States, by means of an international Arrangement have charged ESRO or its successor organisation with the execution of the SL programme. In order to provide for appropriate association of the two Agencies in the execution of both programmes and in order to assure the necessary coordination between them, NASA, acting for and on behalf of the Government of the United States of America, and ESRO, acting for and on behalf of the Governments of those States participating in this Special Project, have drawn up this Memorandum of Understanding which sets out the particular terms and conditions under which such association and coordination will be effected. This Memorandum of Understanding will be subject to provisions of the Agreement between the Governments of the above participating States and the Government of the United States of America concerning this cooperative programme.

ARTICLE I

Objectives

The purpose of this Memorandum of Understanding is to provide for the implementation of a cooperative programme in which ESRO undertakes to design, develop, manufacture and deliver the first flight unit of an SL, and other materials described in this Memorandum. This flight unit will be used as an element to be integrated with the Space Shuttle. This Memorandum sets out furthermore the provisions for ESRO access for use of the SL and for the procurement by NASA of additional SLs, and establishes the cooperative structure between NASA and ESRO for dealing with all questions concerning interface between the Shuttle and SL programmes and concerning the missions to be defined.

ARTICLE II

General Description of the SL Programme, its Interface with the Space Shuttle, and its Uses

1. SUMMARY DESCRIPTION OF THE SPACELAB PROGRAMME

The SL programme provides for the definition, design and development of mannable laboratory modules and unpressurised instrument platforms (pallets) suitable for accommodating instrumentation for conducting research and applications activities on Shuttle sortie missions. The SL module and SL pallet will be transported, either separately or together to and from orbit in the Shuttle payload bay and will be attached to and supported by the Shuttle orbiter throughout the mission. The module will be characterised by a pressurised environment (permitting the crew to work in shirt sleeves), a versatile capability for accommodating laboratory and observatory equipment at minimum cost to users, and rapid access for users. The pallet, supporting telescopes, antennas and other instruments and equipments requiring direct space exposure, will normally be attached to the module with its experiments remotely operated from the module, but can also be attached directly to the Shuttle orbiter and operated from the orbiter cabin or the ground. Both the module and the pallet will assure minimum interference with Shuttle orbiter ground turnaround operations.

2. INTERFACE WITH SHUTTLE

The Shuttle will: serve in missions to deliver payloads to earth orbit; maintain station on orbit for mission durations in the order of seven days or more; provide safety monitoring and control over payload elements throughout the missions; and provide seating and complete habitability for crews, including free movement between the SL module and the Shuttle. In the interest of minimising developmental and operational costs, and maximising reliability, an effort will be made to optimise commonality between SL and Shuttle components.

3. USE OBJECTIVES

The SL will support a wide spectrum of missions for peaceful purposes and will accept readily the addition of special equipment for particular mission requirements. The SL will facilitate maximum user involvement and accessibility. The flight equipment complement will be capable of augmentation as appropriate to satisfy approved programme needs. It will be possible for users to utilise the SL with or without supplementary equipment for a single experiment or, in the alternative, to utilise only a small portion of the SL in combination with other experiments. The standard resources of the SL may be utilised to any degree appropriate by an experimenter adhering to standardised interfaces which are to be defined and procedures which are to be set forth. Considerable flexibility in equipment and mission structuring shall be available to the user for effective mission operation.

ARTICLE III

Phasing and Scheduling

1. PHASE B STUDIES

Based on present schedules, the Phase B (preliminary design) studies of the SL are expected to be completed around the end of 1973.

2. PHASES C & D

At the completion of the Phase B studies, the parties will mutually agree on a design for immediate implementation and development by ESRO in Phases C & D (final design and hardware development and manufacture).

3. COMPLETION SCHEDULES
It is currently planned that the first operational space flight of the Shuttle will occur in late 1979. To permit adequate time for experiment integration, check-out and compatibility testing, the SL flight unit shall be delivered to NASA about one year before the first operational Shuttle flight.

4. SCHEDULE CHANGES
Each party will keep the other fully and currently informed of factors affecting the schedules of the Shuttle and the SL respectively and their potential effects on flight readiness.

ARTICLE IV

Programme Plans

The foregoing gross descriptions of the SL programme and of the phasing, scheduling and working arrangements are amplified in greater detail in the preliminary version, dated 30 July 1973, of the Joint Programme Plan. The parties recognise that many issues remain to be resolved in the Joint Programme Plan, which is to be developed and updated as appropriate by the Programme Heads. This plan is to be based on the results of preliminary design studies now in progress in both Europe and the United States, on the results of independent and joint studies of user requirements, and on the final definition of, and the requirements for intetgration with, the Shuttle.

ARTICLE V

Respective Responsibilities

1. ESRO RESPONSIBILITIES

Among ESRO's responsibilities are the following:

(a) design, develop and manufacture one SL flight unit (consisting of one set of module and pallet sections), one SL engineering model, two sets of SL ground support equipment, initial SL spares, along with relevant drawings and documentation; and qualify and test for acceptance this equipment according to NASA specifications and requirements;

(b) deliver to NASA the items listed above;

(c) design, develop and manufacture such elements as ESRO and NASA may agree to be necessary for the programme in addition to those listed in (a) above;

(d) establish in the U.S. and accommodate in Europe agreed liaison personnel;

(e) provide all necessary technical interface information;

(f) provide agreed progress and status information;

(g) following delivery of the above flight unit, maintain and fund an SL sustaining engineering capability through the first two SL flight missions, and ensure for NASA's account the future availability to NASA of such engineering capability to meet NASA's operating requirements, on the same conditions as would apply to ESRO;

(h) ensure the production in Europe and possibility of procurement by NASA of subsequent flight units, components and spares; and

(i) provide for preliminary integration of experiments which ESRO supports, as well as acquire the corresponding data, within the overall responsibilities of NASA described in paragraph 2 (j) of this Article, and process it.

2. NASA RESPONSIBILITIES

Among NASA's responsibilities are the following:

(a) establish in Europe and accommodate in the U.S. agreed liaison personnel;

(b) provide general technical and managerial consultation;

(c) provide all necessary technical interface information;

(d) provide agreed progress and status information;

(e) monitor ESRO technical progress in selected areas as defined in the Programme Plans;

(f) review and concur in the implementation of ESRO activities critical to the NASA programmatic requirements for the SL as defined in the Programme Plans;

(g) specify, in order to assure successful operation of the SL in the Shuttle system, operational plans, and hardware and operational interfaces as defined in the Programme Plans;

(h) conduct systems analyses for development of operational concepts and utilisation plans, and assess the impact of changes at all SL external interfaces;

(i) develop selected peripheral components, not part of, but necessary to the successful operation of the SL (e.g. access tunnel, docking ports); and

(j) manage all operational activities subsequent to the delivery of the SL, including experiment integration, crew training, check-out, flight operations, refurbishment, data acquisition, preliminary processing and distribution of data.

3. By agreement of the NASA Administrator and the Director General of ESRO, changes may be made in the above responsibilities, as may be desirable for the implementation of this cooperative programme.

ARTICLE VI

Coordination—Liaison—Reviews

1. PROGRAMME HEADS

Each of the parties has designated in their respective Headquarters an SL Programme Head. They will be responsible for the implementation of this cooperative programme and they will meet and communicate as they require.

2. PROJECT MANAGERS

In addition, each of the parties will designate an SL Project Manager responsible for day-to-day coordination in the implementation of this cooperative programme.

3. JOINT SPACELAB WORKING GROUP (JSLWG)

The two Programme Heads will together establish a Joint SL Working Group with appropriate technical representation from each party. The Programme Heads will be co-chairmen of the JSLWG. The JSLWG will be the principal mechanism for:

(a) the exchange of information necessary to inform both parties fully of the status of both the Shuttle and the SL;

(b) monitoring interface items, problems and solutions;

(c) early identification of issues or problems of either party which may affect the other; and

(d) assuring early action with respect to any problems or requirements.

4. LIAISON

The parties shall each provide and accommodate liaison representation at levels as mutually agreed. The representation will be such as to assure each party adequate visibility of the other's progress especially with regard to interfaces and their control. ESRO shall have representation on appropriate Shuttle change control boards to assure adequate opportunity to present the views and interests of ESRO with respect to any change. The ESRO representatives on the boards will have a voice but will not vote. NASA will have similar representation on the comparable ESRO SL board. ESRO and NASA will enable and arrange for visits to their respective contractors as required.

5. PROGRESS REVIEWS

Each party shall schedule progress reviews of its work in the Shuttle and SL programmes and shall provide access to the other to such reviews. Annual reviews will be conducted by the NASA Administrator and the ESRO Director General.

ARTICLE VII

Funding

1. COSTS

NASA and ESRO will each bear the full costs of discharging their respective responsibilities arising from this cooperative programme, including travel and subsistence of their own personnel and transportation charges for all equipment for which they are responsible.

2. AVAILABILITY OF FUNDS

The commitments by NASA and ESRO to carry out this cooperative programme are subject to their respective funding procedures.

3. PRINCIPLE ON PRICING

Neither party will seek to recover government research and development costs incurred in the development of items procured from the other in connection with this cooperative programme.

ARTICLE VIII

NASA Procurement of Spacelabs

1. PRINCIPLE

Subsequent to the delivery by ESRO of the SL unit and other items referred to in Article V, 1 (a), NASA agrees to procure from ESRO whatever additional items of this type it may require for programmatic reasons, provided that they are available to the agreed specifications and schedules and at reasonable prices to be agreed. NASA should give an initial procurement order of at least one SL at the latest two years before the delivery of the SL unit referred to above. Recognising the desirability of gaining operational experience with the first flight unit before ordering additional units, but that the price and availability of production units will be dependent on the maintenance of a continuing production capability, NASA will endeavour to provide significant lead time for any subsequent procurement order.

2. NASA ABSTENTION FROM SPACELAB DEVELOPMENT

NASA will refrain from separate and independent development of any SL substantially duplicating the design and capabilities of the first SL unless ESRO fails to produce such SLs, components and spares in accordance with agreed specifications and schedules and at reasonable prices to be agreed. For any NASA SL programme requirements which are not met by SLs developed under this cooperative programme, NASA will have the right to meet such requirements either by making the necessary modifications to the SLs developed under this cooperative programme, or by manufacturing or procuring another SL meeting such NASA requirements.

3. NOTICE OF PROSPECTIVE REQUIREMENTS

NASA will endeavour to give ESRO advance notice of any prospective requirements for substantially modified or entirely new SLs so as to provide ESRO with an opportunity to make proposals which might meet such requirements.

ARTICLE IX

Contingencies

1. NON-COMPLETION OF FIRST SPACELAB OR FAILURE TO MEET SPECIFICATIONS

NASA's obligations with respect to the SL shall lapse and ESRO will turn over to NASA without charge and without delay all drawings, hardware and documentation relating to the SL if ESRO abandons the development of the SL for any reasons, or ESRO is otherwise unable to deliver the SL flight unit prior to the first operational Shuttle flight, or the completed SL does not meet agreed specifications and development schedules. The right of NASA to use said drawings, hardware and documentation shall be limited to the completion and operation of the SL programme. ESRO shall ensure that it will be in a position to provide as hardware any proprietary item for which it does not hold transmissible rights of reproduction.

2. NON-AVAILABILITY OF SUBSEQUENT SPACELABS

If SLs, components and spares required by NASA after the first flight unit are not available to NASA in accordance with agreed specifications and schedules and at reasonable prices to be agreed, NASA shall be free to produce such units in the United States. For this purpose, ESRO will arrange in advance on a contingency basis any necessary licensing arrangements.

3. DESIGN CHANGES

While it is understood that ESRO will be represented on the Shuttle change control board, NASA reserves the right to require changes affecting the interfaces or operational interactions between the Shuttle and the SL after hearing and considering ESRO's views with respect to the prospective effect of such changes on the SL design or cost. NASA recognises the desirability of avoiding changes resulting in a disproportionate impact on the SL programme. To the extent that changes affect the Shuttle and SL programmes, NASA and ESRO will bear the increases in the costs of their respective Shuttle and SL development contracts.

ARTICLE X

Access to Technology and Assistance by NASA

1. PRINCIPLES

(a) ESRO will have access to technology, including know-how, available to NASA and needed to accomplish successfully its tasks under this cooperative programme; for the same purposes, NASA will have access to technology, including know-how, available to ESRO. NASA will do its best to arrange for such technical assistance as ESRO and its contractors may require for the satisfactory completion of the SL programme. Access to technology and arrangements for technical assistance shall be consistent with applicable U.S. laws and regulations.

(b) NASA will make available to ESRO general information related to the design, development, and use of the Shuttle and orbital system, particularly that required for the understanding of that system.

(c) Requests for use of technology, including know-how, in other than SL development and production tasks will be considered on a case-by-case basis.

(d) To the extent that NASA can make the required information readily available, it will do so without charge; in other cases, NASA will use its best efforts to facilitate its availability on favourable conditions.

(e) The access to technology, including know-how, referred to above will be effected in such a way as not to infringe any existing proprietary rights of any person or body in the United States or Europe.

2. JOINT DEFINITION OF AREAS

The two parties shall provide for the earlist possible joint definition of areas in which help in the procurement of hardware and technical assistance from U.S. Government Agencies or nationals may be required.

3. FORM OF ASSISTANCE

In providing such help to ESRO as may be agreed, NASA may respond on an in-house basis or may refer ESRO and/or its contractors to U.S. contractors. NASA reserves the right to arrange for such assistance in the form of hardware, rather than know-how.

4. QUALITY CONTROL AND ACCEPTANCE

Where ESRO needs to procure U.S. hardware, NASA agrees to use its good offices in connection with arranging the services of U.S. quality control and acceptance and cost control and auditing personnel in U.S. plants where available and appropriate.

5. FACILITATION OF EXPORT LICENSES

Early advance notification of contemplated ESRO procurements of U.S. hardware or technology, including know-how, will facilitate assistance by NASA in connection with arrangements for export licenses consistent with applicable U.S. laws and regulations.

6. USE OF U.S. FACILITIES

Where it is jointly determined that it is appropriate and necessary for the conduct of the cooperative programme, NASA will use its good offices in connection with arranging for the use of U.S. Government or contractors' facilities by ESRO and/or its contractors.

ARTICLE XI

Principles Concerning Access to and Use of Shuttle/SL

1. PLANNING

There shall be adequate European participation in NASA planning for Shuttle and SL user requirements, with a view to providing for inputs relevant to both the SL design and to European use of the SL. Appropriate representation and relevant procedures are being jointly prepared and will be subject to agreement by NASA and ESRO.

2. FLIGHT CREWS

Flight crew opportunities will be provided in conjunction with flight projects sponsored by ESRO or by Governments participating in the SL programme and utilising the SL. It is contemplated that there will be a European member of the flight crew of the first SL flight.

3. SPECIAL PROVISIONS FOR THE USE OF THE FIRST SPACELAB FLIGHT UNIT

(a) In order to assure the integrity of operation and management of the Shuttle system, NASA shall have full control over the first SL unit after its delivery, including the right to make final determination as to its use for peaceful purposes.

(b) With regard to the first flight of the first SL unit, the system test objectives will be the responsibility of NASA. The experimental objectives of this first flight will be jointly planned on a cooperative basis. Thereafter, the cooperative use of this first SL unit will be encouraged throughout its useful life although not to the exclusion of cost reimbursable use. NASA will otherwise have unrestricted use of the first SL unit free of cost.

(c) NASA may make any modifications to the first SL which it desires. Should NASA find it desirable to effect major modifications to this unit, these shall be discussed with ESRO which will be given the opportunity to provide modification kits. With respect to minor modifications, the normal procedures for configuration control will be relied on to provide adequate information on changes.

4. SUBSEQUENT AVAILABILITY AND PREFERRED ACCESS TO PARTICIPANTS

While it is premature to define the ultimate terms and conditions for operation and use of the Shuttle with the SL after the first SL mission, it is expected that the following principles will apply:

(a) NASA will make available the Shuttle for SL missions on either a cooperative (non-cost) or a cost-reimbursable basis. In the latter case, costs which may be charged include, but are not limited to, integration, check-out, crew training and data reduction, processing and distribution, as well as the costs of the launching services provided.

(b) In regard to space missions of ESRO and Governments participating in the SL programme, NASA shall provide access for use of SLs developed under this cooperative programme for experiments or applications proposed for reimbursable flight by ESRO and Governments participating in the SL programme, in preference to those of third countries considering, in recognition of ESRO's participation in this cooperative programme, that this will be equitable in the event of payload limitation or scheduling conflicts. Experiments or applications proposed for cooperative flight will be selected on the basis of merit in accordance with continuing NASA policy; such proposals of ESRO and Governments participating in the SL programme will be given preference over the proposals of third countries provided their merit is at least equal to the merit of the proposals of third countries. ESRO and the Governments participating in the SL programme will have an opportunity to express their views with respect to the judgement of merit regarding their cooperative proposals.

ARTICLE XII

Public Information

Each party is free to release public information regarding its own efforts in connection with this cooperative programme. However, it undertakes to coordinate in advance any public information activities which relate to the other party's responsibilities or performance.

ARTICLE XIII

Patents and Proprietary Information

Each of the parties and their contractors shall retain unaffected all rights which they may have with respect to any patents and/or proprietary information, whether or not they antedate this Memorandum of Understanding. Where it is mutually determined that patentable or proprietary information should be transferred in the interest of successfully implementing this cooperative programme, this may be done under arrangements which fully recognise and protect the rights involved. In addition, each of the parties shall secure from its contractors the rights necessary to discharge the obligations contained in this Memorandum of Understanding in accordance with its internal rules.

ARTICLE XIV

Settlement of Disputes

1. Any disputes in the interpretation or implementation of the terms of this cooperative programme shall be referred to the NASA Administrator and the Director General of ESRO for settlement.

2. Should the NASA Administrator and the Director General of ESRO be unable to resolve such disputes, they may be submitted to such other form of resolution or arbitration as may be agreed.

ARTICLE XV

Duration

This Memorandum of Understanding shall remain in force until 1 January 1985, but at least for five years from the date of the first flight of the SL. This Memorandum shall be extended for three years unless either NASA or ESRO gives notice of termination prior to 1 January 1985, or prior to the expiration of the five years, whichever is applicable. Thereafter, the Memorandum of Understanding shall be extended for such further periods as the parties may agree.

ARTICLE XVI

Entry into Force

This Memorandum of Understanding shall enter into force when both the NASA Administrator and the Director General of ESRO have signed it and it has been confirmed under the terms of the Agreement between the Governments of the participating European States and the Government of the United States of America concerning this cooperative programme.

Dated 14 August 1973

Alexander Hocker
For the European Space Research Organisation

James C. Fletcher
For the National Aeronautics and Space Administration

APPENDIX D

Unit Conversion Table

Multiply	By	To obtain
	Acceleration	
Inches per second squared	2.54	Centimeters per second squared
	Area	
Acres	0.4047	Hectares
Square feet	.0929	Square meters
Square miles	259.1	Hectares
	Density	
Pounds mass per cubic foot	16.02	Kilograms per cubic meter
	Distance	
Feet	0.3048	Meters
Inches	2.54	Centimeters
Nautical miles	1.852	Kilometers
Statute miles	1.609	Kilometers
	Energy	
Kilowatthours	3.60	Megajoules
	Flow rate	
Cubic feet per minute	0.0283	Cubic meters per minute
Gallons per minute	3.7854	Liters per minute
Pounds mass per hour	.4536	Kilograms per hour
Pounds mass per minute	.4536	Kilograms per minute
Pounds mass per second	.4536	Kilograms per second
	Force	
Pounds force	4.488	Newtons
	Power	
British thermal units per hour	1.054	Kilojoules per hour
Brake horsepower	.7457	Kilowatts
Electric horsepower	.746	Kilowatts
	Pressure	
Millimeters mercury	133.32	Newtons per square meter (pascals)
Pounds force per square inch	6.895	Kilonewtons per square meter (kilopascals)
	Temperature	
Degrees Fahrenheit plus 459.67	5/9	Kelvin
Degrees Celsius plus 273.15	1	Kelvin
	Velocity	
Feet per second	0.3048	Meters per second
Inches per second	2.54	Centimeters per second
Knots	1.852	Kilometers per hour
Miles per hour	1.609	Kilometers per hour
	Volume	
Cubic feet	0.0283	Cubic meters
Fluid ounces	.0296	Liters
Gallons	3.7854	Liters
	Weight	
Ounces	28.350	Grams
Pounds	.4536	Kilograms
Tons	.9072	Metric tons (tonnes)