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Paper Session I-B - Spacehab: Augmenting the Shuttle's Middeck Capacity

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SPACEHAB: AUGMENTING THE SHUTTLE'S MIDDECK CAPACITY

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ABSTRACT

SPACEHAB, Inc. is developing a pressurized laboratory which fits in the forward portion of the Space Shuttle payload bay and connects to the crew compartment through an airlock. SPACEHAB's standard middeck-type lockers offer crew-tended access to the microgravity environment for experimentation, technology development, and small-scale production. NASA's Office of Commercial Programs has contracted with SPACEHAB to lease two-thirds of the SPACEHAB's module capacity over the first six missions for commercial research initiatives. Use of SPACEHAB modules also offers an economical intermediate step prior to making a full commitment for commercial use of Space Station Freedom.

THE NEED TO AUGMENT THE SHUTTLE'S MIDDECK CAPACITY

Over the past decade, the United States has faced a steady loss in global leadership in a number of high-technology fields. The space program is a major source of high technology. If this technology is translated into improved production processes and marketable, innovative products, the competitive position of the Nation is enhanced. Because of this potential benefit, the United States Government encourages the commercial use and exploitation of space technologies and systems.

Fundamental to the development of new products and services is the maturation of technologies to the point that a determination can be made concerning their potential for commercial applications. The process of maturing space-related technologies typically requires an extensive program of space flights. The Space Shuttle is currently the only domestic means of accomplishing crew-tended experiments, which are typically carried out in middeck lockers. These lockers are a scarce resource given the infrequency of Shuttle launches and competition for their use.

National Aeronautics and Space Administration's (NASA) Office of Commercial Programs (OCP) conducts a variety of initiatives designed to promote the commercial development of space. One such initiative is the Centers for the Commercial Development of Space (CCDS) Program. The CCDS's, of which there are currently seventeen, are consortia of universities, industrial firms, and non-NASA government entities involved in research and testing phases of potentially commercially viable technologies. Approximately 61 different technologies requiring more than 300 flights of middeck locker capacity are currently being developed by the CCDS's.

NASA also promotes space commerce through direct agreements with industry. One such instrument is the Joint Endeavor Agreement (JEA). Under a JEA, private industry funds experiments and the government provides transportation and other services. NASA requires that the private participant make a good faith effort to apply, commercially, any promising technologies on a timely basis.

The success of NASA's CCDS and Industry Agreements programs has resulted in additional middeck locker flight requirements. Commercial experiments to be flown are targeted to possible breakthrough technologies in areas such as protein crystal growth, zeolite crystal growth, polymers, fluid dynamics, bioprocessing, physiology, and plant growth.

SPACEHAB, INC. - A COMMERCIAL VENTURE WHICH SEEKS TO MEET THE NEED

SPACEHAB was formed in 1983 after the company's founders recognized that the growing demand for crew-tended microgravity research and development opportunities could not be satisfied by the experiment volume allocated to the Space Shuttle's middeck. Originally, the Space Shuttle's middeck extended an additional 10 feet into what is now the payload bay. This area was to act as a miniature laboratory on every Space Shuttle flight, providing a pressurized work environment for astronauts to conduct microgravity research activities. Subsequent changes in Space Shuttle mission requirements forced a change in the Space Shuttle design; the additional middeck area was eliminated and the payload bay was extended to its current configuration.

Although the demand for SPACEHAB middeck augmentation modules seemed clear, SPACEHAB's founders faced several obstacles in organizing a new commercial space venture. In addition to negotiating an agreement with NASA to assure access to the Space Shuttle and organizing a qualified industrial team, SPACEHAB faced the challenge of raising over $100 million of private capital to fund the design, development, and production of the modules.

From 1983 until 1990, SPACEHAB used a combination of venture capital, short-term loans, and subcontractor investment to keep the program on track even during the Space Shuttle flight hiatus following the loss of Challenger. Over $43 million of private capital was invested in SPACEHAB common stock and subordinated debt. Today, SPACEHAB has over 200 equity investors including large aerospace corporations such as McDonnell Douglas, Alenia Spazio S.p.A., and Fairchild Missiles and Space Company.

SPACEHAB's second major financing source that assured on-schedule module production and delivery, was secured in early-1991. The Chase Manhattan Bank agreed to provide $63 million in revolving credit, and purchase $1 million of common stock. This revolving line of credit is being used to complete the few remaining program production activities and will also fund SPACEHAB's operating expenses for the first six flights.

In August 1988, NASA and SPACEHAB entered into a unique NASA agreement designed to encourage commercial ventures utilizing the Space Shuttle. This agreement, called a Space Systems Development Agreement (SSDA), is offered to eligible customers who are in the late development stage of R&D but who intend to realize revenue from the launch. The most significant feature of this type agreement is a deferred payment plan. The fly-now, pay-later aspect of these agreements minimizes the customer's upfront cash flow while allowing NASA to eventually recover costs. The agreement applies to the first flight(s) of a new industry with significant potential national economic or social benefit.

When NASA entered into an SSDA with SPACEHAB, there were no known NASA requirements for use of the module. By 1989, due to the evolving needs of NASA's CCDS and Industry Agreements programs, additional capacity requirements had become apparent and, in early 1990, NASA released a Request for Proposals for a Commercial Middeck Augmentation Module (CMAM). In November 1990, NASA awarded a $184.2 million contract to SPACEHAB to provide the services of CMAM. The firm fixed-price contract leases two-thirds of the pressurized SPACEHAB module's capacity over its first six flights. These flights will cover a 5-year period planned to begin in the spring of 1993. NASA will then make that capacity, equal to about 200 Space Shuttle middeck lockers, available to U.S. private entities for commercial research initiatives.

THE SPACEHAB MIDDECK AUGMENTATION MODULE

SYSTEM OVERVIEW

SPACEHAB's commercially developed and operated middeck augmentation modules are designed to provide simple, reliable, affordable, and regularly scheduled crew-tended access to the microgravity environment aboard the NASA Space Shuttle fleet. SPACEHAB, in close cooperation with its industry team led by McDonnell Douglas Space Systems Company (MDSSC) and Alenia Spazio, has designed and patented a middeck augmentation system which increases the available pressurized volume of a Space Shuttle by approximately 1100 cubic feet. SPACEHAB modules can accommodate approximately 3,000 lb of payload in a pressurized, "shirt sleeve" environment aboard the Space Shuttle. On-orbit accommodations such as power, thermal control, and command/data functions are provided for up to 50 Middeck Locker Volume Equivalent (MLVE) payloads (each with a mass of approximately 60 lb) through standard mechanical and electrical interfaces. Two SPACEHAB flight modules are currently under construction and the first was delivered to SPACEHAB's assembly and

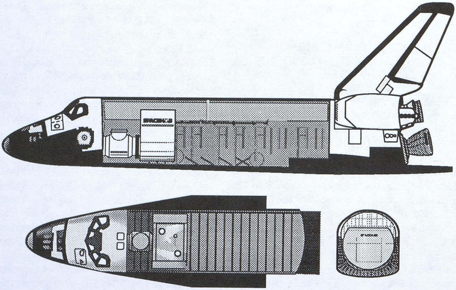


Figure 1. SPACEHAB Module in Orbiter Cargo Bay.

integration facility located near NASA's Kennedy Space Center earlier this year.

SPACEHAB modules are designed to facilitate the user's ability to quickly and inexpensively develop and integrate a microgravity payload. Total cost to the user is minimized by providing standard mechanical interfaces and payload services and by shortening the payload integration period. Unlike other crew-tended microgravity experiment systems, SPACEHAB can integrate a payload only 18 months prior to the requested flight date. Payload interface information and documentation is required only 16 months before launch; the experimenter's hardware does not have to be delivered to SPACEHAB's integration facility until only 8 months before launch.

One of the other key attributes of SPACEHAB's middeck augmentation module system is the frequent and regularly scheduled access to space that has been negotiated with NASA. SPACEHAB modules are already manifested on eight Space Shuttle flights beginning in April 1993. Additional missions will be scheduled to accommodate demand as needed.

As shown in Figure 1, the SPACEHAB module is connected to the the Space Shuttle Orbiter through a modified Spacelab tunnel adapter. Drawing its resources from the Orbiter, a SPACEHAB module distributes power, thermal control, and command/data functions to individual payloads manifested aboard the facility in standard SPACEHAB lockers or racks.

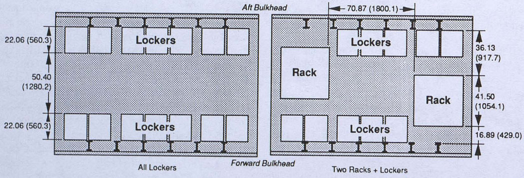


Figure 2. Top View of SPACEHAB Module Accommodations
[dimensions in inches (mm) throughout paper].

Housekeeping services (such as environmental control, lighting, and fire/smoke detection and suppression) provide a "shirt sleeve" environment for two Mission Specialist crew members to operate and monitor dozens of payloads whose combined mass does not exceed 3,000 lb. Environmental control of the module's interior provides ambient temperatures maintained between 65 to 80 degrees Fahrenheit.

PAYLOAD ACCOMMODATIONS

The SPACEHAB module accommodates various quantities, sizes, and locations of payload hardware. Payload attachment locations are available on the the interior forward bulkhead, aft bulkhead, and rack support structures of the module. Access to the exterior bulkheads and top surface of the module to mount payloads is available as an optional service.

Payloads are usually integrated into the module in standard SPACEHAB lockers or SPACEHAB racks and are flown in one of the two generic mounting configurations shown in Figure 2. SPACEHAB lockers are designed to offer identical user interfaces as standard Space Shuttle Middeck lockers. For the "Lockers Only" configuration, the module provides 61 MLVE mounting positions - the forward bulkhead accommodates 20 MLVEs, the aft bulkhead accommodates 41 MLVEs.

In the "Lockers and Racks" configuration, SPACEHAB racks can be mounted in forward or aft positions on either side of the module. These "double racks" are designed with removable front centerposts and can accommodate side-by-side, 19-inch wide standard panels as well as Spacelab and Space Station single and double rack hardware.

In addition to locker and rack payload provisions, two mounting flanges on the interior top module panel are available to accommodate Spacelab optical viewpoints for high-quality Earth or space viewing.

Payload environments (mechanical, electromagnetic, thermal, and pressure) are analogous to those found in Spacelab.

Locker Description

The primary interface between the SPACEHAB module and the payload is a standard SPACEHAB locker which may be used directly or with either one large or two small stowage trays (see Figure 3). The small trays are separated by guides installed on the locker sides. Payloads that cannot be stowed inside trays can be mounted within the locker interior, provided they are isolated from vibration contact with the locker and have "zero-g" retention during on-orbit activities.

User-provided foam inserts can be placed in the trays to package payload equipment. Elastic restraints can also be used for retention. These restraints (bungees), located in the trays, will prevent equipment from floating

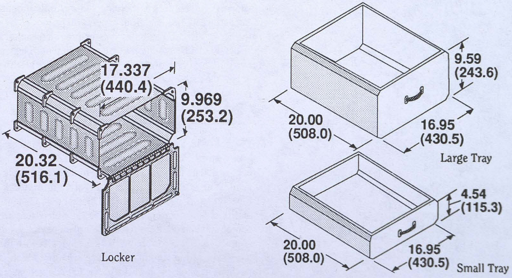


Figure 3. SPACEHAB Locker and Trays.

out when the lockers are opened on-orbit.

Lockers are also designed to be packed solid with insulator material between the locker walls and the contents. The locker has a hinged modular door for on-orbit use and two captive latches for securing the door during launch and landing. The door has a friction hinge for zero-g positioning and can be opened approximately 180 degrees.

Weight/Volume

Lockers have a maximum load-bearing capacity of about 76 lb. Of this maximum capability, 60 lb is available to the payload and 16.4 lb is reserved for the locker's structural mass. If a tray(s) is needed to stow the payload, its mass is included in the payload mass allocation. Small tray mass is 2.4 lb, and large tray mass is 3.3 lb. Based on flight experience and currently manifested SPACEHAB payloads, 60 lb is used as the average combined mass of a locker and its payload when estimating MLVE accommodations and pricing for the user's total mass allocation. For example, a one-half module allocation of 1500 lb is equivalent to 25 MLVEs.

Each MLVE is allocated approximately 2.2 cubic feet of payload volume. If a standard SPACEHAB locker is used, internal volume available to the payload is approximately 2.0 cubic feet.

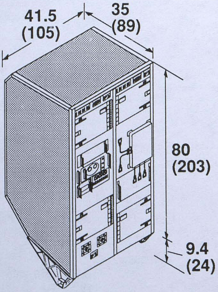


Figure 4. SPACEHAB Rack with Example Payload.

<u>Rack Description</u>

The SPACEHAB module has the capability of supporting one or two of the SPACEHAB payload racks shown in Figure 4. This double rack is designed to accommodate two stacks of side-by-side mounted standard 19 inch pieces of equipment. Single racks accommodate one stack of 19 inch equipment. Double and single racks can be flown in the forward or aft positions and can be mounted on the port or starboard side of the module.

Weight/Volume

The maximum load-bearing capacity of a double rack, including structure, payload, and attached hardware, that can be accommodated is 1400 lb. The maximum allowable payload weight is 1250 lb.

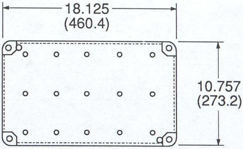
The nominal volume and envelopes for payload equipment mounted in a standard double rack is approximately 65 cubic feet. Minor protrusions of payload equipment may be allowed in front of the rack as determined by operational constraints, crew habitability, etc. The rear of the rack is occupied by fire suppression lines, cabling, and payload utilities. If a rack payload is completely passive, i.e., without power and hence without the need for cooling or fire detection/suppression, more of the rear area may be available for use.

Payload Mounting

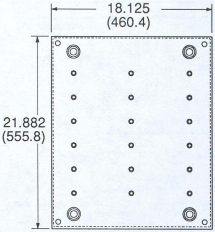
Mounting of payload equipment may be accomplished by means of front panels and user-provided internal support structure such as shelving, runners, rails, mounting hardware, etc. The front panels will be mounted to the front attachment holes. User-provided support structure can be mounted to side attachment holes on rear and front rack posts. Tie struts are available in the rear of the rack for support of fire suppression lines and payload utilities.

<u>Adapter Plate Description</u>

The use of lockers or racks is not essential for integration with the SPACEHAB module. Payloads can be accommodated by direct mounting to the module bulkhead using the adapter plates in Figure 5 or middeck-type mounting panels. (Standard plates come in single and double locker-equivalent sizes.) Subsystem resource accommodations for adapter plate payloads are identical to those for regular locker payloads with the exception of the resource interface location which is payload-defined. If necessary, special adapter plates which occupy more than two locker spaces (either horizontally or vertically) can be provided as an option.



Single Adapter Plate



Double Adapter Plate

Figure 5. Locker Adapter Plates.

PAYLOAD RESOURCES

The following resources are available to payloads in locker or rack configuration:

DC Power

Power is provided to the modules from two Orbiter Standard Mixed Cargo Harnesses (SMCH) cables. A total of 3150 W is available to the payloads which is allocated on a pro-rata and timelined basis.

A maximum continuous power level of 115 W at 28 ± 4 VDC will be provided and should be used for locker payload design planning purposes. DC power outlets, available for forward and aft bulkhead users, are accessed using SPACEHAB-provided cables. Circuit breakers at the locker DC power interfaces are easily interchanged to accommodate specific load requirements. Standard load protection is provided by 5 amp circuit breakers. Due to touch temperature requirements and the passive heat rejection capability of a SPACEHAB locker, actual power and energy usage by passively cooled payloads must be determined on a case-by-case basis.

Rack DC power (and all other subsystem resources except vacuum) is supplied to the Rack Utility Interface Panel (RUIP) via cables through the SPACEHAB floor. Cables for routing power within the rack are provided by the user. A nominal power level of 1 kW at 28 ± 4 VDC can be provided for each rack and should be used for payload design planning purposes.

AC Power

AC power of 690 VA at 115/200 VRMS, 3 phase, 400 Hz, can be made available to a rack or locker location as an optional service. AC cables can also be made available for payload use.

Command/Data

Command and data services are supplied to locker payloads from outlets located on the forward and aft bulkheads, and for racks at the RUIP. SPACEHAB-provided cables are used to route command and data signals between outlets and payload lockers. Allocations of the total command/data system capabilities will be made on a mission-by-mission basis.

Thermal Control

Cooling for locker payloads is by passive and/or forced air cooling or optional water cooling. Available locker air cooling modes are nearly identical to that of the Orbiter middeck lockers and can be passive or active depending on the specific payload requirements. Passive cooling is accomplished by radiation and convection to the passing cabin air. The maximum level expected to be passively cooled from one locker is 60 W assuming no powered lockers border it.

Thermal control of rack payloads is achieved by passive cooling through radiation, convection to the cabin environment, and water cooling. Total module cooling capability is 4000 W.

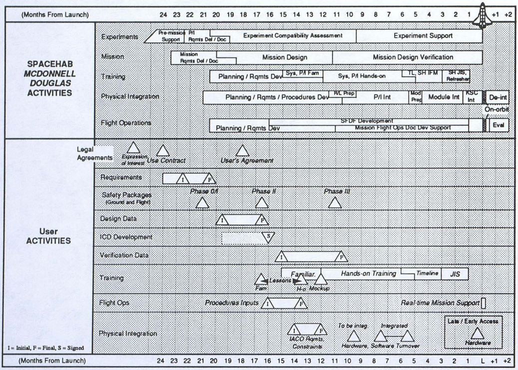


Figure 6. SPACEHAB / Payload Integration Process.

PAYLOAD INTEGRATION

Figure 6 describes the entire SPACEHAB mission/payload integration process, from the initial activities of mission manifesting, integration, and operations through the flight phase, and ending with the post-flight transfer of the payload and products back to the user.

The User Activities in Figure 6 are those standard deliverables required to support module and orbiter integration activities. The schedule for these deliverables is shown as either a discreet event or as "windows" in which the deliverable is required. For example, the training mockup is required at L-12 whereas the formal training required from the user may require only a few hours in presentation and must be scheduled during the period from L-15 to L-4. Milestones should be viewed as final due dates. Actual dates will be negotiated to develop a payload-unique schedule for each SPACEHAB mission and included in the SPACEHAB/Experiment Interface Control Document (ICD). Special assistance to the user for accomplishing any of these activities is available as an optional service.

SPACEHAB - BELLWETHER FOR SPACE COMMERCE

Because SPACEHAB is one of the few companies that has been able to attract significant private investment capital, the company's success will send a positive message about the potential for space commerce in the U.S. SPACEHAB will support the development of breakthrough technologies in such fields as materials processing, organic research, and fluid dynamics. SPACEHAB also provides the opportunity to gather fundamental data and knowledge required to efficiently and effectively develop experiments for use on Space Station Freedom.

Although SPACEHAB is dependant on the Space Shuttle flight schedule for mission opportunities, SPACEHAB modules have been designed to be compatible with all four Orbiters and do not require dedicated Space Shuttle missions. Each module only requires approximately 25 percent of the Space Shuttle's payload bay so SPACEHAB missions can be co-manifested with a wide variety of other payloads and do not required a dedicated Space Shuttle launch. Further, two SPACEHAB flight modules are being produced, each of which can be processed for two Space Shuttle flights per year.

Beginning in 1993, SPACEHAB's Middeck Augmentation Modules will enhance the Space Shuttle's capability to conduct crew-tended microgravity experiments and technology development programs. By providing frequent, regularly-scheduled, reliable, and economical access to space for government and industrial users, SPACEHAB'S modules will foster the development of new space-based technologies for commercial applications and provide a smooth transition to activities planned for Space Station Freedom.