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Spacelab Users Guide

A short introduction to Spacelab and its use

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FOREWORD

The purpose of this document is to introduce Spacelab to likely future users and to present its potential in the fields of science, applications and technology. This orbital laboratory concept will be available throughout the 1980's. If you feel that you can use the facilities offered by Spacelab you are invited to contact:

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INTRODUCTION

Spacelab is an orbital facility that provides a pressurised, 'shirt-sleeve' laboratory (the module) and an unpressurised platform (the pallet), together with certain standard services. It is a re-usable system, which is transported to and from orbit in the cargo bay of the Space Shuttle Orbiter and remains there throughout the flight. Spacelab extends the Shuttle capability and the Orbiter/Spacelab combination can be regarded as a short-stay space station which can remain in orbit for up to 30 days (the nominal mission duration is 7 days). In orbit, the experiments carried by Spacelab are operated by a team of up to four payload specialists (men or women) who normally work in the laboratory, but spend their off-duty time in the Orbiter cabin.

The purpose of Spacelab is to provide a ready access to space for a broad spectrum of experimenters in many fields and from many nations. Low-cost techniques are envisaged for experiment development, integration and operation. The aim of this document is to provide a brief summary of Spacelab design characteristics and its use potential for experimenters wishing to take advantage of the unique opportunities offered for space experimentation.

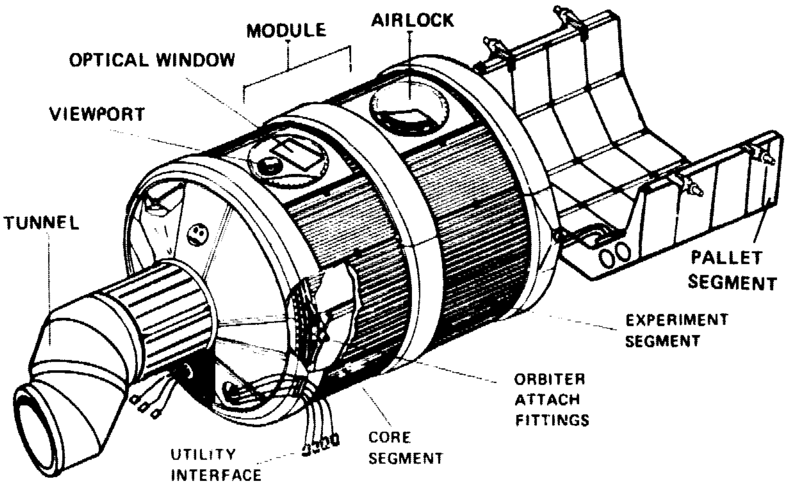


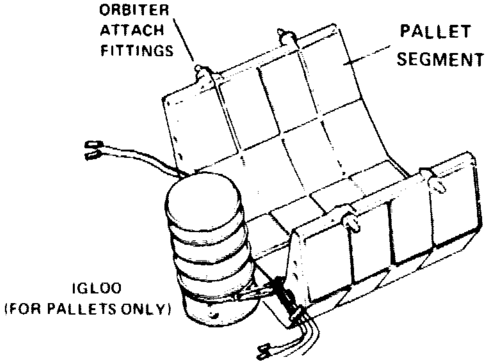
Fig. 1. Spacelab external design features

SPACELAB DESCRIPTION

The principal design features of Spacelab are shown in Figs. 1 and 2. The module may be composed of one or two identical cylindrical shells (2.7 m long, 4.1 m in diameter) enclosed by two end cones, whereas the pallet is composed of up to 5 segments, each 2.9 m long, of unpressurised structure. The module and pallet elements are firmly attached to the orbiter.

The core segment contains the basic Spacelab subsystems but also has volume set aside for experiments. The experiment segment provides additional experiment space. The subsystems and experiment equipment are housed in standard 19" racks. These racks are attached to the floor so that the racks and associated floor elements can be removed during ground operations. Also, equipment in the racks, which is mounted on slides, can be withdrawn during the orbital flight so that the equipment is readily accessible.

The pallet segments may be attached individually to the Orbiter or in continuous trains of up to three rigidly attached segments. When only pallets are to be flown, essential subsystems can be carried in an igloo which provides a pressurised and thermally controlled environment for them. Experiments mounted on the pallet can be controlled from the Spacelab module, the Orbiter cabin, or from the ground. Additionally, a manipulator arm controlled from the Orbiter, or extra vehicular activity (EVA) by members of the Orbiter crew can be used for performing certain direct experiment activities.



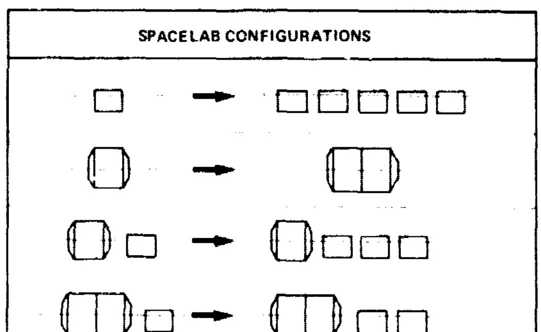


TABLE 1 – COMMON PAYLOAD SUPPORT ITEMS

ITEM	DESCRIPTION AND USE
Airlock	One airlock (1 m dia, 1 m length) available, to be used in top opening of module; allows direct access to space from module (supports up to 100 kg)
Optical Window	Skylab-type window permits observations from inside module for high quality viewing in the visible and near-infrared parts of the spectrum; size 41 x 55 cm.
Viewport	Two viewports (30 cm diameter) available, one in the aft end cone, the other one in a top opening of the module.
Film Storage Vault	Provides modular storage for up to 150 kg of film
Vent	Permits attainment of vacuum for chambers etc. located in the module
Feed-through	Permits passage of lines (fluids, signals, etc.) peculiar to experiments between module and pallet.

Fig. 2. Sectional views of Spacelab module.

For those experiments requiring specific operating conditions, certain elements of common payload support equipment can be flown, if desired. These items are listed in Table I and some possible locations indicated in Figs. 1 and 2.

Functional interfaces between the Orbiter, module and pallet are provided by suitable utility connections. Access to the module from the Orbiter cabin is by means of a tunnel. The latter attaches to the EVA adapter which in turn attaches to the Orbiter cabin itself. The variable length of the tunnel permits some freedom in placing the Spacelab elements in the cargo bay, to provide better viewing conditions and/or to satisfy the centre-of-gravity constraints placed on the Spacelab and its payload by the Orbiter.

A relatively mild environment is foreseen for Spacelab experiments. Some of the principal parameters are given in Table 2.

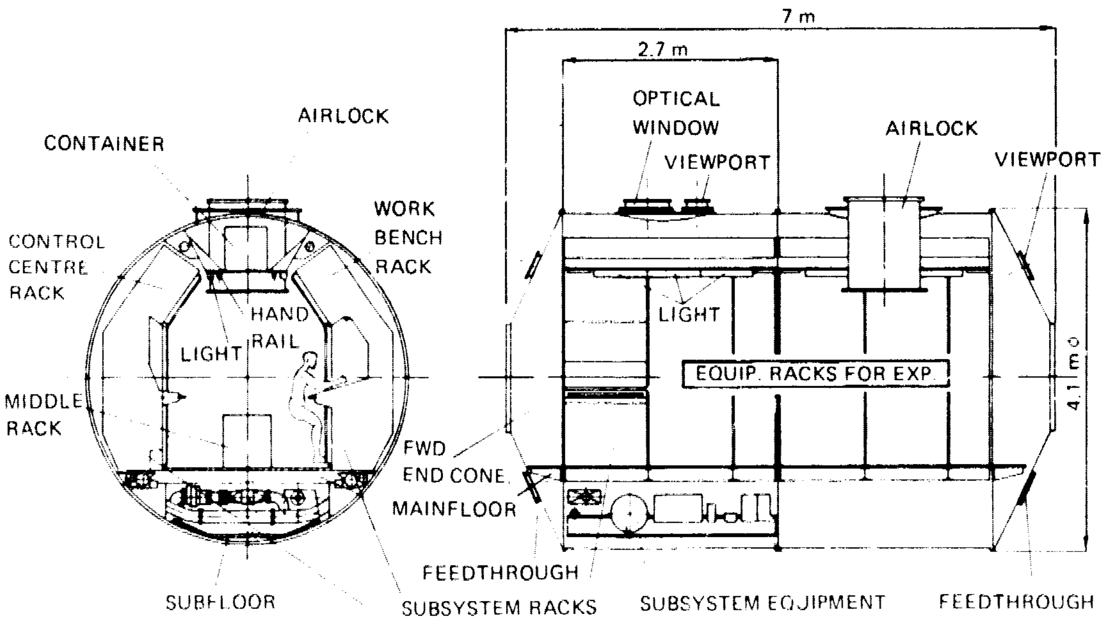
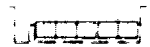
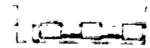


TABLE 2 – PRINCIPAL ENVIRONMENT PARAMETERS

PARAMETER	APPROXIMATE VALUES
Acceleration	Maximum 3 g linear acceleration during ascent and descent; typically 10^{-4} g on orbit.
Vibration	145 dB acoustic noise in cargo bay (launch only); 136 dB acoustic noise inside module (launch only); typically 4 g RMS random vibration input to equipment in racks in the module.
Thermal	Inside the module: equipment cooling through forced air in the range 20 to 40°C, cabin air in the range 18 to 27°C (adjustable); On pallet: equipment cooling by cold plates with temperatures in the range 10 to 40°C.
Contamination	Arises from Orbiter, Spacelab and experiment equipment. Precautions will be taken in design to reduce level as far as practically possible. Dumps can be programmed.

The Spacelab concept possesses considerable flexibility in its application to a variety of missions. This very important characteristic arises from two sources. Firstly, the Space Shuttle flight parameters may be varied so that the orbit inclination, orbit altitude (200 to 900 km) and resulting ground coverage may be selected for mission compatibility. During the first few years of Shuttle operation, the East Coast launch site at Kennedy Space Center will be used so that the possible range of inclinations is 28.5 to 57°. Later, the West Coast site at Vandenberg will become available, thereby ensuring orbit inclinations up to 104°. Also the Orbiter orientation (all directions with an accuracy up to 0.5° per axis) and flight duration time (up to 30 days) can be adjusted as required.

In the second place, Spacelab mission flexibility results from the modular approach adopted in the design. The module and pallet can be varied in size by selecting from the available Spacelab elements (illustrated in Fig. 1) in such a way that the resulting configuration fits the needs of the mission in question. Three basic configurations are apparent – module only, module plus pallet and pallet only. Further flexibility is provided by the availability of the common payload support equipment. The subsystem elements are also modularised, so that certain components (e.g. cold plates, equipment racks, recorder) may be used or removed as required. This feature means that, on a particular Spacelab flight, only those mission-dependent elements required by the experimenter are flown, permitting additional payload weight to be substituted for the mission-dependent equipment not needed.

Spacelab Configuration / Available to users	 short module + 9 m pallet	 long module	 15 m pallet	 Independ. susp. pallet
o Payload weight (kg)	5500	5500	8000	9100
o Volume for experiment equipment				
Inside module (m³)	8	22	–	–
On pallet (m³)	100	–	160	100
o Pallet mounting area (m²)	51	–	85	51
o Electrical power (28 V DC 115/200 V at 400 Hz AC)				
Average (kW)	3 – 4	3 – 4	4 – 5	4 – 5
Peak (kW)	8	8	9	9
Energy * (kWh)	300	300	500	500
o Exp. Support computer with central processing unit and data acquisition system	← 64 K core memory of 16-bit words → ← 320 000 operations per second. →			
o Data Handling				
Transmission through orbiter	← Up to 50 Mbps →			
Storage digital data	← Up to 30 Mbps →			
o Instrument pointing sub-system IPS	Mounted on pallet, will provide arc second pointing for payloads up to 5000 kg			

* Energy can be increased by the addition of payload-chargeable kits, each providing 840 kWh and weighing approx. 350 kg (at landing).

USER SERVICES

The Orbiter/Spacelab subsystems provide basic services for running Spacelab itself and for the payload. These services are available to the experiments via standard interfaces and have been designed to ensure that near-laboratory-type equipment may be used. The actual resources available to the payload are a function of the configuration being flown. Table 3 summarises the services provided in the case of four typical Spacelab configurations. It is the task of the mission planner to ensure that the sums of the requirements of all experiments in the payload does not exceed the total resources available.

In addition to the subsystem support described in Table 3, an instrument-pointing subsystem (IPS) for use on the pallet will be part of the programme-supplied equipment. This IPS will have a capability for pointing equipment up to 5000 kg in mass and 3 m in diameter with arc second accuracy.

Table 3. Spacelab services for users.

SPACELAB UTILISATION

Spacelab users will be drawn from the various disciplines of science, applications and technology. Investigations have shown that, at least, the following fields are likely to obtain benefits from the utilisation of Spacelab:

- high-energy astrophysics
- ultraviolet, optical, infrared and X-ray stellar, planetary and solar astronomy
- atmospheric, ionospheric (plasma) and magnetospheric physics
- life sciences (including biology, biomedicine, behaviour)
- remote Earth-sensing (meteorology, land-use planning, resources, pollution control, etc.)
- material sciences (e.g. crystal growth, pure metals and alloys, composite materials) and fluid physics
- processing and manufacturing in space (e.g. electrophoresis, high-strength materials)
- communications and navigation
- advanced technology in all disciplines

These fields are cited as typical and it is expected that additional areas that might gain from using Spacelab will be identified as the programme matures. It is foreseen that Spacelab will play an important role in the various development phases of those disciplines, which include pure research, instrument R&D, experimental processes and the execution of operational programmes.

Spacelab provides a capability for two modes of experimentation – man-tended activities or automated observations. The choice of mode is left to the experimenter, who may prefer to have an operator in attendance when it is felt that his presence can improve the overall efficiency of the planned experimentation and fully exploit unexpected events. On the other hand, he may feel that automated operation of the equipment is preferable.

In addition to the basic services provided by Spacelab, certain experiment facilities (e.g. furnaces, telescopes, high-power lasers) will be available for certain missions. These 'facilities' are not provided as part of the Spacelab Programme but will be supplied from 'user'

ATMOSPHERIC AND
SPACE PHYSICS

SPACE PROCESSING
APPLICATIONS

ASTRONOMY

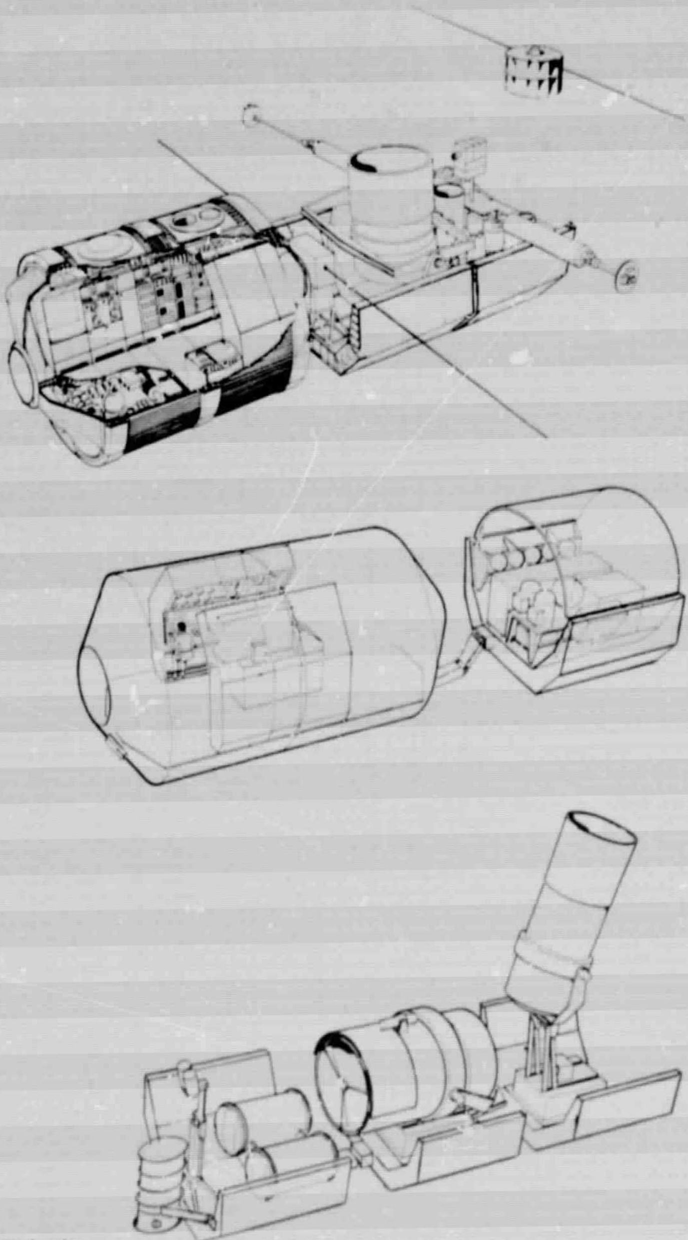
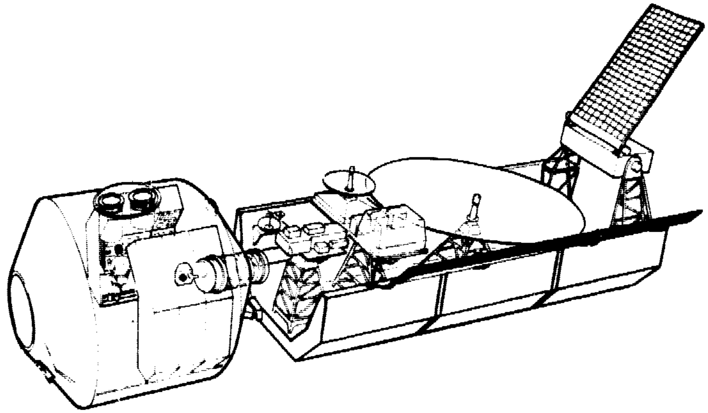
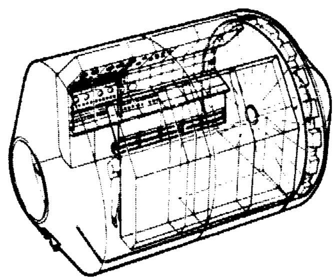


Fig. 3. Spacelab configurations for various payloads

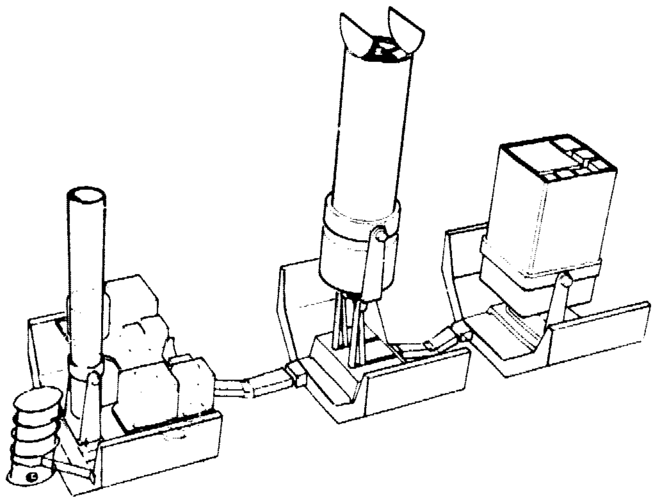
EARTH OBSERVATIONS



LIFE SCIENCE



SOLAR PHYSICS



sources, and experimenters from a wide variety of disciplines may take advantage of them for exploring their particular problem areas. In this way it will be possible to attract users of Spacelab from all levels of the scientific and technical communities, be it small university groups or large government agencies. Thus, the participation of an experimenter in Spacelab activities may take four basic forms, viz:

1. by provision of a complete experiment unit, i.e. facility plus detectors or samples;
2. by supplying experiments for use with a common facility, e.g. 'behind the focus' type experimentation;
3. by provision of an independent experiment which does not utilise a facility; and
4. by use of the data generated during a Spacelab mission without the provision of any equipment itself, as in the case of certain Earth-observation data.

In planning experiments that require attendance, it must be stressed that payload specialists who fly in Spacelab will be scientists and technicians rather than professional astronauts, and no rigorous, long-duration, pre-flight training is envisaged.

In some cases it may be desirable to involve the user community on the ground. This involvement can be achieved by communicating experiment data to the ground, in real time, via the Tracking and Data Relay Satellite System. Conversely, commands may be transmitted from the ground to Spacelab.

Studies carried out by ESA and NASA have shown that realistic payloads can be planned for accommodation in Spacelab. Depending on the mission objectives, various configurations result. Typical results for six disciplines are illustrated in Fig. 3.

Fig. 3. Spacelab configurations for various payloads

SPACELAB/PAYLOAD OPERATIONS

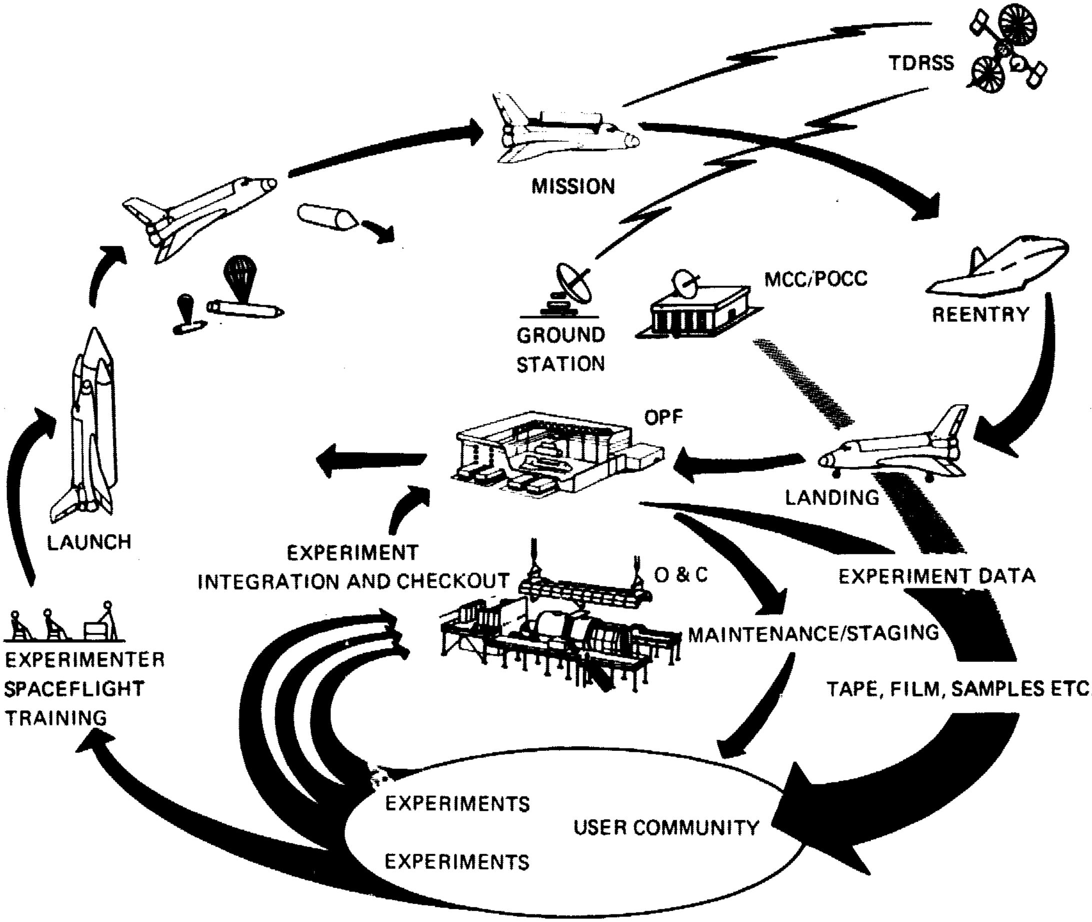
The schematic profile of Figure 4 represents the operational cycle of the Shuttle, Spacelab and its payload. The activities are repeated from flight to flight but with a different payload complement. The overall responsibility for these operations rests with NASA. Spacelabs and their payloads may be decoupled from the Shuttle turn-around cycle, thereby permitting more time for off-line payload preparation and integration.

It is intended that the experimenter be given an active role both on the ground and during the flight itself. The various phases envisaged for experiment integration are described as follows:

- Level IV: integration and checkout of experiment equipment with individual experiment mounting elements (e.g. racks and pallet segments) – activities that will be possible at the user's home facility.
- Level III: combination, integration and checkout of all experiment mounting elements (e.g. racks, rack sets and pallet segments) with experiment equipment already installed, and of experiment and Spacelab software, i.e. payload integration normally carried out at Kennedy Space Center (KSC).
- Level II: integration and checkout of the combined experiment equipment and experiment mounting elements with the flight subsystem support elements (i.e. core segment, igloo) and experiment segments when applicable – activities normally performed at KSC.
- Level I: integration and checkout of the Spacelab and its payload with the Shuttle Orbiter, including the necessary pre-installation testing with simulated interfaces – this procedure is carried out at the actual launch site.

The Level II integration procedure for module-located experiments is facilitated by the roll-out design concept adopted for Spacelab. The payl ad is contained in the rack and floor combination, which is literally rolled into the Spacelab shell by means of a roller-rail system (Fig. 5).

Special organisations have been set up in Europe and the USA to ensure that the relevant integration phases are effectively executed. These organisations also ensure that adequate support is given (including the necessary ground support equipment) to the experimenter during the equipment development phase.

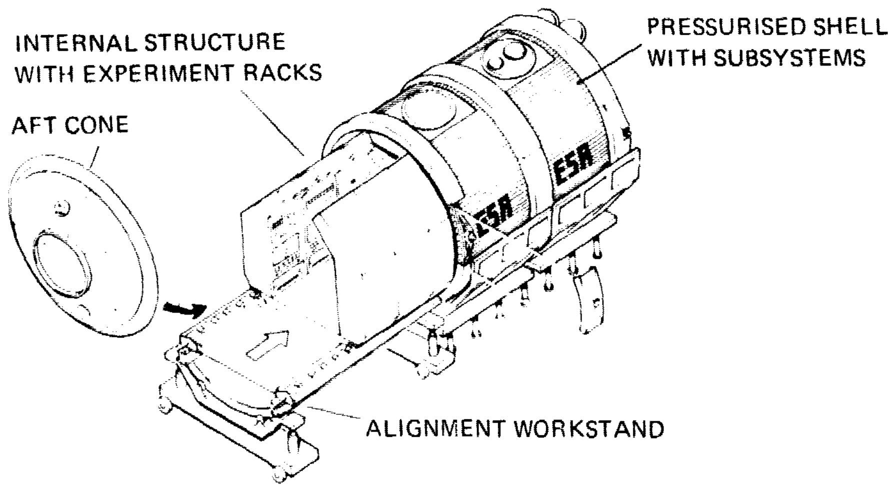


MCC/POCC – Mission Control Centre/ Payload Operations Control Centre
OPF – Orbiter Processing Facility
O & C – Operations & Checkout
TDRSS – Tracking and Data Relay Satellite System

Fig. 4. Shuttle - Spacelab operations cycle.

During the flight, an Earth-bound experimenter can interface directly with his on-board equipment, but this must be done via the Payload Operations Control Center in Houston, Texas. Stored data, specimens, and other results will be distributed to the experimenter as soon as possible after the Orbiter landing. The payload specialist for a particular mission will be selected and trained by the sponsoring user organisation, and it is intended that he be drawn from the scientific and technical community with a specific interest in that mission. A training period of about one to two years is currently foreseen, and it will involve payload and Shuttle-environment familiarisation. Although the payload training may be carried out at a number of locations, the Shuttle-environment (flight) familiarisation will be conducted by NASA.

It is stressed that flying experiments on board Spacelab is envisaged as a low-cost activity. This philosophy applies equally to experiment development, payload integration, and flight transportation. In general, a minimum of documentation and compliance requirements will apply although basic safety constraints must be met. Transportation costs will be prorated on the basis of demands placed on weight, volume, power, data handling, crew time, etc.



MATERIALS SELECTION, SAFETY AND RELIABILITY

Relaxation of materials control for payload elements housed within the module means that the current NASA constraints (NHB 8060.1A) concerning off-gassing, odours and flammability will not be applied. Commercial equipment can be used even if the precise material composition is unknown. However, in such cases, an off-gassing screening test will be required at black-box or higher level. Flammable materials are not acceptable unless they are suitably isolated. Materials susceptible to stress corrosion must not be used for support bracketry because of the safety hazard under crash-landing loads.

Payload elements accommodated in the Orbiter cabin must meet the requirements of NHB 8060.1A since the atmosphere of the Orbiter must not be compromised.

Built-in Spacelab fire-supression systems, atmospheric scrubbers, a trace gas contaminant analyser and face masks are available. Additional safety features of the Shuttle-Spacelab system include the provision of abort and rescue capabilities.

Fig. 5. Roll-out concept for experiment integration.

SCHEDULE

The first flight of Spacelab is foreseen for the third quarter of 1980. Subsequently, a mission model for Spacelab flight will be followed which reflects the user needs and the available funding. Existing models should not be regarded as a commitment, but will be used for planning and checking the associated ground-support equipment, software and procedures. Tentative estimates of Spacelab flight opportunities indicate that, starting at about 5 per year in the early-80s, the launch rate may build up to about 10 per year in the mid-80s. Higher rates can be achieved should the need arise. At present multi-discipline flights and flights dedicated to a single discipline are envisaged.

A fully functional engineering model will be available in the US from mid-1978. This model will be used for the development of maintenance and refurbishment procedures and also for experiment integration verification, crew training and some mission simulation.

Experiment development times will depend on the type and complexity of the equipment involved, but, generally, experiment gestation times of months (rather than years normally associated, with automated satellites) are foreseen. It is estimated that the time for the payload integration phases III through I will not exceed about 6 months for the initial missions and about 30 days for later ones.

EXPERIMENT SELECTION PROCEDURES

Because of the nature of Spacelab missions, the procedure for selecting experiments to achieve the mission objectives will vary from flight to flight. Hence, no hard and fast rules can be laid down. Normally both Agencies will select experiments from within their respective programmes and from competitive proposals generated by the user community in answer to an Announcement of Opportunity (AO). However, in special cases and depending on the type of mission, other mechanisms may be involved. NASA and ESA are currently developing procedures that will ensure easy and rapid access to Spacelab. Once approved, these procedures will be incorporated in later versions of this document. Experiment proposals may be submitted on an unsolicited basis or in answer to particular AOs.

More details relating to how an experimenter may get on board Spacelab can be obtained by contacting the organisations listed in the Foreword of this Guide.

USER DOCUMENTATION

A minimum of documentation is envisaged for the control of user equipment destined for use on Spacelab. Details of the interfaces to be satisfied between the experiment equipment and Spacelab will be found in the 'Spacelab Payload Accommodation Handbook', ESA SLP 2104. This document also contains a detailed description of the Spacelab system and subsystems, together with complete information on the environmental and operational requirements. This document is the sole reference for Spacelab-to-Experiment interfaces and payload-equipment design. Additional basic documents that describe the general operational aspects of Spacelab are the Spacelab Ground Operations Requirements Document and the Spacelab Mission Operations Requirements Document.

These three basic documents are available from either ESA or NASA (see address in Foreword).

For every Spacelab mission, additional mission-specific documentation will be required. The basic document will be a Mission Implementation Plan which will provide organisational and technical details for the achievement of that mission. This Mission Implementation Plan will be generated in response to requirements specified by the prospective experimenters themselves.

Full-scale mock-up of Spacelab.