Economy of Middeck Payloads

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ABSTRACT

Whether adding microgravity to an experiment as a key ingredient or as an “X” factor, investigators need to minimize cost and risk while assuring adequate control and data.

The crew quarters of the Space Shuttle Orbiter, called the Middeck, offers the optimum environment for this type of activity. The experiment packages can be controlled by the investigator until shortly before launch, and can be retrieved shortly after landing. Utilities are readily available. Human interaction and observation by astronauts and crew members is also possible.

NASA is optimizing this resource with its new Middeck Accommodations Rack (MAR), which displaces the original galley, normally carried only on Spacelab module flights.

INTRODUCTION

Just below the cockpit and flight deck of the Space Shuttle Orbiter is the crew quarters area known as the middeck. This comfortable environment was not originally designed to accommodate the needs of experimental payloads. It was designed to accommodate human needs and activities. Investigation of phenomena and experimentation are not usually included in the list of primary human needs, but where there are humans and opportunities for unique investigations, experiments usually emerge.

It seems inevitable that scientific investigators will seek out and utilize any available space for experiments in the benign environment of the Shuttle middeck. Its habitable microgravity conditions make it an ideal nursery for embryonic, low-complexity experiments that still need human care to thrive.

Since the first middeck experiments were flown in available stowage lockers, there has been growing interest in middeck payloads. The manned environment facilitates crew interaction with payloads, greatly increasing the potential for observation and successful operation of certain experiments.

Arrangements can be made to load experiments on the middeck shortly before launch and to retrieve them shortly after landing. For some experimenters, this is essential.

One of the main reasons, however, for the growing interest in middeck payloads is economy. Readily available utilities enhance middeck payload accommodations.* Lower cost is also assured by the prudence of NASA in making the best use of available space and resources by standardizing payload accommodations and carefully communicating all requirements to interested investigators.

The economy factor makes it more practicable for experimenters to utilize reflight opportunities. The potential for reflights, per se, is a big incentive to many investigators.

Attractiveness of the middeck was summed up by the writer of one study, "It offers an ideal location for the first essential step of experiment concept and apparatus validation — a step that is desirable before larger resources are committed to more ambitious payload bay experimentation." As early as September 1983, NASA began evaluating the middeck payload experience, assessing the provisions that had been made to

*All utilities required by a payload must be negotiated with the National Space Transportation System Program Office (NSTSPO) on an individual basis. The documents referred to and comments in this paper describing the availability of utilities are not to be construed as NSTSPO sanctioned.
meet continuing demand for middeck experiment space, identifying suitable locations for experiment accommodation, and seeking the most versatile location for a dedicated middeck experiment station.

A LOOK AT THE MIDDECK

Located below the flight deck, the middeck serves as crew quarters during Shuttle flights (fig. 1). It connects to the flight deck by a ladder and to the payload bay by an airlock. The middeck contains the hygiene compartment, crew storage lockers, launch/landing seating accommodations, sleeping accommodations, the galley, a few other features, and a little space to move around in. Beneath the middeck floor is an equipment bay containing plumbing, service utilities, and other equipment. Forward, the middeck is dominated by 33 stowage lockers attached to the wire trays of two avionics bays. Aft is the airlock, flanked by nine stowage lockers (attached to the wire trays of an avionics bay) on the right side and the hygiene compartment on the left side (fig. 2).

Although middeck stowage lockers were designed to carry clothing, food, and personal items of the flight crew, they have also been used as the primary middeck payload containers. Lockers may be replaced by adapter plates to mount larger payloads. Also, the galley, designed to warm food and dispense water, has been replaced by a large experiment payload on several flights.

STANDARD LOCKERS.-- All of the 42 standard modular lockers on the Shuttle are located in the middeck. Since they were designed for crew equipment stowage, only a few of them per flight are available to be adapted for experiment payloads.

Standard lockers have inside dimensions of 9.969 inches high, by 17.337 inches wide, by 20.320 inches deep (about 2 cubic feet of interior space). They are secured to the avionics wire trays by four bolts and have a load capacity of 60 pounds. They have hinged doors with a magnetic latch and friction hinge for on-orbit “zero-g” positioning and two captive latches for securing the locker during launch and entry maneuvers. These standard doors are also available in a modified version with three removable panels allowing access to provide power or cooling to the experiment payload, if needed. Any or all of the panels may be removed for flight without weakening the locker.

Two sizes of precision, pressure-formed plastic trays are available for standard lockers. The large tray fills up a locker and has inside dimensions of 9.969 inches high, by 17.337 inches wide, by 20.320 inches deep. Its volume is 1.8 cubic feet, and it weighs about 3.4 pounds. Two small trays fill up a locker and have inside dimensions of 4.74 inches high, by 17.057 inches wide, by 20.120 inches deep. They hold .85 cubic feet each and weigh 2.45 pounds each. Separation of the trays in the locker is accomplished by installing special guides, containing friction devices, in the sides of the lockers.

Foam inserts can be placed in the trays to cushion the stowed items. The inserts may be customized to fit the experiment configuration. Elastic restraints can be used to prevent items from floating out if the locker is opened in orbit.

DOUBLE LOCKERS.-- Also available are double lockers which displace two standard lockers. They have interior dimensions of 21.154 inches high, by 17.337 inches wide, by 20.320 inches deep (about 4.3 cubic feet of interior space). They weigh 25 pounds and carry a payload of up to 95 pounds.

ADAPTER PLATES.-- Adapter plates allow experiment packages that do not fit into a locker to be mounted in lieu of lockers. Standard plates available include a single plate to replace one locker, a double plate to replace two lockers, and a lightweight double panel that mounts directly to the avionics wire trays to replace two lockers.

Lightweight double panels have a decided payload capacity advantage over the old double plates, which must be mounted on top of two single plates attached to the avionics wire trays.

Capacities for the adapters, are shown in table 1.

<table>
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<tr>
<th>TYPE OF ADAPTER</th>
<th>PAY LOAD</th>
<th>PANEL WEIGHT</th>
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<td>L/W DOUBLE</td>
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<td>6.8 lbs</td>
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TABLE 1.—ADAPTER PLATE CAPACITIES

THE GALLEY LOCATION.-- The Orbiter’s galley (normally carried only on Spacelab flights) is a floor to ceiling enclosure on the left side of the middeck, 82.3 inches high, 18 inches deep, and 25.5 inches wide. It attaches at three points, and is provided with utilities connections at its base. On a number of occasions, it has been replaced by a payload unit which used the same attachments and similar utilities connections.

UTILITIES.— Utilities available for middeck payloads include:

- AC and DC electrical power supply
- Active and passive cooling
- Vacuum/vent line connections
- Data handling (limited)

Electrical Power available includes three DC outlets and two AC outlets. The DC power is at 28
volts, 10 amps per circuit and is shared with an 
outlet on the flight deck. The AC power is at 115 
volts, 400 Hz, three phase, with three amps per 
phase per circuit, and is also shared with an outlet 
on the flight deck. (Standardized cables for 
making connections are available.) Two electrical 
outlets are in the overhead panels (ceiling) of the 
middeck, another is at top left of the forward 
lockers, and one AC and two DC connections 
emerge at the base of the galley location.

Passive cooling for the experiments is done by 
heat rejection into normal cabin air, with 
maximums of 60 watts for lockers and 90 watts for 
experiments mounted on adapter plates. Active 
cooling is done by fan-driven cooled air and 
pump-driven cooled water. The cooled water 
comes from the Orbiter payload heat exchanger 
to a quick-disconnect fitting at the galley. 
Investigators provide fans and pumps.

The vacuum/vent system is only accessible from 
the quick disconnect stations at the hygiene 
compartment and on the deck just forward of the 
airlock.

Basically, data handling systems for middeck 
payloads are user provided. However the 
middeck does have a limited data handling system 
that was designed for clinical observations of 
astronaut vital signs. The biomedical data is input 
through connections in the middeck ceiling and 
processed by a program in the payload station 
data processor. This facility is limited to two 
channels and can only be used when the 
spacecraft is in high-bit-rate mode. It operates at 
0-5 volts and samples at a rate of 100 samples per 
second. There are three connections for it on the 
middeck ceiling.

MIDDECK PAYLOAD CONFIGURATIONS.-- Thus far, payloads are in four basic configurations:

1. Those contained in one or more lockers, 
   having no interface of electrical power or other 
   utilities with the orbiter. An example is the 
   Isoelectric Focusing (IEF) Experiment, which uses 
   electro-osmosis in microgravity to separate 
   chemical compounds. (fig 3).

2. Those enclosed in one or more lockers, but 
   having electrical power and/or other utilities 
   interface with the Orbiter. The Initial Blood 
   Storage Experiment (IBSE) is a good example 
   (fig.4). The IBSE consists of four dewars, 
   containing blood bags packaged two each into 
   two middeck lockers. The dewar lids contain 
   thermoelectric coolers controlled by electronic 
   assemblies in the lockers, and DC powered fans 
   mounted in the locker doors provide a flow of 
   cabin air to the heat rejection surfaces.

3. Those that are adapter-plate mounted, like the 
   MLR, and require electrical power or other 
   Orbiter utilities interface (fig 5). For example, the 
   MLR consists of an Experiment Apparatus 
   Container (EAC) mounted to a double plate and a 
   Support Electronics Package (SEP) mounted to a 
   single plate. The EAC contains four independent 
   chemical reactors with heating and stirring 
   capabilities. The SEP contains a microprocessor 
   and a tape recorder.

4. Those that include relatively large, unitary 
   structures like the CFES (Continuous Flow 
   Electrophoresis System). The CFES (fig. 6) is 
   designed to utilize a microgravity environment to 
solve a difficult pharmaceuticals manufacturing 
problem. However, this "pilot plant" type 
   experiment occupies the volume of about eight 
   standard lockers. It has three major components, 
a large fluids system module, an experiment 
   control and monitoring module, and a sample 
   storage module. Its installation was greatly 
   facilitated by designing the fluid systems module 
to be the same shape and size as the galley. This 
enabled it to use the same sturdy fastener system 
as the galley. When the galley is removed the 
   CFES module can be secured to its same 
   attachment points. (During the missions when 
   the galley was replaced by CFES, the food warmer, 
   food, etc., were stored in standard lockers.)

INTERFACE DESCRIPTION.--NASA documents 
JSC-20879 and JCD-2-IM001 (references 2 and 3) 
define the middeck environment and capabilities 
in detail.

PAYLOADS FLOWN TO DATE

So far, there are more than 40 different scientific 
experiment packages prepared as middeck 
payloads (table 2). More than two dozen of these 
have already been flown, and eight of them have 
flown an average of more than five times. For 
example, the various Student Experiments (SSEP) 
have flown nine times, the Monodisperse Latex 
Reactor has flown seven times, the CFES eight 
times, and the Radiation Monitoring Experiment 
(RME) 10 times. Many of the experiments replace 
more than one locker space. Flying repetitive 
missions is one of the real advantages of middeck 
payloads, and these figures are given to highlight 
the demand for middeck locker space.

To date, middeck experiments have used a total of 
about 128 standard lockers, an average of about 
seven per available flight. This does not count use 
of galley space by CFES.

Counting use of galley space as the equivalent of 
five standard lockers for the eight CFES flights, 
experiments have used a total of 166 lockers, an 
average of about nine per flight.

PREPARING FOR THE FUTURE.-- In 1983, a NASA- 
sponsored study was published to show the 
middeck's potential to accommodate experiment 
payloads. 1The study shows that there are 
numerous potential areas in the middeck for 
supporting payloads. However any area used is at
the expense of some other activity or capability, and only the available stowage lockers and the space occupied by the crew's galley can readily accommodate small experiment payloads. The galley area appeared to be the most promising for additional payloads in that it required no orbiter modifications, offered easy access to utilities, and resulted in no decrease of available space in the middeck.

Since that study, more than a dozen Space Transportation System (STS) Shuttle flights have been accomplished. Ten different experiments have flown in the middeck, several of them on five or more reflights. More reflights have been requested, a dozen new experiments have been certified flight ready, and designs for about eight others have been accepted.

To satisfy this growing demand, NASA's objective is (without costly modification of existing Orbiters) to make the potential payload space even more flexible to enable an optimum number and variety of experiments to be flown.

A significant step toward achieving this goal is the development of the Middeck Accommodations Rack concept. This concept makes the galley space as flexible as the standard locker space by providing a payloads enclosure the same size and shape as the galley for each Orbiter.

The MAR concept provides greatly improved flexibility for handling payloads in the middeck. It opens up the galley area for small experiment payloads. Most significantly, it requires no modification of the Orbiters.

**THE MAR (Middeck Accommodations Rack)**

The MAR will add 15 cubic feet of volume for up to 350 pounds of payload and will be installed in the galley location on the left side of the Orbiter middeck. It can hold five additional lockers, three Experiment Apparatus Containers (EAC's), or a larger (unitized) payload than can normally be carried in the cabin. It provides power and cooling via a utilities subsystems unit.

Five MAR's are to be manufactured after design and certification. One of these will be used for certification tests and refurbished as a trainer and fit-check unit."

NASA has undertaken to design and fabricate the MAR at JSC to produce a structure which can be easily installed in any Orbiter to accommodate payloads and have design versatility to permit a variety of configurations (fig. 7). The basic structure of the MAR extends into the cabin slightly more than does the galley, but otherwise matches for excellent interchangability. A power distribution and cooling subsystems unit fits into the bottom section of the MAR assembly. When equipped with five standard lockers, the MAR stacks the three middle lockers horizontally and the top and bottom lockers on their sides. (Orientation is not significant since the lockers function in a weightless environment.) The bottom locker replaces the power and cooling subsystems unit.

Housing three Equipment Apparatus Containers in the MAR saves the space of six standard lockers, since each EAC requires two locker spaces. Yet with three EAC's there is room for the utilities subsystems, and some space left at the top.

The MAR is well suited for large unitized payloads, such as an experimental furnace for processing materials under microgravity conditions.

**THE UTILITIES --** Electrical power distribution panels for the MAR will accommodate up to five power-consuming payloads. Three power connections are normally available at the galley location: two 28VDC, 19A, 530W connections and one 115VAC, 400 cycle, 95W connection. However, power availability must be negotiated for each mission. Investigators supply the wiring harness from the MAR panel to the payload.

A 1-kW cooling system circulating forced air through an internal heat exchanger will provide atmospheric cooling for the interior of the MAR. If a payload needs additional cooling, the investigator may provide a circulating pump and cooling plate to connect to the payload heat exchanger cooling loop.

**PROJECT MANAGEMENT --** Design and fabrication of the MAR is very closely monitored by NASA, with direct oversight by the Flight Projects Engineering Office of the JSC Engineering Directorate in coordination with NASA's Commercial Development and Shuttle Payload Engineering Divisions and the Space Division of the U.S. Air Force. Design of the MAR is being done by Lockheed-EMSCO in Houston, while the Technical Services Division of JSC's Center Support Directorate will do the fabrication. Integration of the MAR as a Shuttle component will be achieved by the Integration and Operations Office of the National Space and Transportation System Office in concert with the centers of operation in Florida and California.

A total of 36 NASA, Air Force, and contractor organizations will have responsibilities in seeing that all applicable standards are met in accordance with program requirements.

Nevertheless, the MAR project fits neatly into the existing STS development framework, so that its gestation time is short. Program requirements were approved in January this year; the first of the hardware will be delivered this fall.
DELIBERABLES.— A handling and shipping stand will be delivered with each of the five MAR’s. These stands will be used strictly to facilitate installation of subsystems, shelves, lockers, or payloads into the MAR during checkout and shipping. The MAR structure proper will weigh between 90 and 130 pounds. However, the total of structure, subsystems, and payloads can weigh up to a maximum of 500 pounds for any specific configuration of the MAR.

Deliverables do not include ground support equipment (GSE) or hoisting equipment required for installing the MAR in the middeck. Current planning is to install flight-ready MAR’s into the Orbiter during the horizontal processing by a procedure similar to that used for installing the CFES. However, GSE quick-release handles will be provided as needed for the manual installation.

The MAR has to be rugged to meet its flight certification requirements. It is designed to meet vigorous structures and vibration tests, to resist corrosion, mildew and static charge accumulation, and to last a minimum of 10 years or 100 missions.

SUMMARY

The orbiter middeck location gives investigators more opportunity to conduct some of the same kinds of unique microgravity-based materials processing, biomedical, and pure science experiments that are done on Spacelab, but at less expense and with opportunities for reflights. This location is much in demand for nurturing embryonic “proof of concept” space-utilization devices. Here they can be economically developed until they metamorphose into mature satellite or space station facilities. Several key factors have attracted a growing backlog of payloads.

+ Habitable environment
+ Man/experiment interface
+ Late installation in countdown
+ Early removal after landing
+ Reflight potential

Utilization of the galley location by the CFES demonstrated that this arrangement provides about 50 percent more payload space than would normally be available. (There are usually fewer than 10 lockers available for payloads, and the galley location is equal to five or six.) The MAR was designed to more fully exploit the galley location, introducing greater flexibility for sizes and types of middeck experiment payloads.

The whole MAR concept was inspired from a no-nonsense, economical point of view. It improves the payload capacity of the Orbiter middeck without the enormous expense of modifying the Orbiters.

REFERENCES


ACKNOWLEDGEMENTS

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<td>9</td>
<td>D</td>
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<td>Visual Function Tester-2</td>
<td>.5</td>
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LEGEND:  C = CONCEPT,  D = DESIGNED,  F/R = FLIGHT READY,  In D = DESIGNED,  Ret = RETIRED.
Figure 1.- Orbiter middeck, seen from aft starboard.

Figure 2.- Orbiter middeck, seen from port forward.
Figure 3.- Isoelectric Focusing Experiment (IEF).

Figure 4.- Initial Blood Storage Experiment (IBSE).
Figure 5.- Monodisperse Latex Reactor (MLR) mounted in the middeck.

Figure 6.- Continuous Flow Electrophoresis system (CFES) replacing galley and three lockers.
Figure 7. - Middeck Accommodations Rack (MAR) -- basic structure and two configurations.