Spacelab Operations Planning

Thomas J. Lee
Manager, Spacelab Program, Marshall Space Flight Center

Follow this and additional works at: https://commons.erau.edu/space-congress-proceedings

Scholarly Commons Citation
https://commons.erau.edu/space-congress-proceedings/proceedings-1976-13th/session-1/1
ABSTRACT

The Spacelab design requirements which have been jointly developed by the National Aeronautics and Space Administration (NASA) and the European Space Agency (ESA) were strongly influenced by two primary considerations: (1) an attempt to satisfy as many of the low Earth orbit scientific and application user's requirements as practical utilizing the Shuttle launch vehicle; and (2) the necessity to have an efficient and economical mode of operation.

ESA has adhered to these considerations in their design and development program while NASA has adhered to these considerations in the planning for the Spacelab operations in the 1980's.

This paper presents a summary of the NASA planning in the areas of ground, launch, and flight operations and experiment integration to effectively operate the Spacelab.

INTRODUCTION

The Space Transportation System (STS) is being developed to transport people and material more economically and routinely between the ground and Earth orbit. The STS concept substantially reduces the cost of space operations by repetitive use of most of its major components. The experimenter's costs are also reduced because his instrumentation and equipment will be returned to Earth for reuse or repair rather than be abandoned in orbit. The user has been involved with Spacelab from the beginning. His involvement in establishing the accommodations that Spacelab should provide has insured the incorporation of user requirements into Spacelab design.

The Spacelab module and pallet, either together or separately, will be carried to and from Earth orbit in the Shuttle payload bay and will be attached to and supported by the Orbiter throughout the mission. The Spacelab will have a minimum of interference with Orbiter ground turnaround operations.

The NASA, with the Marshall Space Flight Center (MSFC) as the lead center, has the responsibility to plan for Spacelab operations in conjunction with STS operations.

The STS (Spacelab) and its payload functions and interfaces are shown in Figure 1. The shaded portions depict the STS (Spacelab) responsibilities, and the non-shaded depict the payload responsibilities. The NASA Headquarters and center-level responsibilities are shown. The total mission cycle is divided into two phases: those selected activities leading up to mission or payload approval, and those activities associated with the mission execution. The first phase activities are generally referred to as the STS Utilization Planning (SUP). The second phase activities include both the STS (Spacelab) and payload operations.

A NASA center will be assigned authority to manage each payload. Within the center, a payload Mission Manager will be assigned who will coordinate and integrate the functions required for successful payload mission completion. These functions include payload interface, payload mission planning, payload analytical and physical integration, and payload flight operations. The locations of these functional activities will vary, e.g., physical integration at Kennedy Space Center (KSC), mission operations at Johnson Space Center (JSC), payload mission planning at the payload Mission Manager center, etc. The Mission Manager provides a focal authority to integrate and manage the Spacelab payloads from flight approval through mission termination.

SPACELAB OPERATIONS

NASA is exploring the ways in which the STS System can best be adapted to support various user needs. They are responsible for the development of an experiment integration approach that is applicable to all Spacelab payloads, defining the most efficient ground sequences for maintaining Spacelab and for installing payloads and for developing techniques that will reduce ground preparation time and make effective use of the inventory of Spacelab hardware. NASA is also developing automated techniques for mission
planning and for the efficient use of the time of the flight crew, including the payload specialists. Similarly, in the area of data management, NASA is investigating means of handling large quantities of experimental data and of developing efficient software approaches.

The Spacelab operations necessary to accomplish the payload mission planning, payload analytical and physical integration, software integration, ground processing of the Spacelab elements and payloads, flight operations, and data management comprise many varied activities and interfaces. The major operational activities, functions and related interfaces that take place after an experiment has been approved and assigned to a particular Spacelab mission are depicted in Figure 2.

PAYLOAD MISSION PLANNING

Some of the major elements and interfaces of payload mission planning are depicted in Figure 3. User requirements basically dictate the "job" while the STS capabilities and constraints influence or limit the degree of satisfaction of the "job." Payload analytical integration provides typically mass properties, crew activity elements, layouts and mission specific constraints, etc., and is driven by the output of payload mission planning. Culmination of various efforts is anticipated to be in a payload flight definition document.

Orbital analysis is characterized by optimization of the flight orbit to satisfy the payload requirements or constraints, identification of opportunities for target observations (if appropriate), specification of orbital environment to be experienced and identification of orbital characteristics necessary for on-orbit activity timelining. On-orbit activity timelining is concerned with the integration of payload requirements, STS capabilities and constraints, orbital and crew data to describe the time sequence of activities of crew and equipment necessary to accomplish the flight objectives. In addition, the systems and subsystems resource requirements (power, data, etc.) associated with this flight plan are determined. Based upon the on-orbit activity timelining effort, the desired targets, location and availability, the attitude requirements to be imposed upon the STS operator, and the pointing requirements to be satisfied by the IPS and other pointing systems are defined.

The payload mission planning sequence for a multi-user payload is shown in Figure 4. A multi-user payload may be either single or multi-discipline. The multi-discipline payload is composed of many separate experiments and objectives grouped together to take advantage of the Spacelab’s capabilities, mission parameters and objectives. Payload integration analysis and planning will normally be the responsibility of the payload Mission Manager at a NASA field center. Experiments will be installed in Spacelab racks and pallet elements at a site specified by the user, e.g., the user’s site or a NASA center. Final experiment payload installation and interface verification will occur at KSC.

When selected for flight, the individual users will prepare a list of their requirements. The organization responsible for integration of the payload will consolidate these requirements and negotiate incompatibilities with the users. There is extensive exchange between the payload integration analysis and the payload mission analysis to ensure all incompatibilities are resolved. During this time frame, the users are proceeding in the development of their experiment.

The planning cycle for multi-user payloads during the operational period will be nominally initiated no earlier than two years prior to flight and characterized by one iteration and one update. As flight experience is increased, the ability to further compress this cycle will be actively pursued. Interfaces with the payload developers and scientists will be a continuing activity while STS operator interface will be primarily via STS capabilities and constraints from computer data bases or documents early in the cycle and then direct from launch minus ~ six months till flight.

The flight plan integration function is the responsibility of the STS operator. Planning outputs of the payload flight planning and the STS flight planning are married to insure compatibility of flight relative to resources, activities, safety, requirements and constraints. This activity picks up momentum near launch minus ~ six months.

Inherent in the planning for a flight is the tradeoff analysis invested effort versus scientific return. The greater return desired the higher the planning effort necessary to be applied. Effecting the nature of this relationship is the complexity of the payload complement.

PAYLOAD ANALYTICAL INTEGRATION

Payload analytical integration is an active process of analyses to assure that the experiment payload is compatible to the mission objectives and profile ground and flight operations and that the resource demands upon the Spacelab systems can be satisfied (mechanical, power, thermal, data, environmental, etc.). The major payload analytical
integration activities are depicted in Figure 5. These analyses require interfaces with the user community, with the payload mission planning activity and with ground and mission operations planning. The payload mission planning activity provides typically an activity timeline, power profile, a radiation history, etc. These integration analyses provide inputs to the payload flight definition document and hardware processing documents.

The flight support analysis establishes the requirements for analyzing the functions and resources required to perform the mission from onboard or from the ground. The onboard tasks analysis establishes the requirement for analyzing compatibility of flight crew tasks with payload and Spacelab system configuration (man/system task compatibility analysis). The analysis will establish requirements for onboard resources to perform onboard tasks. The mission support crew analysis establishes the requirements to define the ground support facility resources and the mission rules and mission constraints. A training and simulation requirements analysis for both the flight crew and the ground mission support crew will determine the resources required, the level of training and simulation, the methods, and time required for training. Requirements for operating procedures, such as contingency and standard operating procedures, for the flight crew and the ground mission support crew will be established.

The experiment-to-systems compatibility analysis assesses experiment compatibility with Spacelab capabilities and constraints, mission objectives, and with other experiments' objectives, operations, and envelopes. The experiment-to-systems compatibility analysis is further divided into typical disciplines or Spacelab subsystem tasks and sub-tasks. For example, under the Environmental Control System (ECS) analysis, a thermal analysis will be conducted on each mission to determine the orbital absorbed heat fluxes on the Spacelab and payload. Based on these calculated fluxes, orbital temperature will be predicted. In addition, trace gas contamination accumulation internal to the module will be analyzed. Based on either known or predicted payload trace gases generation rates and the removal capability of the ECS, a contaminant accumulation history will be generated. As another example, the consumables analysis will take photographic film requirements of individual experiments and the payload, along with the film projection and special handling requirements, and will determine the compatibility of the film with ground and flight environments. The availability of stowage volume in the Spacelab for the quantity of film required will be verified. Film prelaunch loading and post flight off-loading requirements and constraints will be analyzed against the prelaunch and post-flight schedules.

The ground operations analysis identifies support requirements, necessary facility, ground support equipment (GSE) and flight hardware modifications, and provides for implementing documentation, hardware and software. The results of the ground operations analyses must be provided in sufficient time to implement required changes. Longest lead times are anticipated for facility changes and flight hardware GSE modifications.

The payload analytical integration flow for a multi-user payload is depicted in Figure 6. The organization responsible for the Spacelab multi-user payload integration interfaces with the users during payload development and with the STS operation during STS flight and ground operations planning. Payload detail integration requirements and descriptions are defined and provide inputs to the STS integrated flight and ground operations planning activity. The payload flight definition document that results from the payload mission planning and payload analytical integration activities provide inputs to the STS flight operations documents. The payload analytical integration activity also provides major inputs to the STS ground operations documents.

SOFTWARE INTEGRATION

Spacelab software is comprised of the flight, ground, support software, and the user's experiment software.

ESA will deliver to NASA: the subsystem computer operating system and associated flight applications software; the experiment computer operating system; the electrical ground support equipment computer operating system and associated automatic test equipment software; and the support software required to maintain the software systems.

The user depending upon mission requirements may be responsible for the development of his experiments software. Experiments software, or that part of the experiment software requiring integration with the Spacelab systems software, will be integrated within a Software Test and Integration Laboratory (STIL). Other functions performed with this facility include maintenance of the software and preparation and delivery of flight and ground software for hardware integration. The experiment software which does not require software integration can be delivered directly to KSC. The flight and experiment software will be integrated with the flight hardware at KSC.
activity utilizing domestic satellites for high-bit rate data and terrestrial links for low-bit rate data. Both data transmitted electronically and that retrieved upon Shuttle landing will be received at payload operations, preprocessed if necessary, and delivered to the users for further data reduction, data analysis and archiving (Figure 8).

All commands for the mission and payload operations will be routed through the Mission Control Center (MCC) at JSC for uplink to the Orbiter, Spacelab, and payload.

INITIAL SPACELAB MISSIONS

The previously described techniques are planned for an operational Spacelab. However, the first two Spacelab missions are considered to be Spacelab performance verification flight tests (VFT). The first Spacelab mission is a joint NASA/ESA mission with the primary objective to verify the Spacelab system and subsystem performance capabilities, verify Spacelab/Orbiter and Spacelab/experiment interface compatibility and determine the Spacelab induced environments. The secondary objective is to obtain valuable scientific and applications data from a common U.S./European multidisciplinary payload and to demonstrate to the user community the broad capability of Spacelab for scientific research.

In performance of the primary objective, MSFC has the lead in planning for the VFT. Presently, VFT requirements have been defined. VFT instrumentation requirements are being defined and Spacelab resources allocations for verification flight instrumentation are being developed.

Some of the detailed VFT requirements are:

- **Environmental Control System** -- Evaluation of passive thermal control system, experiment cooling, Shuttle heat rejection support, Spacelab humidity and temperature control, ground support, ECS contingency mode.

- **Command and Data Management System (CDMS)** -- Evaluation of activation/deactivation procedures, control and display, Spacelab/Orbiter interface, TDRSS ground station to payload operations link, CDMS operational and contingency modes.

- **Structures** -- Evaluation of low frequency dynamic response loads, vibration and acoustic, attachment point verification, leak rate.

- **Electrical Power Distribution System** -- Evaluation of power characteristics nominal and backup, power interface, electromagnetic interference compatibility, power storage characteristics, thermal protection of batteries.

- **Habitability** -- Evaluation of stowage, general purpose work station, internal crew aids, emergency procedures.

- **Environment** -- Evaluation of radiation within Spacelab and film vault, low-level acceleration.

- **Materials** -- Evaluation of thermal control coating.

- **Contamination** -- Evaluation of particulate matter, condensable vapor, humidity, background brightness, radiation, molecular column density, particles in field of view, molecular deposition, electric and magnetic fields.

In performance of the secondary objective, the Memorandum of Understanding between the NASA and the ESA provides that the experimental objectives of the first Spacelab flight be jointly planned between NASA and ESA. During the past year, NASA and ESA have engaged in numerous planning meetings regarding the establishment of a set of experimental objectives to be accomplished on the first Spacelab mission. In arriving at this set of experimental objectives, NASA and ESA agreed that certain selection criteria should prevail. Some of the more important criteria are:

- The payload should be complementary to and consistent with future Spacelab missions, while emphasizing reusable hardware elements and techniques.

- Payloads should demonstrate to the user community and the general public the uniqueness of Spacelab and its broad potential for research and applications.

Some of the detailed recommended experiment objectives address the disciplines of atmospheric physics, space processing, Earth observations, space technology, life sciences, astronomy and communications.

The planning cycle for the first payload mission is illustrated in Figure 9. The relationship of the experiment development, payload mission planning and STS flight planning is shown. Spacelab missions 1 and 2 planning has been initiated, and the Spacelab resources allocations are being developed. In addition, a "strawman" payload has been selected and detail integrated planning is underway to define mission, integration,
and operations requirements and interfaces.

The relationship of the payload analytical integration activities to the first mission planning, STS flight operations, and STS ground operations is shown in Figure 10. The payload analytical integration provides inputs in terms of defining flight and ground integrated payload requirements. Some of the key inputs to the payload analytical integration activities are the experiment requirements and descriptions, STS constraints, and Shuttle and Spacelab accommodations.

The first Spacelab mission is planned for the third quarter of 1980. The Spacelab configuration will be a long module plus one pallet. The resources available will be: weight - 3950 kg, pressurized volume 21.5 M³, unpressurized mounted area 15.9 M², on-orbit power 3.1 kW, and electrical energy 260-360 kWH.

CONCLUSION

The present Spacelab operations planning baseline includes 226 Spacelab missions during 1980-1991. The Spacelab is indeed a challenging program. It will offer new opportunities for many different scientists and engineers throughout the world to engage in space research and the utilization of space. The Spacelab in conjunction with other elements of the STS will provide the user with a versatile and economical means of going into space. Much of the program is based on experience, but new techniques in experiment integration and mission operations are being introduced to simplify space flight for the user. These include:

- Reusability of experiment hardware.
- Greater payload weight and resource capability.
- Manned access to experiment during flight.
- Active participation in experiment operations.
- Reduced time between experiment selection and flight.
- Progressive development of experiment program through multiple flights.
- Minimum flight training for payload specialists.
- Simplified interface control through standardization.

REFERENCES

(1) Spacelab Systems Requirements, Level II, European Space Research and Technology Center, SLP/2100.

(2) Spacelab Payload Accommodations Handbook, European Space Research and Technology Center, SLP/2104.


ILLUSTRATIONS

Figure 1. Operations Functions and Interfaces.
Figure 2. Spacelab Operations Overview.
Figure 3. Payload Mission Planning Elements/Interfaces.
Figure 4. Multi-User Payload Mission Planning Flow/Interfaces.
Figure 5. Payload Analytical Integration Elements/Interfaces.
Figure 6. Multi-User Payload Analytical Integration Flow/Interfaces.
Figure 7. Flight Operations.
Figure 8. Overall Spacelab Data Flow.
Figure 9. First Spacelab Payload Mission Planning Flow/Interfaces.
Figure 10. First Spacelab Payload Analytical Integration Flow/Interfaces.
PAYLOAD
CONSOLIDATION &
COORDINATION

PAYLOAD
DEVELOPMENT

MISSION
MANAGER

PAYLOAD
MISSION,
PLANNING & ANALYTICAL
INTEGRATION

PAYLOAD 
OPERATIONS

GROUND
OPERATIONS

FLIGHT
OPERATIONS

STS
UTILIZATION PLANNING

OPERATIONS

FIGURE 1
SPACELAB OPERATIONS OVERVIEW

PAYLOAD MISSION PLANNING
PAYLOAD SPECIALIST TIMELINE (GET HRS.)

PAYLOAD
SPECIALIST 1
SPECIALIST 2
SPECIALIST 3

POWER kw
10 11 12 13 14 15 16 17 18

OPTIMIZATION

SOFTWARE INTEGRATION

GROUND OPERATIONS

COMMUNICATIONS

DATA

FLIGHT OPERATIONS

USER COMMUNITY

FIGURE 2
PAYLOAD MISSION PLANNING ELEMENTS/INTERFACES

USER REQUIREMENTS/DEFINITIONS
STS CAPABILITIES/CONSTRAINTS

PAYLOAD MISSION PLANNING

ORBITAL ANALYSIS
ON ORBIT ACTIVITY TIMELINE
ATTITUDE/POINTING REQUIREMENTS

CREW ACTIVITY ELEMENTS
MASS PROPERTIES
LAYOUTS
MISSION SPECIFIC CONSTRAINTS

PAYLOAD ANALYTICAL INTEGRATION

PAYLOAD FLIGHT DEFINITION DOCUMENT

FIGURE 3
MULTI-USER PAYLOAD
MISSION PLANNING FLOW/INTERFACES

INDIVIDUAL USERS

PAYLOAD A
FLIGHT 1
REQUIREMENTS

PAYLOAD L
FLIGHT Y
REQUIREMENTS

SPACELAB PAYLOAD INTEGRATION

INTEGRATE
REQUIREMENTS
L - 24 MOS

STS OPERATOR

STS DATABASE

STS FLIGHT PLANNING
L - 13 WKS

MULTI-USER PAYLOAD
MISSION PLANNING

PAYLOAD A
DESIGN/DEVELOPMENT/FABRICATION
MISSION PLANNING

PAYLOAD L
DESIGN/DEVELOPMENT/FABRICATION
MISSION PLANNING

INTEGRATE
REQUIREMENTS
L - 13 WKS

STS CAPABILITIES
CONSTRAINTS

L - 13 WKS

PAYLOAD DETAIL
FLIGHT PLAN
L - 26 WKS

PAYLOAD DETAIL
FLIGHT PLAN
L - 26 WKS

INTEGRATED
FLIGHT PLAN
L - 5 WKS

FIGURE 4
PAYLOAD ANALYTICAL INTEGRATION ELEMENTS/INTERFACES

- USER REQUIREMENTS/DEFINITIONS
- STS CAPABILITIES/CONSTRAINTS

PAYLOAD MISSION PLANNING:
- POWER PROFILE
  - TIMELINE
  - RADIATION PROFILE

PAYLOAD ANALYTICAL INTEGRATION:
- FLIGHT SUPPORT ANALYSIS
- EXP/SYSTEM COMPATIBILITY ANALYSIS
- GROUND OPERATIONS ANALYSIS

PAYLOAD FLIGHT DEFINITION DOCUMENT

PHYSICAL INTEGRATION REQUIREMENTS DOCUMENTS

FIGURE 5
MULTI-USER PAYLOAD ANALYTICAL INTEGRATION FLOW/INTERFACES

PAYLOAD A
- FLIGHT 1 REQUIREMENTS DEFINITIONS

PAYLOAD L
- FLIGHT Y REQUIREMENTS DEFINITIONS

INDIVIDUAL USERS

SPACELAB PAYLOAD ANALYTICAL INTEGRATION

INTEGRATE REQUIREMENTS

MULTI-USER PAYLOAD ANALYTICAL INTEGRATION

PAYLOAD A
- DESIGN/DEVELOPMENT/FABRICATION

PAYLOAD L
- DESIGN/DEVELOPMENT/FABRICATION

STS CAPABILITIES CONSTRAINTS

STS DATA BASE

STS PLANNING

STS FLIGHT/GRD. OPS. DESIGN

STS DETAIL FLIGHT/GRD. OPS. PLANNING

INTEGRATED FLIGHT/GRD. OPS. PLANNING

FIGURE 6
FLIGHT OPERATIONS

STS FUNCTIONS
- Command of Flight
- Flight Safety
- Orbiter/Spacelab Resources Management
- Remote Manipulator Operation
- EVA

PAYLOAD FUNCTIONS
- Setup Experiment Equipment
- Operate Experiments
- Observe Results
- Alter Experiment Operation to Maximize Science Return
- Maintain Experiment Equipment

SHUTTLE/SPACELAB

GROUND SUPPORT

STS FUNCTIONS
- Shuttle Operation
- Spacelab Resources Management Support
- Flight Plan Integration
- Data & Communications Management
- Orbiter/Spacelab Contingency Analysis

PAYLOAD FUNCTIONS
- Ground-Based User Support to Payload Specialist
- Command Functions to Enhance P/L Specialist Time and Science Return
- Science Data Management
- Real Time Payload Activity Rescheduling
- Payload Contingency Analysis

FIGURE 7
OVERALL SPACELAB DATA FLOW

TDRS

TDRS GROUND STATION

DOMSAT

THRU PUT

NASCOM

HIGH RATE

MISSION OPS.

COMMAND

PAYLOAD OPS.

DIFFERENTIAL

USER

DATA DELIVERY

RECORD

PREPROCESS

DATA ANALYSIS

ARCHIVE

LANDING

TAPES SAMPLES

FIGURE 8