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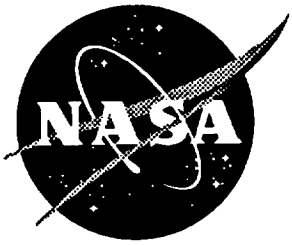

# Shuttle to Space Station Transfer of the Materials Exposure Facility

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## Foreword

The Materials Exposure Facility (MEF) is proposed by Langley Research Center (LaRC) as an attached payload for Space Station. This paper reports the logistics of transferring the MEF robotically from the Shuttle launch carrier to Space Station Freedom for active integration at a specific external payload site. During the time of this study the Space Station was redesigned and the International Space Station Alpha (ISSA) evolved. A similar evaluation of the logistics of transferring the MEF from the Shuttle to ISSA has been initiated at LaRC.

## Acknowledgments

Mr. Don E. Avery and Mr. Uriel M. Lovelace, Langley Research Center are acknowledged for their technical contributions to this report.

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## List of Acronyms

| | |
|---|---|
| EVA | Extravehicular Activity |
| ISSA | International Space Station Alpha |
| MEF | Materials Exposure Facility |
| MBS | MRS Base System |
| MRS | Mobile Remote Servicer |
| MT | Mobile Transporter |
| OTCM | ORU-Tool Change-out Mechanism |
| PMAS | Propulsion Module Attach Structure |
| SMCE | Spacecraft Materials and Coatings Experiments |
| SPDM | Special Purpose Dexterous Manipulator |
| SRMS | Shuttle Remote Manipulator System |
| SSRMS | Space Station Remote Manipulator System |
| STSP | Space Transportation System Program |
| UF-2 | Utilization Flight 2 |
| ULC | Unpressurized Logistics Carrier |

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## ABSTRACT

The Materials Exposure Facility (MEF) is being proposed by LaRC as the first long-term space materials exposure facility with real-time interaction with materials experiments in actual conditions of orbital space flight, Reference 1. The MEF is proposed as a Space Station external payload dedicated to technology advancement in spacecraft materials and coatings research. This paper will define a set of potential logistics for removing the MEF from the Shuttle cargo bay and the process required for transferring the MEF to a specific external payload site on Space Station Freedom (SSF), Reference 2. Figure 1 illustrates the SSF configuration used for this study. The kinematics and ability to successfully perform the appropriate MEF maneuvers required were verified. During completion of this work, the Space Station was redesigned and the International Space Station Alpha (ISSA) configuration evolved, Reference 3. The transfer procedure for SSF was valid for ISSA; however, a verification of kinematics and clearances was essential. Also, SSF and ISSA robotic interfaces with the Orbiter were different.

## 1. INTRODUCTION

The Spacecraft Materials and Coatings Experiments (SMCE) are a collection of the MEF experiments for the study of long-duration space environmental effects on advanced materials and coatings. The SMCE are twenty-six experiments individually packaged in the MEF facility trays. The experiments can be removed robotically or installed on-orbit throughout the life of the facility. Some experiments will be long term, residing in the facility approximately five years, while other experiments will require change-out in six month to one year intervals. The exposure facility shown in Figure 2

is an aluminum tray support structure approximately 3 feet (H) x 6 feet (W) x 14 feet (L). The maximum MEF launch mass with a complement of 26 experiments is approximately 4,500 pounds. Each experiment is self contained within a tray and is allocated 75 pounds for the experiment weight. The total weight of the experiments and trays is approximately 2,990 pounds. The MEF power and data electrical system will be initialized at payload integration to the station payload site. The facility will remain passive during launch and Shuttle/Station transfer operations.

The MEF is proposed to be attached to the SSF Port 1 - Face 6 - Bay 2 lower truss attached payload site as shown in Figure 3. Prime truss locations have been designated for attached payload sites on SSF as shown in Figure 4. The lower payload site was selected for the MEF facility to provide experiments with ram, wake and nadir exposure allowing the effects of directionally-dependent environmental constituents such as atomic oxygen to be studied. The MEF is scheduled to be launched fully integrated with 26 experiments. The Unpressurized Logistics Carrier (ULC) has been selected as the launch carrier for the MEF. STSP Utilization Flight 2 (UF-2) is manifested for attached payloads and is a potential launch flight for MEF. This paper will discuss the MEF experiment change out operations, the logistics required to transfer the MEF from the Shuttle to a specific SSF payload site, and to remove the ULC/MEF from the Orbiter's Utilization Flight 2 proposed manifested flight, Reference 4.

## 2. MEF COMPONENTS

The MEF primary structure supports 26 experiment trays. MEF is designed to facilitate the robotic change-out of the experiment trays. A latch bolt, power connector and data connector are provided at each experiment tray position to secure the tray and service experiment requirements for power and data. Figure 5 shows the location of these components on the support structure.

The facility is designed so that eight trays are located on both the ram and wake faces, four on the Port and Starboard faces and two on the nadir face providing the exposure to allow the effects of directionally-dependent environmental constituents such as atomic oxygen to be studied. The MEF tray layout in shown in Figure 6.

Each experiment tray weighs 40 pounds and is identical in construction, facilitating its interchange ability. The structure of the tray consists of an isogrid baseplate, side support structure and sheet metal sides. The tray displayed in Figure 7, is a 45 degree truncated pyramid on three sides with a straight fourth side. The tray is self-guided into position due to the geometry of the structure. Alignment is insured through the combination of an alignment pin located under the tray and secured in position with a latch bolt, Reference 5.

### 2.1 MEF/SMCE Tray Change-out Logistics

The 26 SCME trays are equipped with micro-interfaces and latch bolts designed for robotic and extravehicular activity (EVA) manipulations, References 5 and 6. One arm of the Special Purpose Dexterous Manipulator (SPDM) would grapple to a micro-interface on the MEF while the other arm equipped with the ORU-Tool Change-out Mechanism (OTCM) grapples to a specific experiment tray micro-interface or MEF H-handle and robotically unlatches the latch bolt and removes the experiment tray from the MEF. The experiment is transferred robotically from the MEF to the tray carrier on the ULC utilizing the SPDM. New experiment trays in the tray carrier are removed and installed robotically on the MEF reversing the above change-out procedure.

## 3. PROPOSED MEF/STATION OPERATIONAL SCENARIO

### 3.1 Shuttle Docking to SSF

The on-orbit scenario of transferring the MEF from the Shuttle to SSF begins with docking the Shuttle to the Station. The ULC grapple fixture must be accessible to the Shuttle Remote Manipulator System (SRMS). This will depend largely on the Shuttle flight manifest and the location of the ULC in the cargo bay. Figure 8 illustrates one configuration of the ULC/MEF in the cargo bay. In the event the ULC grapple fixture is not accessible to the SRMS, the following options may be available:

- Off-load other payloads from the Shuttle cargo bay first. This will allow the SRMS accessibility to the ULC grapple fixture for removing the ULC.

- Relocate the grapple fixture on the ULC. This will give

the SRMS access to the grapple fixture if off-loading is not an option.

- Use the Space Station Remote Manipulator System (SSRMS) to remove the ULC with the attached MEF from the Shuttle cargo bay and place the ULC on the Mobile Remote Servicer (MRS) Base System (MBS) Propulsion Module Attach System (PMAS). This option was not allowed on SSF. However, this is an option for the ISSA.

Further evaluation of the Shuttle to ISSA transfer process utilizing the SSRMS will be reviewed as the MEF/ISSA design matures.

### 3.2 SRMS Hand-off ULC/MEF to SSRMS

A crew member in the Orbiter activates the SRMS to grapple the ULC, disengage the trunion latches and lift the ULC and MEF from the cargo bay toward the MBS. Figure 9 shows the SRMS attached to the ULC in the cargo bay.

The SSRMS then attaches to the other ULC grapple fixture and receives the ULC and MEF in a hand-off operation from the SRMS as shown in Figure 10.

### 3.3 SSRMS Docks the ULC/MEF to the MBS

After receiving the ULC/MEF, the SSRMS then soft docks the ULC with the MEF to the MBS PMAS. The PMAS capture latch will then hard dock the ULC to the MBS. Figure 11 highlights this operation. The PMAS is Station structure with accommodating trunion latches and electrical interfaces that receives and latches propulsion modules, external payloads, and ULC's to the MBS and Station interfaces. The SSRMS then releases the ULC. A crew member in the Space Station activates and relocates the MBS/Mobile Transporter (MT) to a position above the external payload attach site.

### 3.4 SPDM Removes Robotic Fasteners

The SSF crew member then activates the SSRMS and moves it into position to attach to the SPDM. The SPDM is grappled to the end of the SSRMS to allow additional reach capability in reaching the MEF

"hard-to-get-to attachment fasteners." One arm of the SPDM will attach to one of the MEF provided H-handles for stability while the other arm grapples to specific micro interfaces or H-handles and robotically detaches the MEF/ULC attach fasteners with the OTCM. Several fasteners will remain attached to the ULC until the SPDM is released from the SSRMS and grappled to the MBS. The SSRMS will now grapple to the MEF and apply its brake while the SPDM releases the remaining MEF fasteners as shown in Figure 12. The SPDM is then disengaged from the SSRMS and repositioned on the MBS.

### 3.5 SSRMS Positions MEF on SSF Attach Payload Site

Once the Facility is detached from the ULC, the SSRMS positions and soft-docks the MEF to the PMAS at a specific external payload site. The PMAS capture latch then hard docks the MEF completing the mechanical and electrical integration of the MEF to SSF as shown in Figure 3. The SSRMS releases from the MEF grapple fixture and returns to the MBS. The Station crew member then relocates the MT with the ULC still attached to a location for off-loading other ORU's or attached payloads.

## 4. RESULTS OF ANALYSIS

Analyzing the proposed operational scenario addressed questions and concerns about the feasibility of conducting a Shuttle to Station transfer of the MEF. Critical findings that surfaced during the analysis are as follows:

- The hand-off maneuver can be completed successfully within the capability of the planned Station and Orbiter components.

- The SPDM/SSRMS will have the necessary reach capability to disconnect all of the connectors used to attach the MEF to the ULC.

- A clearance problem exists with the SRMS attaching to the ULC grapple fixture for the proposed UL-2 flight configuration, Reference 7, and as shown schematically in Figure 13. Discussions with Boeing engineers indicated that it may be possible to relocate the ULC grapple fixtures. Another option to allow adequate clearances would be to off load other manifested cargo prior to removing the ULC/MEF.

- There are no other major clearance concerns with respect to other components during the on-orbit operation.

## 5. CONCLUDING REMARKS

The ability to successfully perform the Shuttle to Station hand-off maneuver utilizing the SSRMS with the SPDM assistance in releasing the MEF from the ULC and robotically attaching the MEF to the Station was verified. However, clearance problems do exist with the manifested UF-2 flight. The Silicon Graphics, Inc. computer system utilizing Wave Front Technologies, Inc. software package was used to successfully perform and verify the kinematics and MEF maneuvers. A MEF video was produced by David Shannon, NASA, Langley Research Center recording the operational scenario of the hand-off maneuver, Reference 8.

The hand-off maneuver may also be used for ISSA payload transfer. However, verification of kinematics will be required. Also, the SSRMS can be used to remove payloads from the Orbiter cargo bay for the ISSA configuration. This transfer maneuver was not possible for SSF. The concept of utilizing the SSRMS for transferring the MEF from the Shuttle to ISSA is currently being reviewed at LaRC.

## REFERENCES


1. MEF Video, NASA, LaRC, David T. Shannon, Jr., July 1993, PN#93-2.

2. WP-2 Attached Payload Accommodations, Exhibit C Task C92KC-051 Report, April 1992, under Contract NAS 9-18200.

3. International Space Station Data Book, JSC 32324, November 1993.

4. Space Shuttle Systems Payload Accommodations, NSTS 07700, Volume XIV, Rev J, January 1988.

5. Space Station Program Robotic Systems Integration Standards, Volume II: Robotic Interface Standards, SSP 30550, June 1992.

6. EVA Tools and Equipment, JSC-20466, Rev B, November 1993.

7. Internal Space Station Alpha Manipulator Assembly Sequence Feasibility Assessment, AF-1R Through Assembly Complete, JSC-37941, April 13,1994.

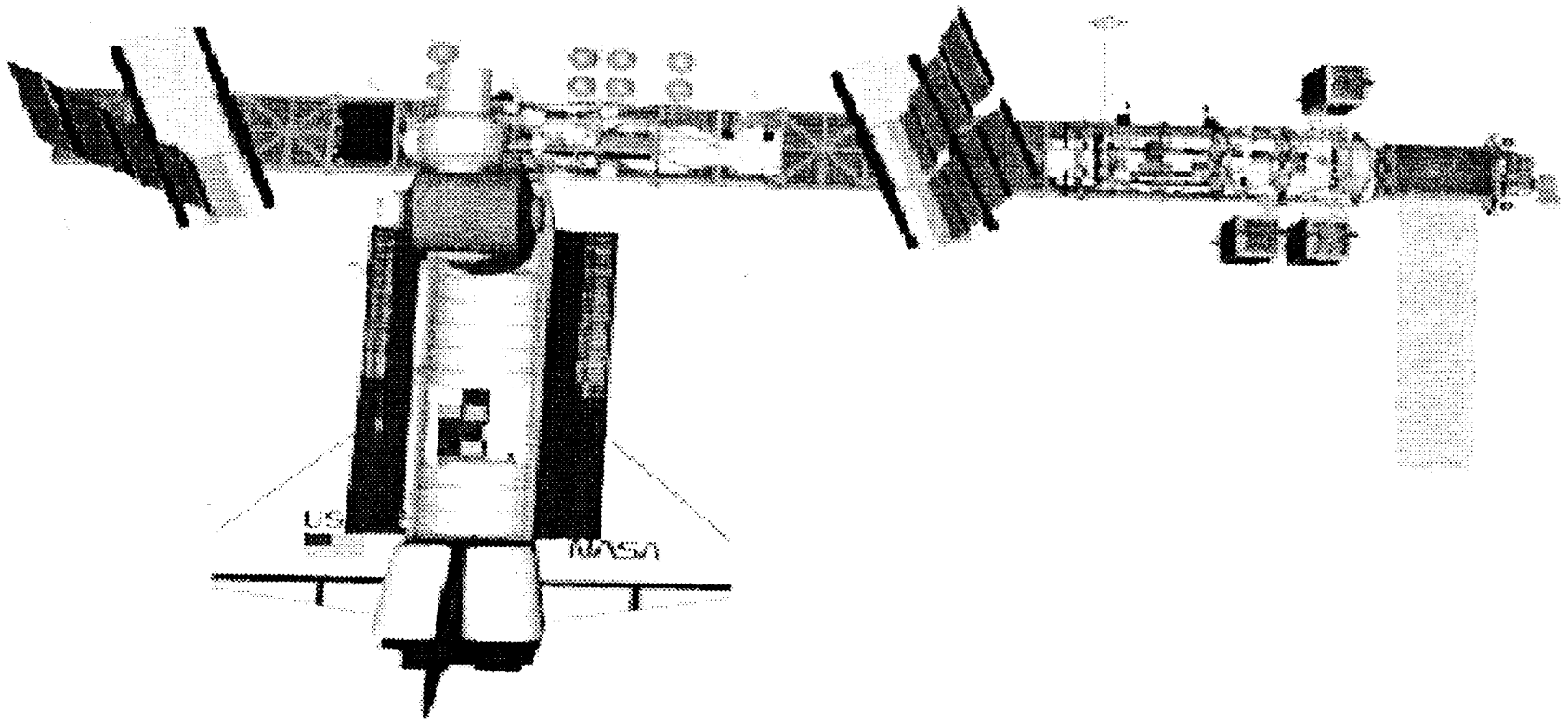


**Figure 1. Space Station Freedom Configuration**

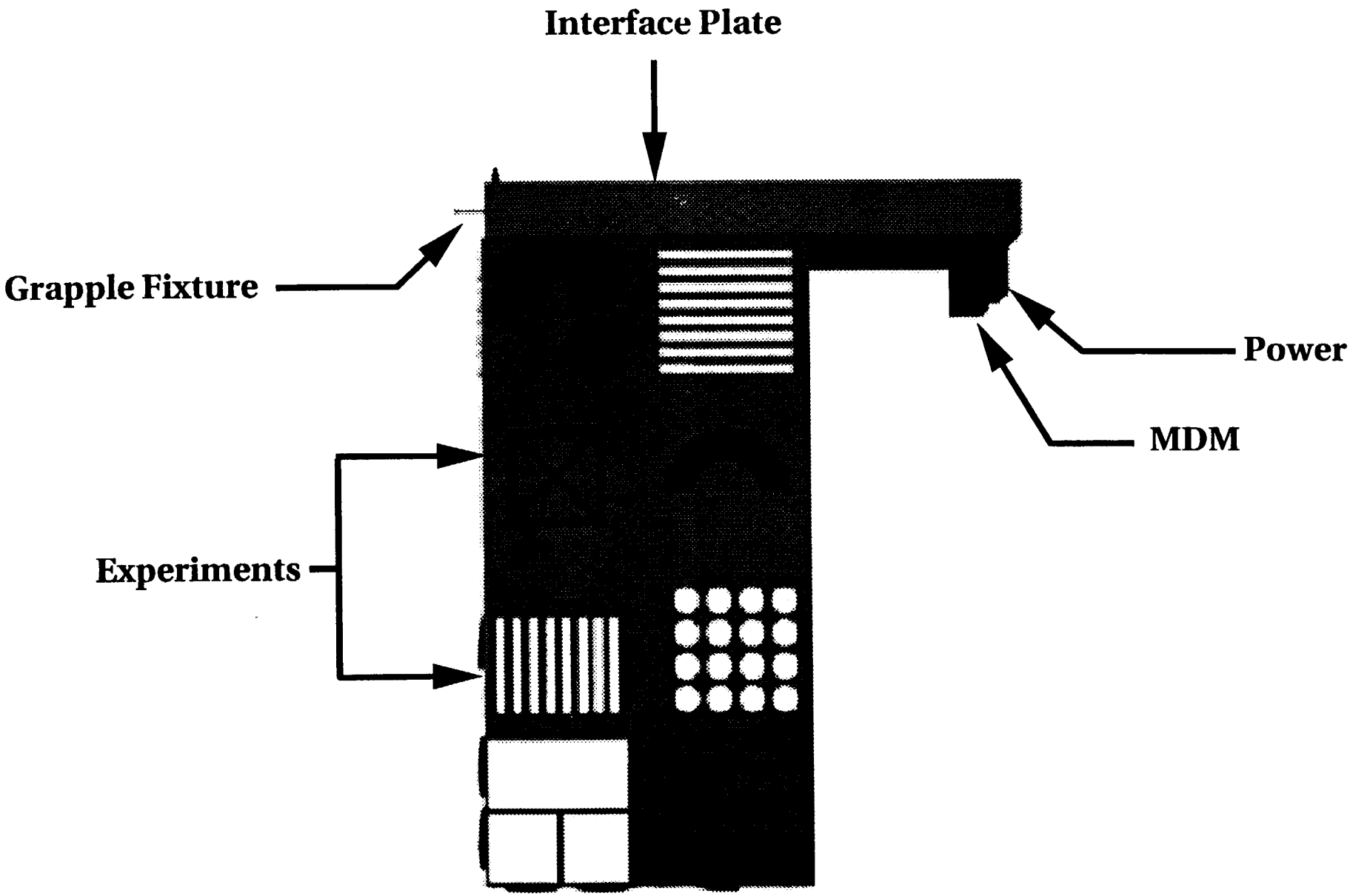



Figure 2. Materials Exposure Facility

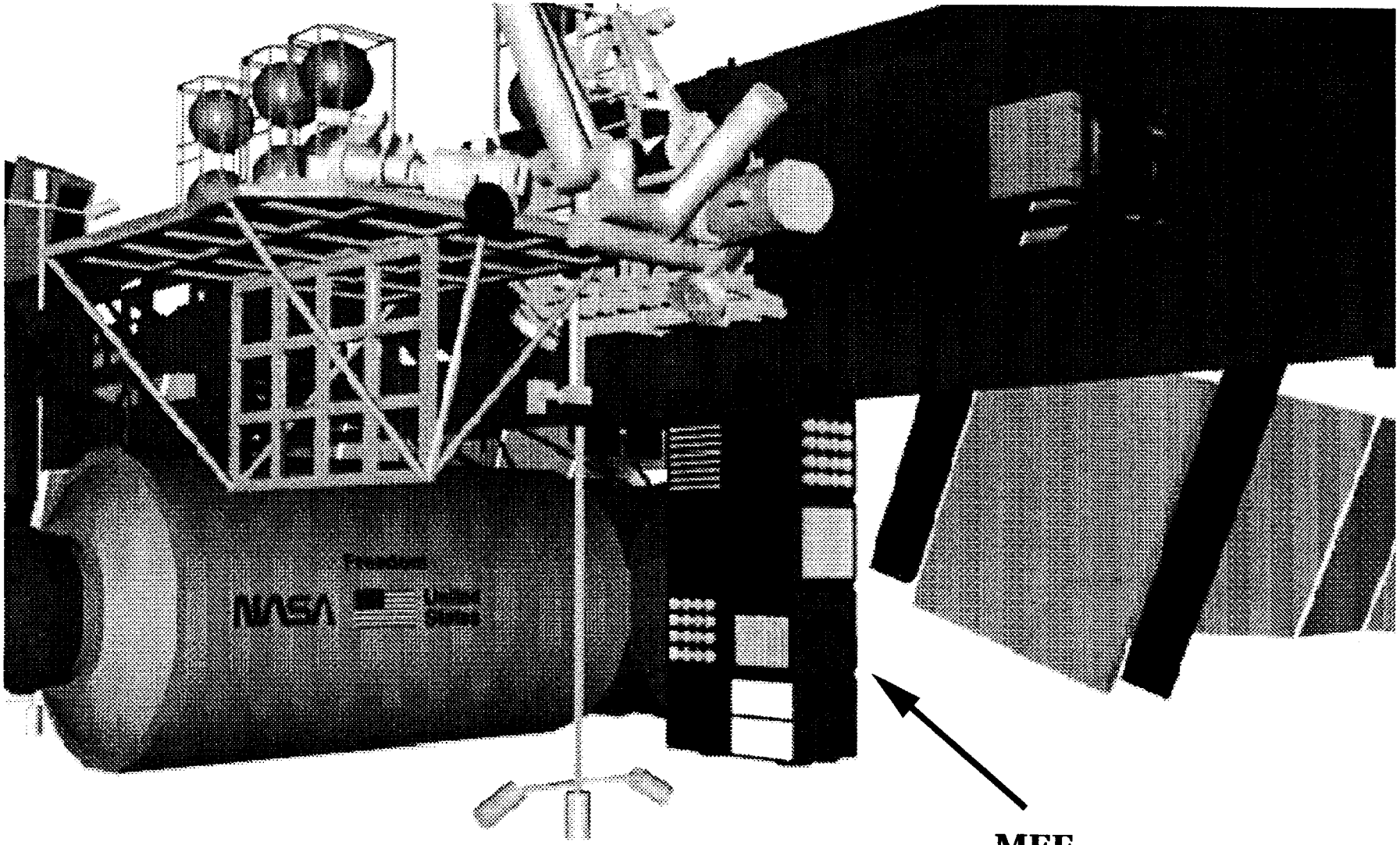



**Figure 3. MEF Attached to SSF**

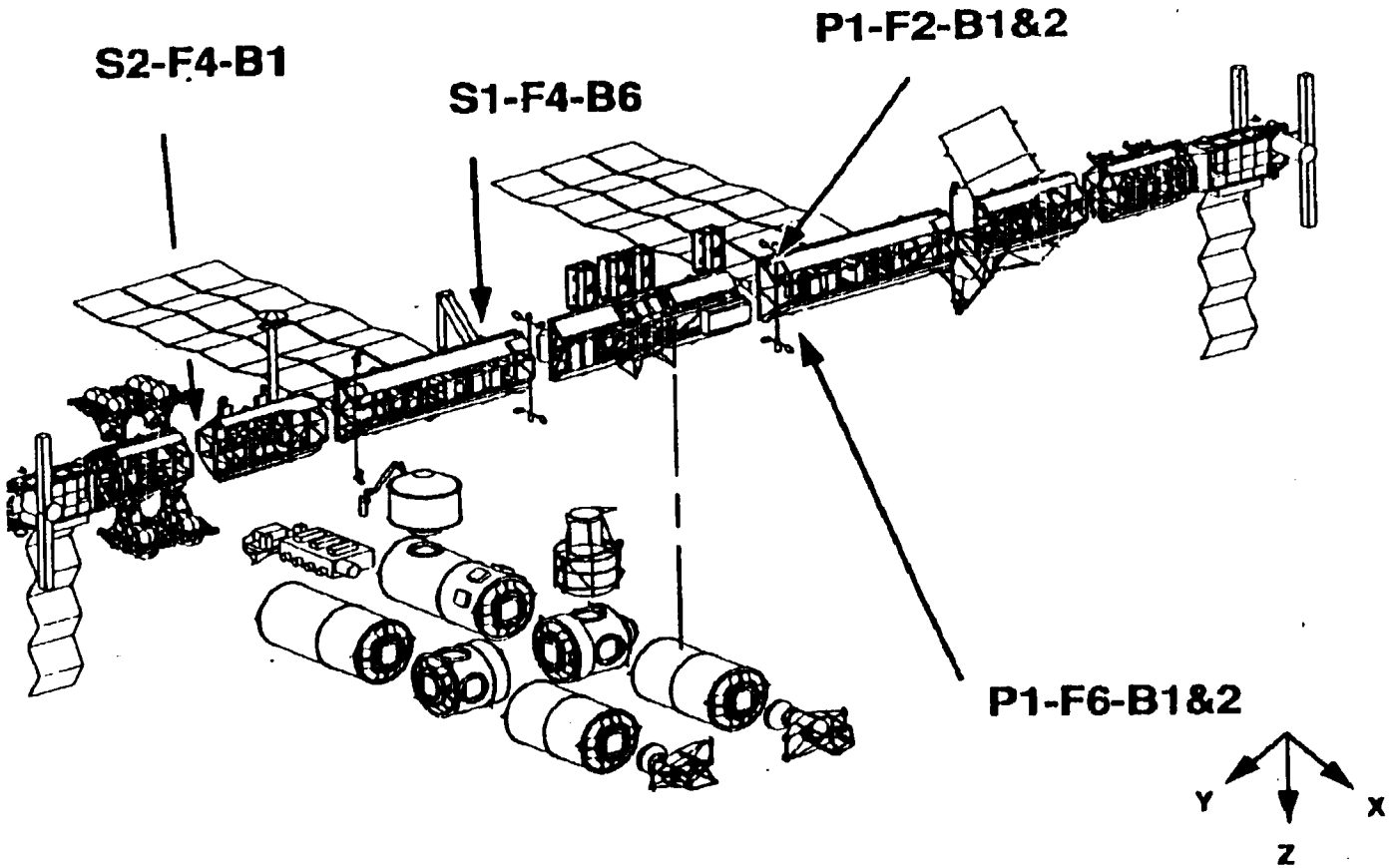



Figure 4. Attached Payload Sites

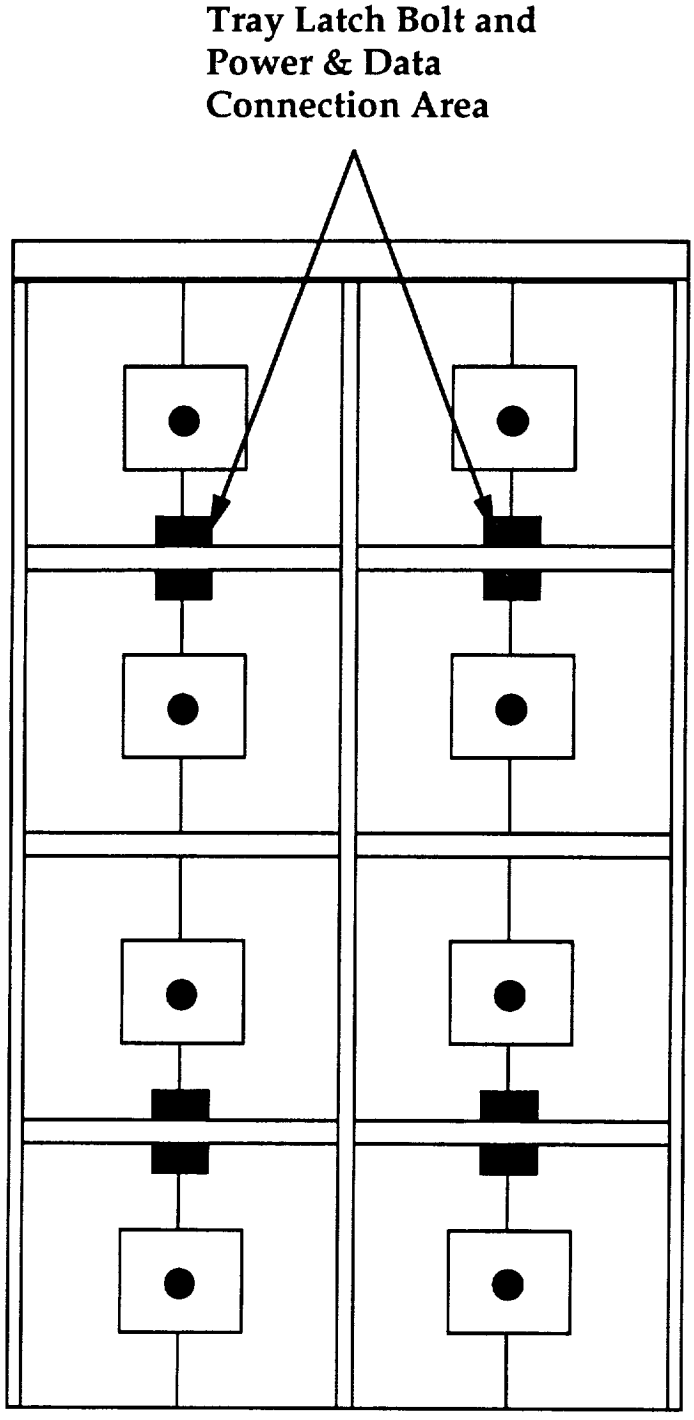
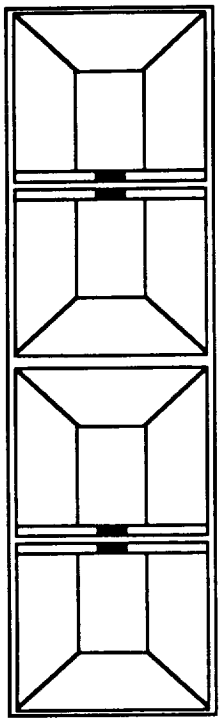
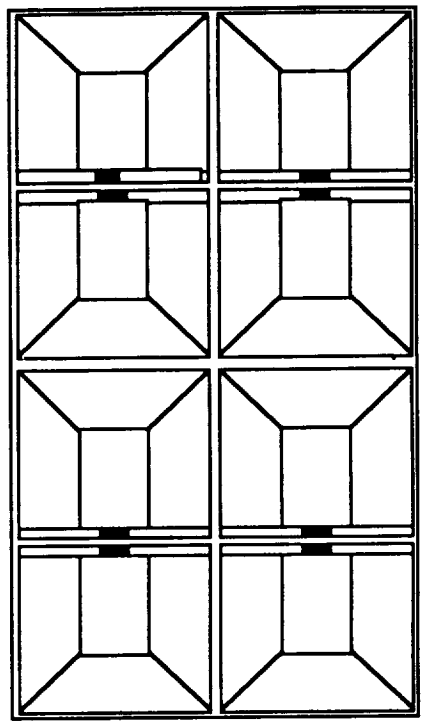



Figure 5. MEF Experiments with Latch, Power and Data Connection



PORT/STARBOARD



RAM/WAKE

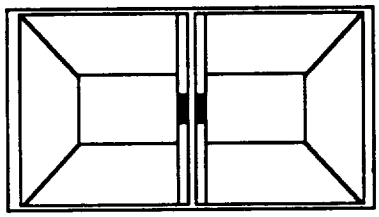


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Figure 6. MEF Tray Layout

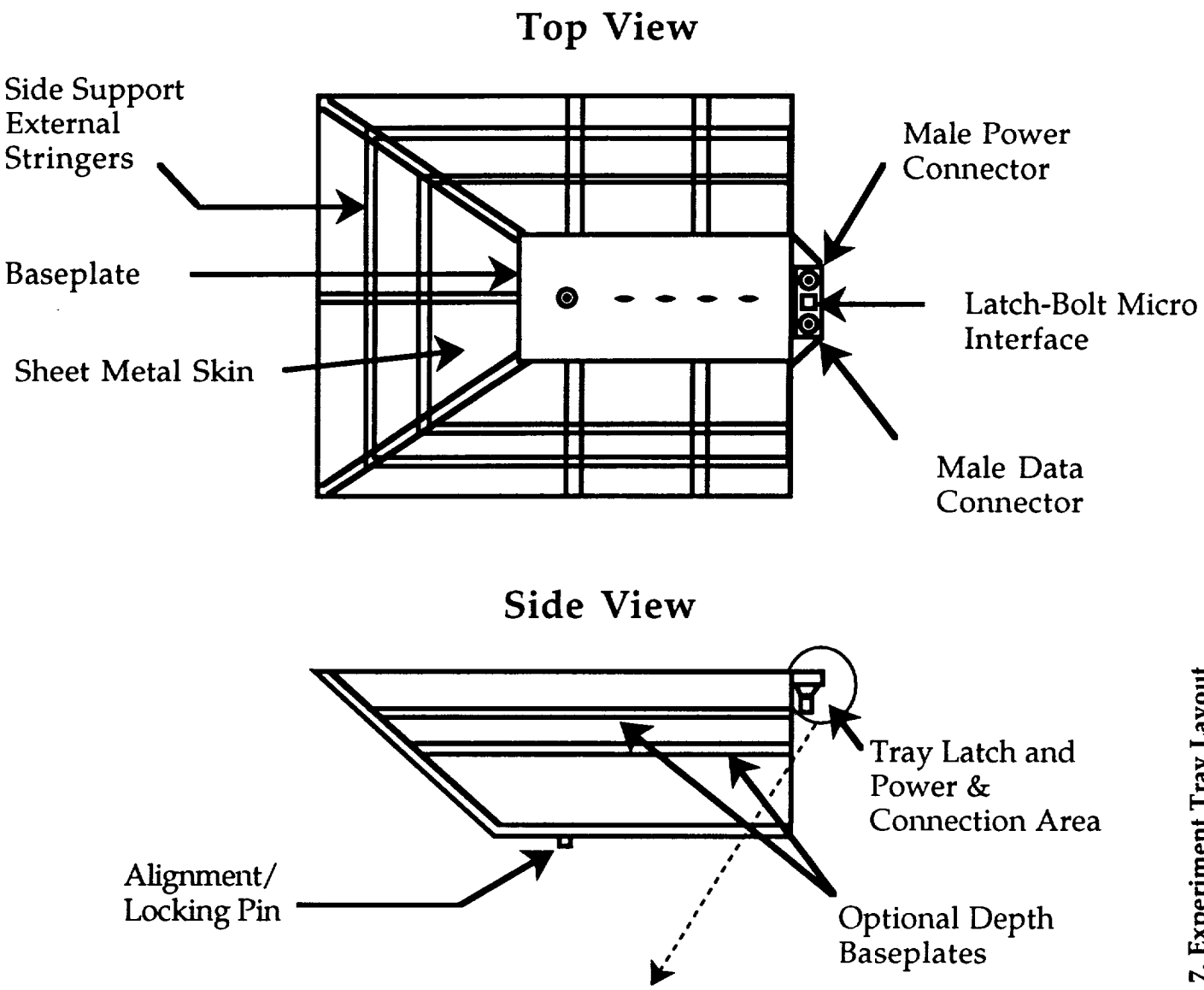


Figure 7. Experiment Tray Layout

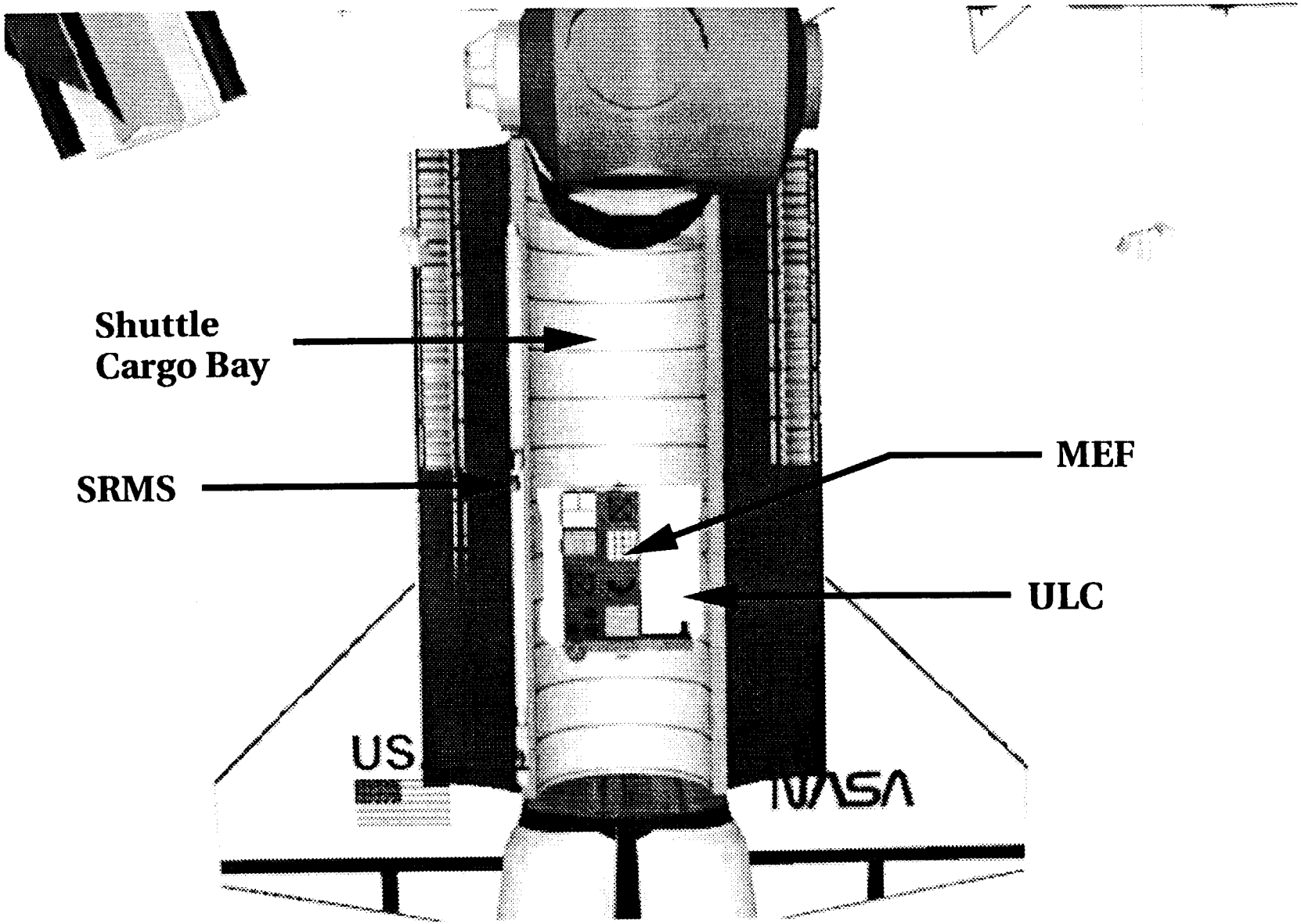


**Figure 8. ULC/MEF Located in STS Cargo Bay**

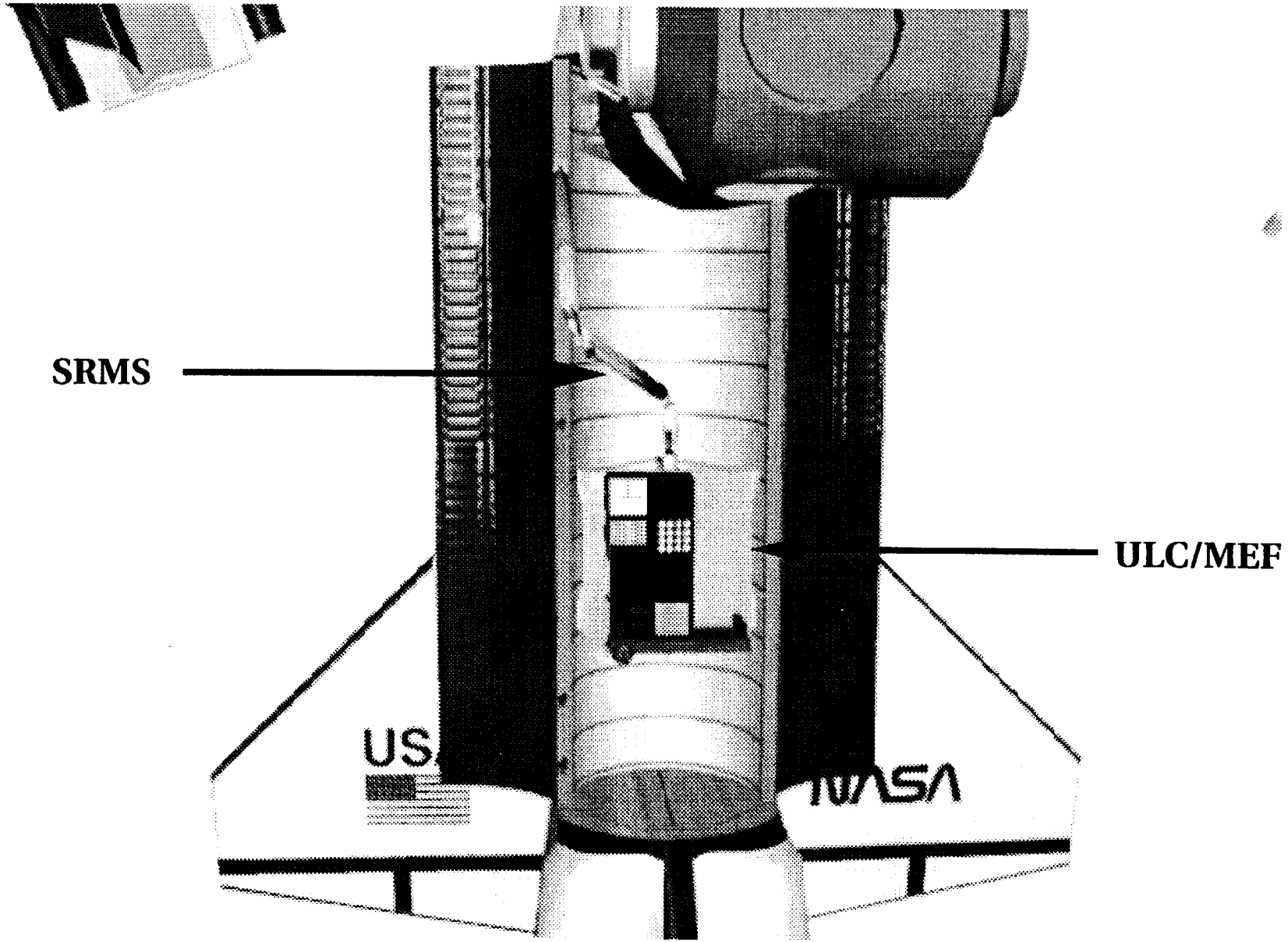


**Figure 9. SRMS Grappled to ULC**

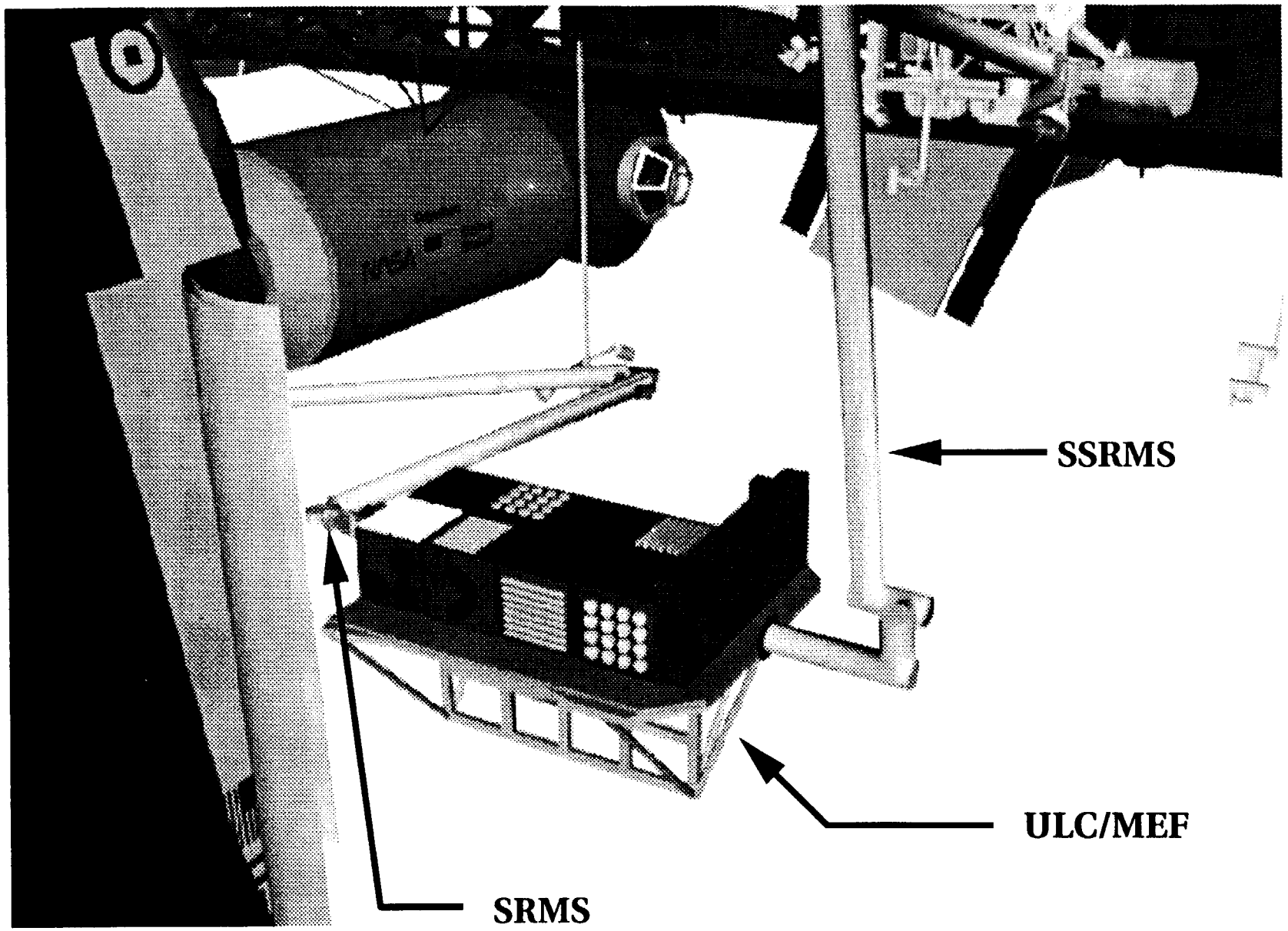


**Figure 10. ULC/MEF Hand–Off Operation**

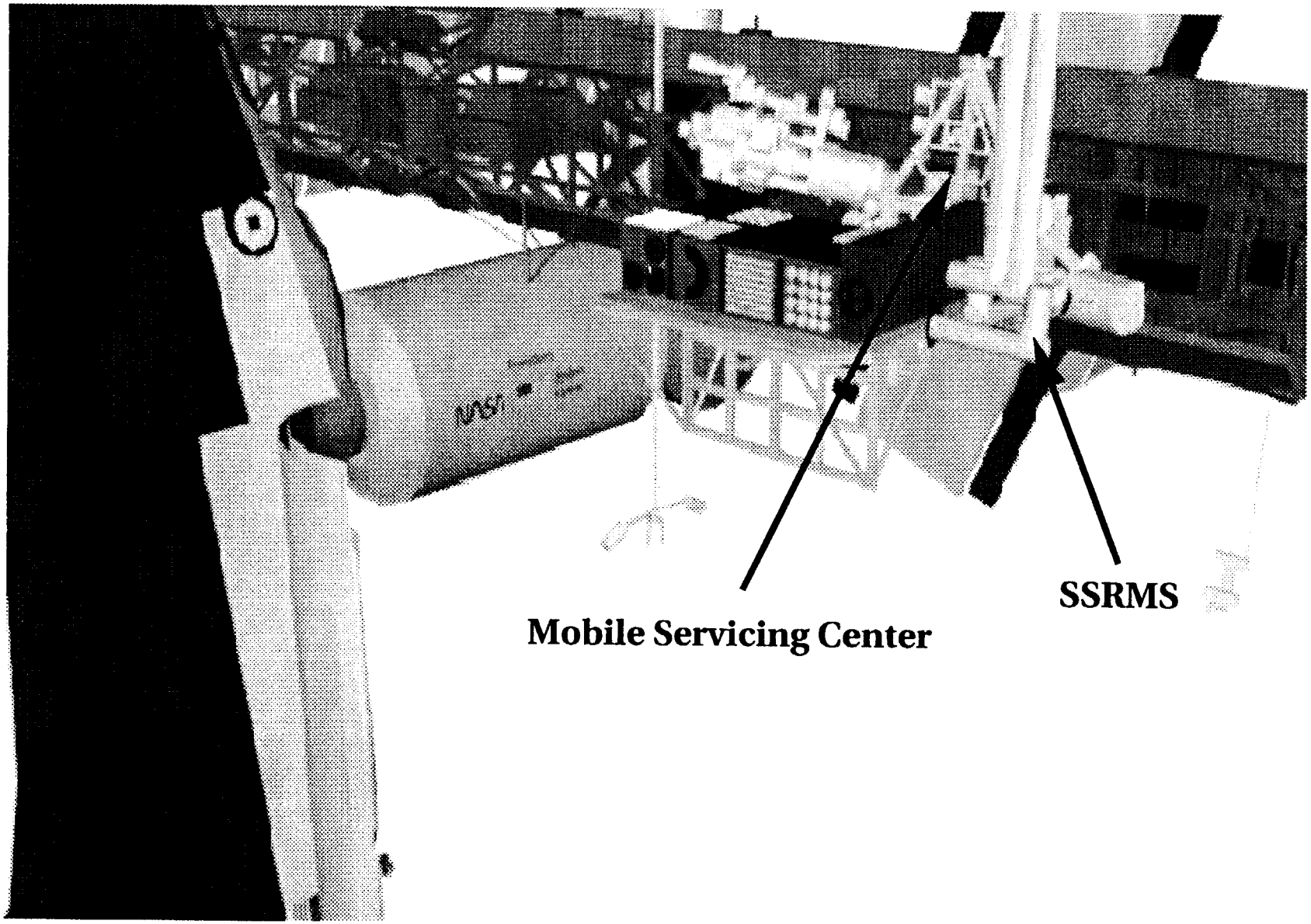


**Figure 11. ULC/MEF Docked to Mobile Remote Servicer**

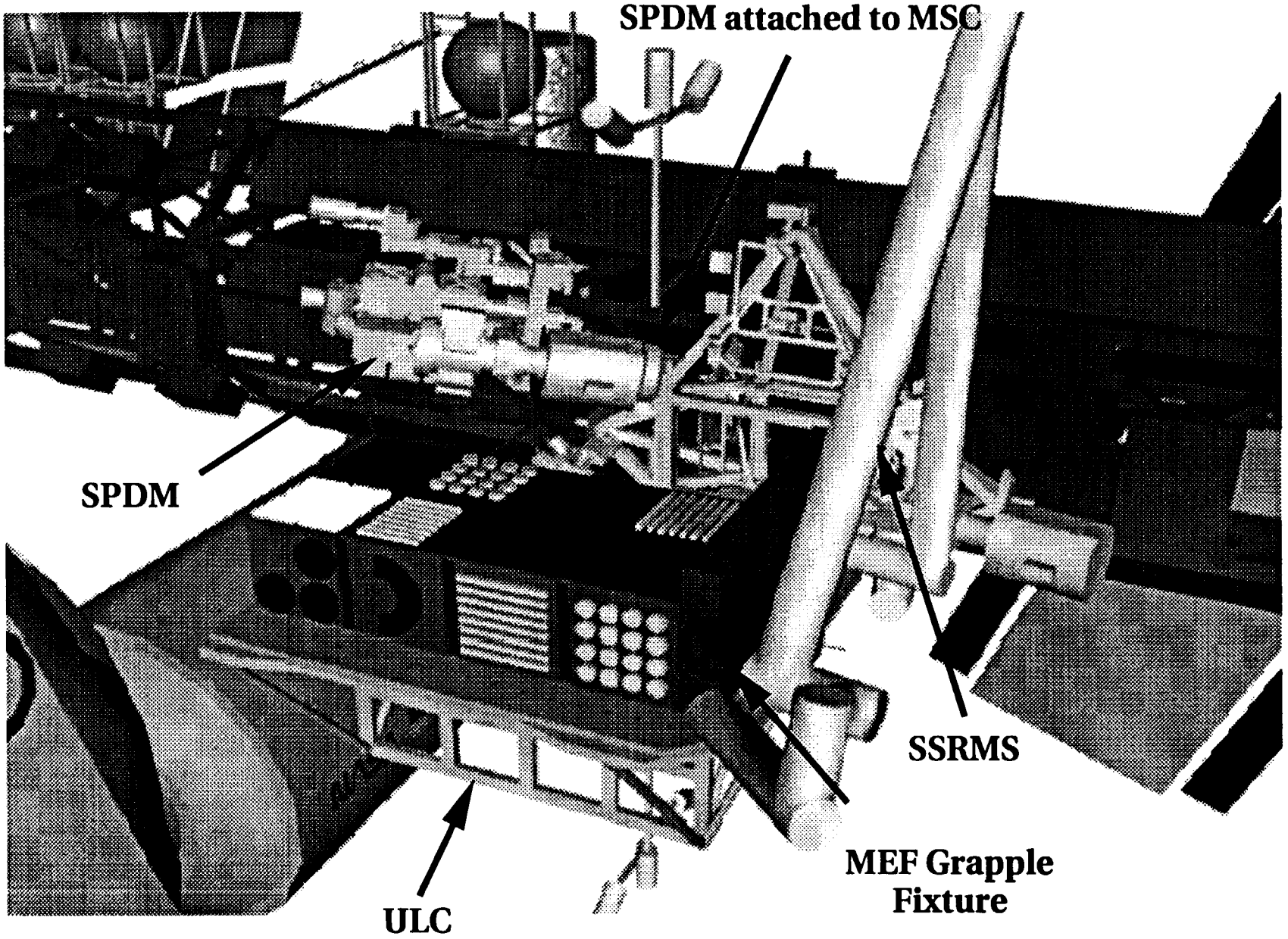


**Figure 12. SSRMS Maneuvering to Grapple the MEF**

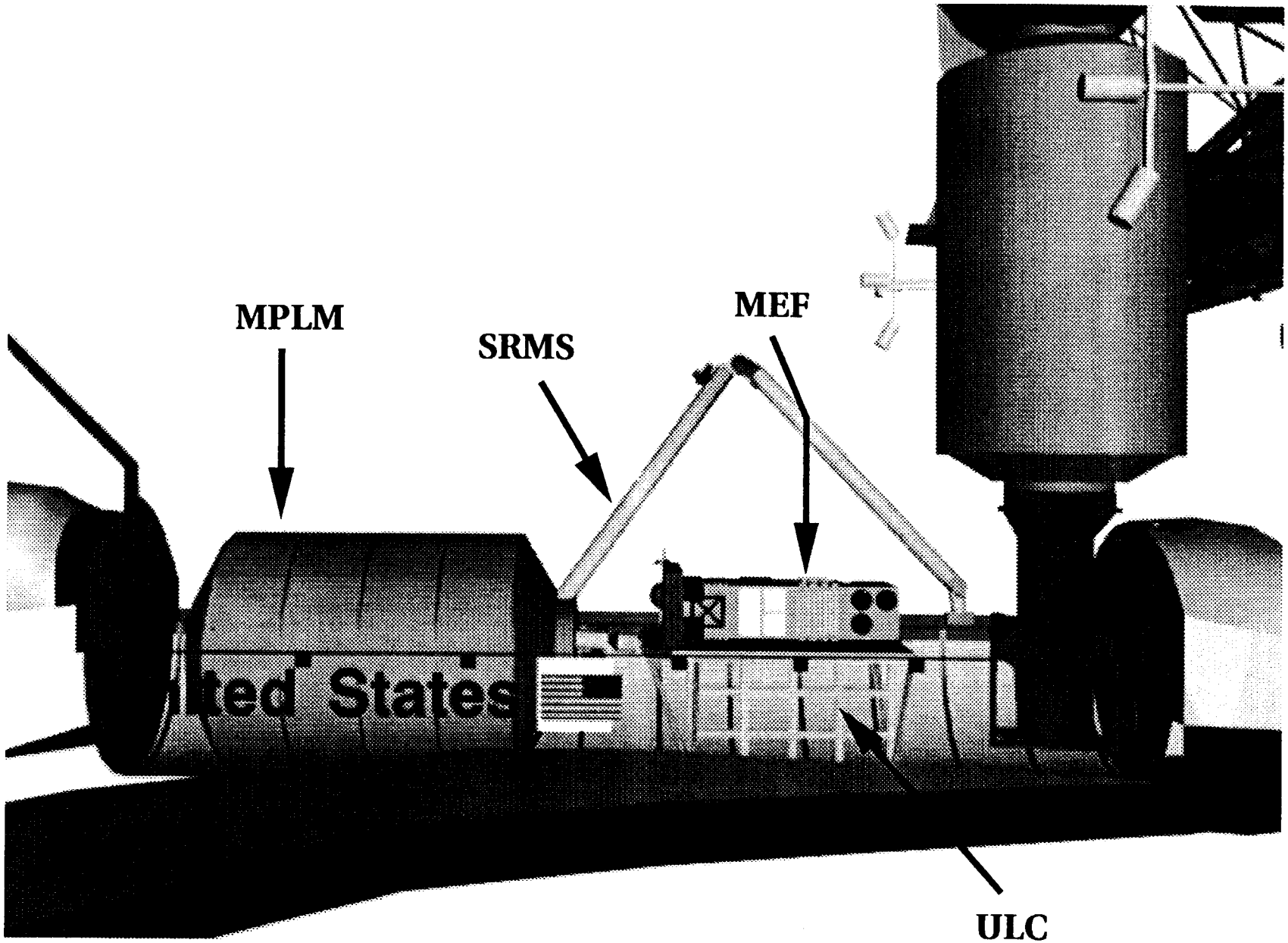


**Figure 13. STSP Proposed Utilization Flight 2**

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