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MISSION PECULIAR EQUIPMENT SUPPORT STRUCTURE
A PLATFORM FOR SPACE CONSTRUCTION

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INTRODUCTION

America's Space Transportation System (STS), the Space Shuttle, requires carriers to support payloads in the cargo bay. As a result, the Mission Peculiar Equipment Support Structure (MPESS) was designed to carry partial payloads aboard the Shuttle. With completion and approval of the MPESS design, Teledyne Brown Engineering built six structures and delivered them to the National Aeronautics and Space Administration (NASA).

The MPESS is a lightweight carrier that bridges the Shuttle payload bay from sill to sill and occupies approximately one-fourth of the bay. The MPESS attaches to the sides and bottom of the Shuttle cargo bay, and there are 30 or more locations where it can be positioned. It can support 1,916 kilograms (4,225 pounds) of payload. Its basic construction consists of an upper section for experiment attachment and a lower truss type section that provides additional support, stability, and load carrying capability. The basic MPESS carrier can be outfitted with equipment to become a laboratory for scientific research or a platform for construction or deployment of large space structures.

Two space construction experiments, the Experimental Assembly of Structures in Extravehicular Activity (EASE) and the Assembly Concept for Construction of Erectable Space Structures (ACCESS) were mounted on the MPESS inside the Space Shuttle payload bay. For the EASE/ACCESS mission, the MPESS served as an equipment carrier and as a work platform for the two astronauts who assembled the structures in orbit. While the MPESS was somewhat benign compared to the experiment hardware, it worked ideally as a platform for constructing the two large space structures. The EASE/ACCESS mission was highly successful, and results from the mission are contributing significantly to ongoing space programs.

CUSTOMIZING THE MPESS FOR THE EASE/ACCESS PAYLOAD

NASA Headquarters selected the EASE and ACCESS experiments and assigned them as a payload to be flown aboard Space Shuttle mission 61-B from November 26 to December 2, 1985. The Marshall Space Flight Center (MSFC) Spacelab Payload Project Office was responsible for managing the EASE/ACCESS mission. This responsibility included selecting the appropriate payload carrier for the two experiments and designing a plan for integrating the experiments with the carrier to form the payload.

The MPESS was selected as the EASE/ACCESS carrier because it was available for flight in the inventory of NASA hardware. On previous missions, the MPESS was used to support scientific instruments and a large deployable space structure This successful track record suggested that the MPESS would be a stable work platform for the EASE/ACCESS construction experiments yet take a minimal amount of space in the payload bay.

Teledyne Brown, the MSFC Payload Mission Integration Contractor, designed and fabricated the MPESS for NASA and customized it for the EASE/ACCESS payload. The MPESS had to be outfitted with equipment for mounting the experiments, canisters for stowing equipment, and restraints for aiding crew members during the Extravehicular Activity (EVA).

In its basic form, the MPESS is 70 centimeters (27.5 inches) from front to back, 441 centimeters (173.5 inches) wide, and 262 centimeters (103 inches) deep with the top surface approximately level with the Shuttle cargo bay sill and the triangular base reaching to an attach point at the bottom (keel) of the cargo bay. Four standard trunnions join the MPESS with the side of the Shuttle. The main structural members are 10 centimeter by 10 centimeter (4 inch by 4 inch) aluminum alloy square tubes with interconnecting members dividing the upper platform into six sections or bays. The members and diagonal crossmembers are joined by stainless steel fasteners. Figure 1 shows the basic MPESS design.

BASIC MPESS

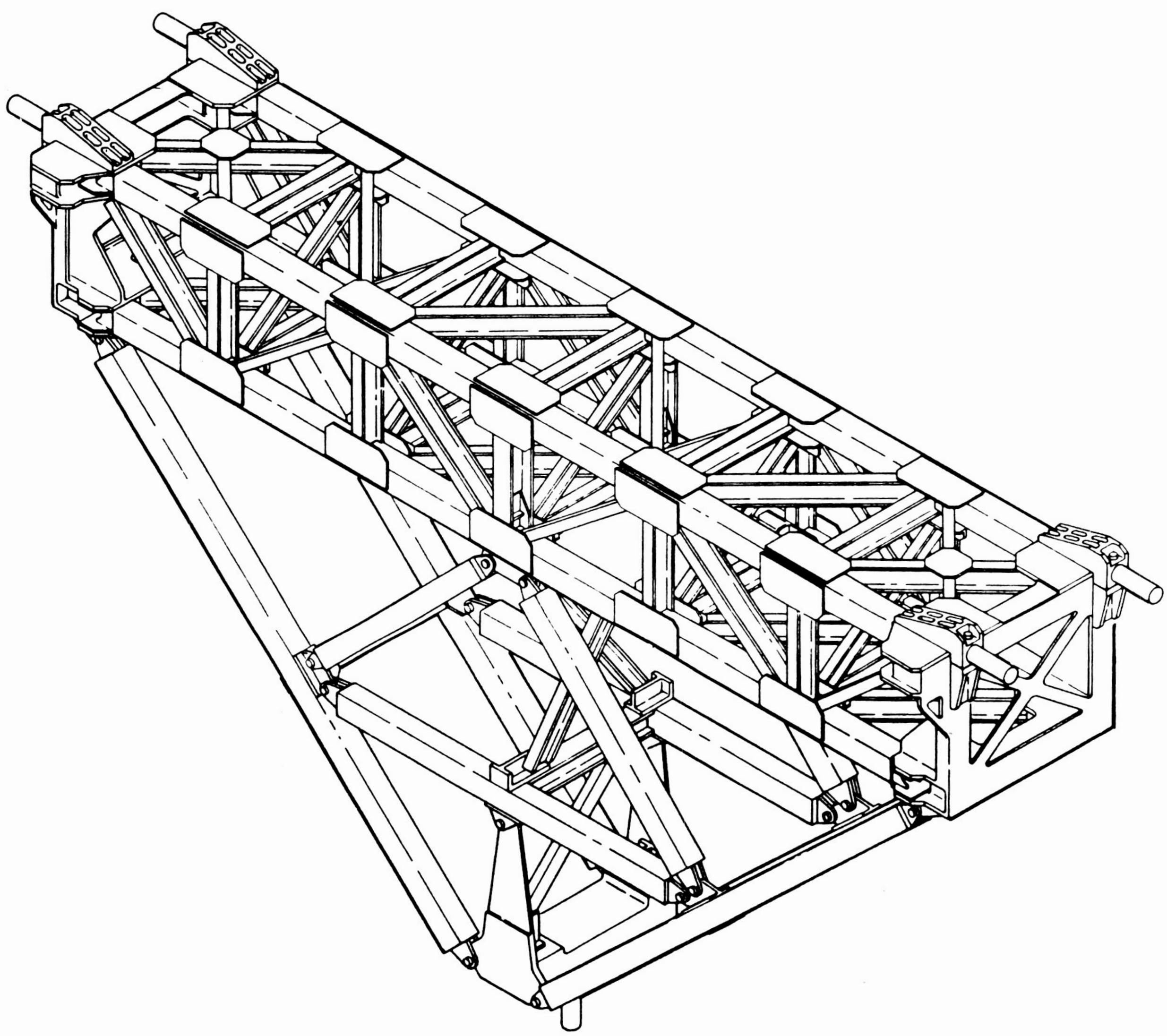


FIGURE 1

Structural members may be added to the basic MPESS to accommodate an assortment of experiment equipment. This type of construction enables the support structure to accommodate experiments of various sizes and shapes. Its open, truss-type construction also allows access for experiment installation and removal. Structures may be attached at standard bolt locations on the MPESS or may require the use of unique interface hardware or brackets to adapt the experiment to the support structure bolt locations.

The first step in tailoring the MPESS for the EASE/ACCESS payload was to design a blueprint showing the approximate locations of the experiment hardware on the equipment support structure. The plan called for EASE beams to be mounted on the front face of the triangle-shaped MPESS structure and for connector clusters (nodes) and one base cluster to be mounted on top of the platform. For ACCESS, the struts were to be stowed inside two canisters mounted on top of the MPESS; nodes were to be stowed inside a rotating, circular canister attached to the back side of the MPESS; and an assembly fixture on which ACCESS was built was to be clamped on the back side of the MPESS in a horizontal position parallel to the top of the MPESS platform. Figures 2 and 3 show the final MPESS configuration with the EASE/ACCESS equipment attached.

Before the equipment could be mounted in this configuration, Mission Peculiar Equipment (MPE) had to be designed to provide an interface for attaching the hardware to the MPESS. Initially, Teledyne Brown worked with MSFC to design nine interface plates, each approximately 86.3 centimeters by 96.5 centimeters (34 inches by 38 inches); three plates each were to be mounted to the front, top, and rear of the MPESS.

These initial plates were one inch thick; however, as weight of the experiment hardware increased, the total payload weight had to be reduced to stay within the payload's weight limits. Lighter plates were substituted in non-critical areas, but the plates remained an inch thick at load carrying points where hardware was to be directly attached. The final configuration used thin interface plates bridging areas between the heavier mounting plates. A total of 24 plates were used with ten plates on the top, nine on the back and, five on the front of the MPESS. Some of the attachment plates were further machined to lighten them after stress tests indicated that they could be lighter without affecting their load carrying capacity. To reduce weight even further, panels behind the EASE beams were covered with Beta cloth; heavier material was not needed because no equipment was mounted here, but covering was required to prevent the EASE beams from becoming wedged inside the MPESS framework. These techniques reduced the weight of the MPESS from 518 kilograms (1,140 pounds) to 195 kilograms (430 pounds) without compromising safety.

Since the MPESS was to serve as a work station for the astronauts who would assemble the structures, crew aids were necessary. Handrails were needed to help the astronauts translate about the work area, and foot restraints were needed to anchor the astronauts in place as they assembled the structures. The location of these aids was critical to the success of both experiments, especially the ACCESS experiment because the astronauts were required to be anchored in the foot restraints as they built the structure bay by bay in assembly line fashion. (The EASE experiment was built with the astronauts working in fixed foot restraints and unrestrained while tethered.)

MISSION PECULIAR EQUIPMENT SUPPORT STRUCTURE

Rear View

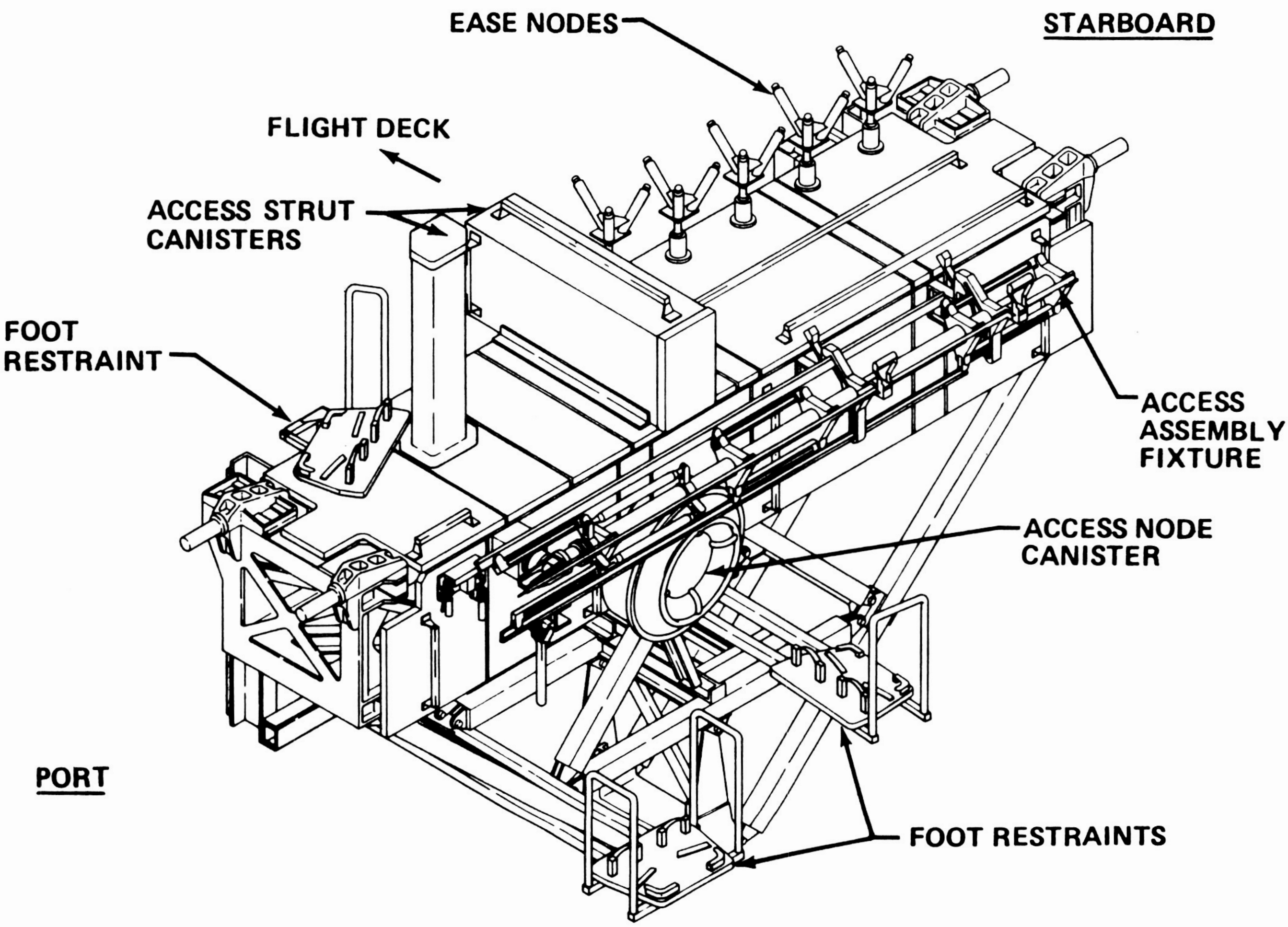


FIGURE 2

MISSION PECULIAR EQUIPMENT SUPPORT STRUCTURE

Forward View

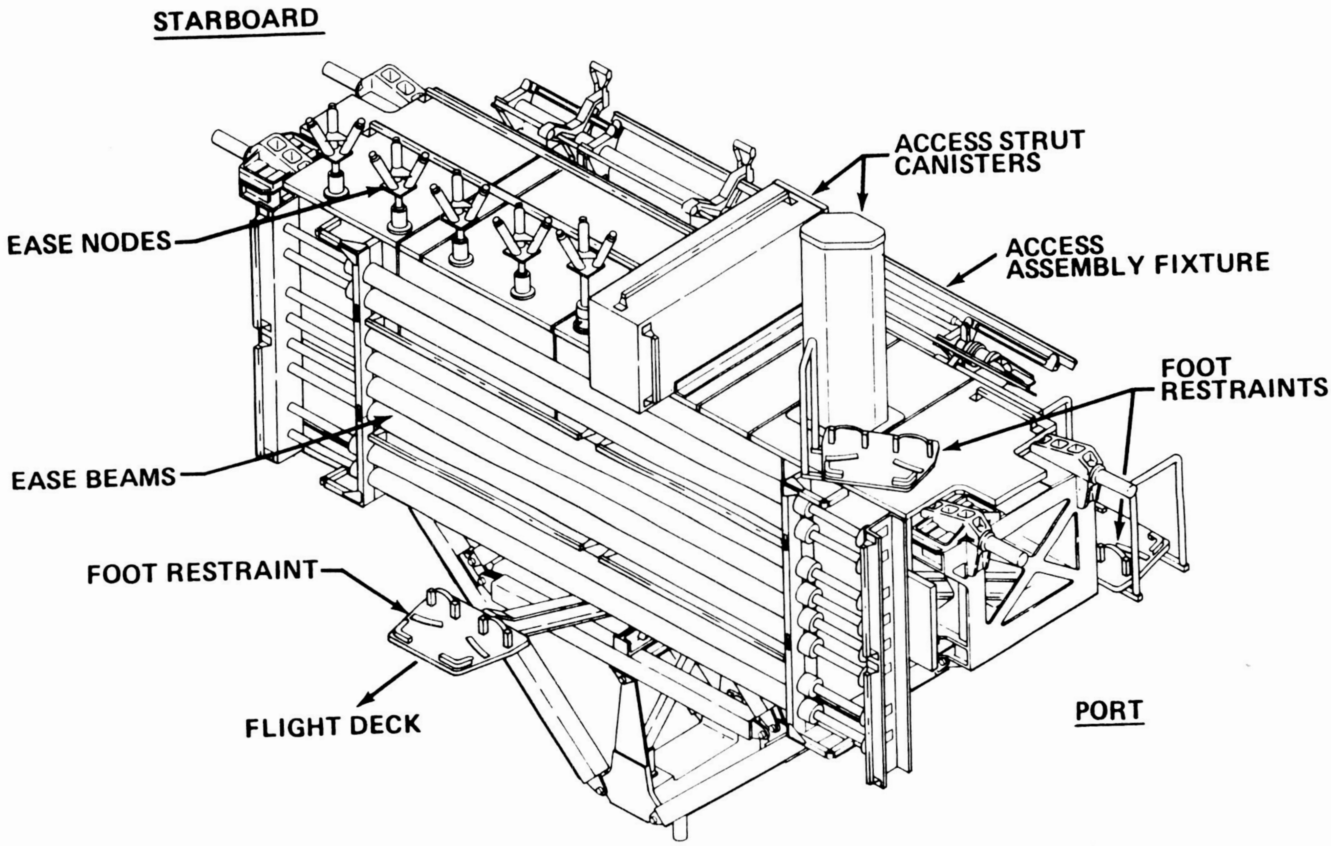


FIGURE 3

Experiment requirements dictated the general location for the handrails and foot restraints. (All crew aids were positioned per NASA standards MSFC-STD-412 and JSC-10615A) Since the crew members moved all around the MPESS at different times during the EVAs, handrails were positioned in several locations including the sides of the MPESS and on the ACCESS strut and node canisters. Foot restraints used for ACCESS were attached to the top and forward side of the MPESS. A foot restraint used for the EASE experiment was located on the forward side of the MPESS where the EASE beams were clamped.

Before specific astronauts were named to the mission, anthropometric standards were used to determine temporary locations for the handrails and foot restraints. It was critical that these crew aids be located for safety and ease of operations. This meant that the restraints had to be positioned so that each crew member could reach designated parts of the structures. For instance, the EVA astronaut had to be able to reach the assembly fixture to connect nodes and struts and build each side of the ten cells that formed the ACCESS truss tower. For the EASE experiment, the crew member unstowing the beams had to be able to hand the beams to his partner working approximately 4 meters (2 feet) away at the top of the structure.

Once the crew was assigned to the mission, the two astronauts who would assemble the structures were measured for reach, body length, and other human factors data. The locations, height, and length of the foot restraints were adjusted continually as a result of several neutral buoyancy simulations in which the crew practiced working in foot restraints while assembling and disassembling the structures and doing other experiment tasks. Figures 2 and 3 show the final configuration for the EASE/ACCESS handrails and foot restraints.

With the completion of the design for the Mission Peculiar Equipment, the interface plates, handrails, and support brackets for the foot restraints were fabricated at Teledyne Brown Engineering facilities. These components were designed and built per established quality control criteria to provide flight quality hardware meeting all safety requirements; therefore, safety verification was assured.

Prior to the completion of manufacturing, the interface plates were attached to the MPESS. The handrails and foot restraint support brackets were attached to the MPESS for a fit check but they were removed and shipped in separate containers to Kennedy Space Center (KSC). The EASE components also were attached to the MPESS to ensure adequate fits and proper envelope clearances. After these checks, the MPESS was packaged and shipped to KSC for integration of the experiment hardware. At the Kennedy Center, the payload was assembled in the Operations and Checkout Building. Personnel from NASA and Teledyne Brown were on call as technical advisors and were present at KSC when the crew exercised the integrated hardware; however, no modifications were made to the MPESS at this time.

Other inspections and checks were performed by KSC personnel during and after integration to ascertain that the design and assembly of all systems were compatible with the requirements of the orbiter into which it was placed. During the KSC closeout inspection, personnel discovered that a handrail slightly interfered with the RMS envelope. After consulting with the crew, a decision was made to remove the handrail rather than modify it to a shorter height or change its location. No problems occurred on orbit as a result of removing this handrail.

ENSURING EFFICIENT OPERATIONS

Once the MPESS has been customized to support a particular payload, the next step is to ensure that it will work efficiently and safely. During the design, manufacturing, and integration process, Teledyne Brown supported additional efforts to ensure that the total integrated payload would fit properly in the cargo bay. Analyses were performed based on drawings and information supplied by the experimenters to ascertain the correct layout and envelope of the total integrated payload. This guaranteed that no part of the experiment payload would extend beyond the clearances for crew translation or would interfere with the operation of parts of the Space Transportation System such as the payload bay doors or the Remote Manipulator System (RMS).

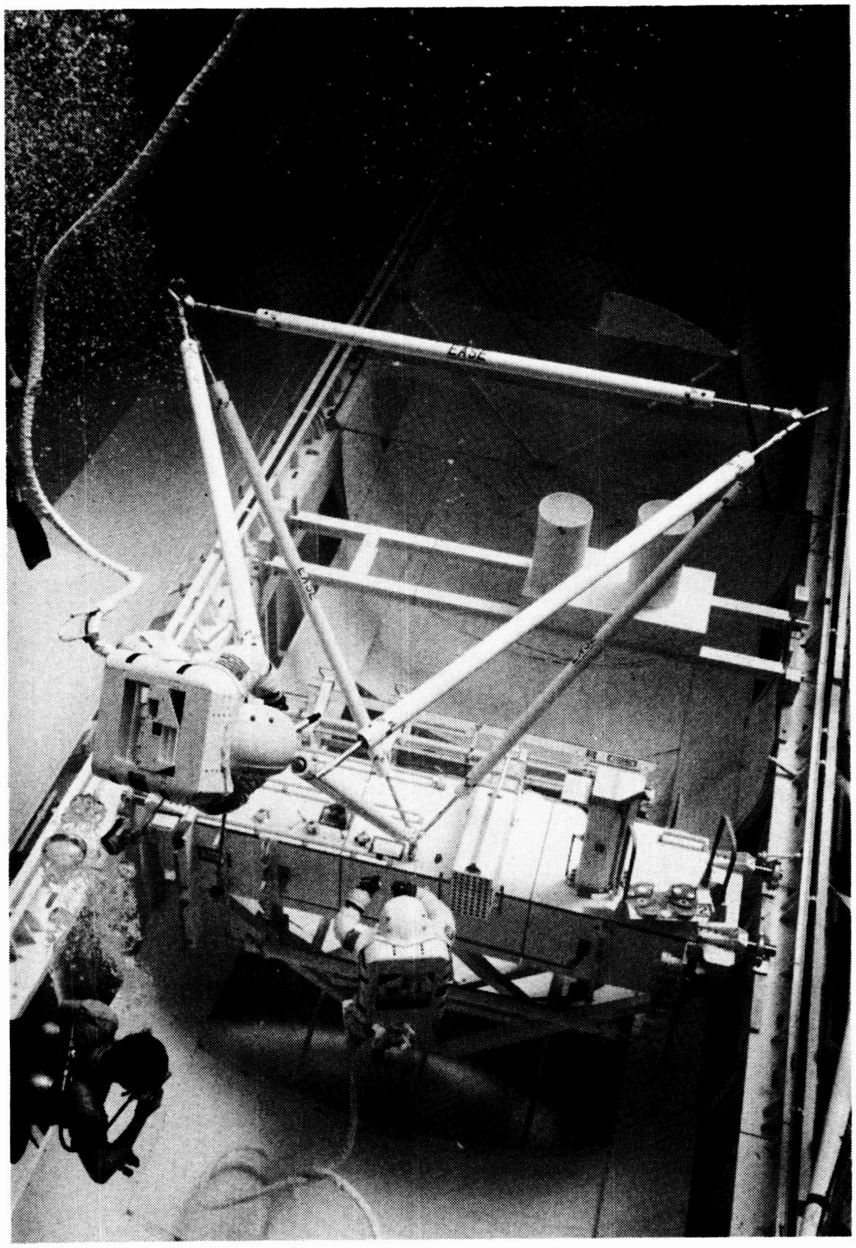
In another study, loads at the points where the experiment hardware attached to the interface plates were analyzed. This research proved that the plates were strong enough to support loads induced on the hardware as the structures were assembled and also during launch and landing. No thermal analysis of the MPESS hardware was needed because similar data were already available from previous flights.

Another integral part of the EASE/ACCESS payload development was verification of safe and compatible interfaces in the MSFC Neutral Buoyancy Simulator (NBS). A mockup of the MPESS was designed and fabricated for several series of tests completed in the two-year period before the mission. These tests were critical in determining the proper placement of the foot restraint supports required by the crew for experiment operation and crew handrails required for translation between work stations. Teledyne Brown supported MSFC in these tests to assure trouble free operation of the MPESS and to collect data to refine the payload for on-orbit operations. Figure 4 shows EASE being assembled in the MSFC/NBS.

As the mission launch date approached, training took place in the MSFC/NBS and the Johnson Space Center Weightless Environment Training Facility (WETF). These tests focused on training the crew to assemble and disassemble the experiments and perform other tasks such as removing the assembled structures from the MPESS for manipulations and then reattaching them to the support structure. Even at this stage, hardware and operating procedures continued to be refined. Training activity culminated in joint integrated simulations during which the crew practiced critical EVA operations in the WETF while other personnel rehearsed their roles in supporting the flight from the ground.

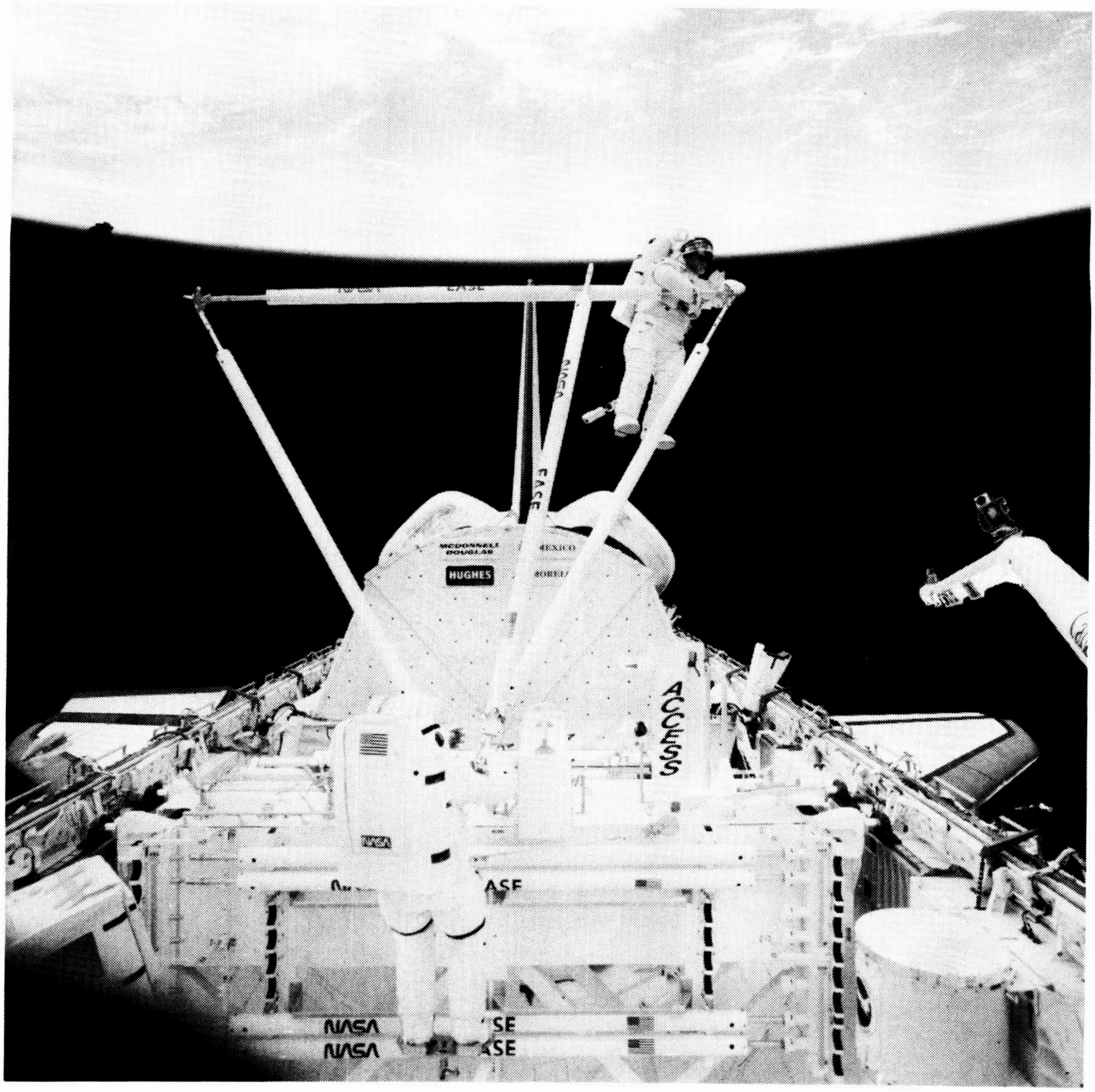
When integrated into the cargo bay of the orbiter, the payload remained dormant until exercised by the crew members during the two EVAs. During the structural assemblies, the MPESS integration team along with the MSFC mission management team and the experimenters were on hand at both the JSC Customer Support Room (CSR) and the MSFC Huntsville Operations Support Center (HOSC) to provide technical expertise. Only one minor problem occurred; during the second EVA the

EASE ASSEMBLY IN THE MSFC NEUTRAL BUOYANCY SIMULATOR



EASE base cluster connector could not be permanently reattached into the receptacle on the MPESS. The astronauts solved this problem by replacing the base cluster connector with a spare EASE node cluster and completing the experiment operations.

All other operations proceeded smoothly. During the first EVA, the astronauts assembled and disassembled the 12-meter (40-foot) ACCESS truss tower, and they assembled and disassembled the EASE tetrahedron several times. For the second EVA, they completed a variety of tasks including assembling and disassembling both structures from the Manipulator Foot Restraint (MFR) work station attached to the RMS and removing and manipulating the assembled structures. Throughout all these activities, the MPESS proved to be a stable platform. Figure 5 shows EASE being assembled in orbit.



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OTHER APPLICATIONS FOR THE MPESS

Several Mission Peculiar Equipment Support Structures have been used already for Shuttle missions. NASA currently has five of these carriers available for use in its inventory of STS equipment. Each MPESS has a 10-year shelf life and is designed to be flown for 10 missions; then it can be reused after it is requalified for flight.

Since the Shuttle must transport a variety of payloads, the support structure fills the need for a carrier system that can accommodate different experiments. However, unlike some other Shuttle carriers, the MPESS occupies only 0.91 meters (3 feet) of the cargo bay. Per NASA requirements the structure was designed to have a standard hole interface pattern, provide support at an elevated position, and have a natural frequency between the STS liftoff and landing frequency.

The first payload to use the support structure was the MSFC managed OSTA-2 payload composed of two sets of experiments for investigating materials processing in microgravity. This payload was launched on June 18, 1983 aboard STS-7 and was one of NASA's first science missions on the Shuttle. One experiment, the Materials Experiment Assembly (MEA), sponsored by NASA studied two ways of mixing metals in microgravity to make advanced alloys and semiconductors. The other experiment sponsored by the West German Ministry for Research and Technology studied fluid dynamics and the way metals mix and disperse in low gravity.

Since the successful OSTA-2 mission, an MPESS has been used for Materials Science Laboratory (MSL) missions. For these payloads, the MPESS was outfitted with furnaces for studying alloys processing in space and acoustic levitators for fluid behavior research. Unlike the EASE/ACCESS payload, these missions required little crew interaction. Therefore, when the MPESS was customized for these missions, integration planners concentrated on providing the support structure with the thermal, electrical, and command and data handling systems necessary to support the experiments.

The first large structure flown aboard the MPESS was the OAST-1 payload dedicated to collecting data on large, deployable solar array panels similar to those being designed for future spacecraft. During this mission, a large 30.9-meter (100-foot) solar array was deployed successfully in several configurations from a canister mounted on top of the MPESS. When tailoring the MPESS for this experiment, investigators had to concentrate on connecting complex avionics equipment required to monitor and control the deployment and retraction of the array.

The MPESS has also been adapted for two Goddard Space Flight Center (GSFC) programs: Spartan and Get Away Special (GAS) canister bridges. For Spartan, the MPESS is equipped with an MSFC release/engage mechanism to which the Spartan carrier can be attached. The release mechanism allows Spartan to be deployed and reattached by the RMS. For the GAS bridge program, any combination of 5 to 12 canisters, weighing from 158.8 to 181.4 kilograms (350 to 400 pounds), can be mounted to the sides of the MPESS. Get Away Specials can carry a variety of payloads including small, deployable satellites.

Upon completion of the EASE/ACCESS mission, experiment and MPE hardware were removed from the MPESS and returned to the appropriate organization. The MPESS was placed in the NASA hardware inventory at KSC. Numerous flights contemplated for the near future will use the MPESS to support a variety of payloads currently under development, including additional Materials Science Laboratory missions and on-orbit phased array radar simulation experiments. The evolution of the MPESS carrier fleet has resulted in a system which provides low cost, quick turnaround, and frequent flight opportunities for users.