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IAF-92-0689

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Abstract

The Space Shuttle will be the primary vehicle to support the launch, assembly, and maintenance of the Space Station Freedom (SSF). In order to accommodate this function, the Space Shuttle orbiter will require significant modifications. These modifications are currently in development in the Space Shuttle Program. The requirements for the planned modifications to the Space Shuttle orbiter are dependent on the design of the SSF. Therefore, extensive coordination is required with the Space Station Freedom Program (SSFP) in order to identify requirements and resolve integration issues. This paper describes the modifications to the Space Shuttle orbiter required to support SSF assembly and operations.

Introduction

The National Aeronautics and Space Administration (NASA) will utilize the Space Shuttle for the launch, on-orbit assembly, and maintenance of the Space Station Freedom (SSF). For SSF assembly missions, the Space Shuttle orbiter will carry elements of the SSF to a 28.5 degree inclination, 220 nautical mile altitude (nominal) orbit . The Space Shuttle orbiter will mate with the partial SSF configuration and the additional SSF elements will be assembled using the Shuttle Remote Manipulator System (SRMS). After completion of mated assembly operations, the orbiter will demate from the SSF and return to Earth.

For SSF operations and utilization missions, the Space Shuttle orbiter will be launched into the nominal orbit, rendezvous and mate with the SSF. The transfer of crew, supplies, materials, and experiments will then be accomplished. The orbiter will demate from the SSF and return to Earth.

Mating the Shuttle orbiter to the SSF is more complex than previous NASA programs which utilized the docking of space vehicles of similar mass. Mating the Shuttle orbiter to the SSF becomes more complex as the mass of the SSF increases during assembly phase. The differences in the mass and location of the center-of-gravity of the Shuttle orbiter and the SSF, relative to the mating systems, complicates the mating procedure. NASA currently plans on utilizing two different techniques for mating the Space Shuttle orbiter to the SSF. The initial Shuttle missions flown to assemble SSF do not require pressurized attachment for crew transfer. For Mission Build (MB)-1 through MB-5, berthing utilizing the SRMS will be the primary means of orbiter to SSF mating. After the first five SSF assembly flights, a docking system will be utilized on the Space Shuttle orbiter as the primary means of mating the orbiter to the SSF.

All four Space Shuttle orbiters will be modified to accommodate SSF assembly and utilization flights. The most extensive modification required to the Space Shuttle orbiter is the development and integration of the docking system. The other significant modification required is upgrades to the SRMS.

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Berthing

Berthing is the joining of two spacecraft by using a manipulator to bring the vehicles structurally together. For the first five SSF assembly flights, the Space Shuttle orbiter will be mated to SSF by the use of the Shuttle Remote Manipulator System (SRMS). The Shuttle orbiter will approach SSF and, prior to contact, initiate station keeping to null out any rate differentials. The SRMS will then grapple SSF and bring the Unpressurized Berthing Adapter (UBA) into the orbiter payload bay as shown in Figure 1. The UBA consists of a trunnion structure attached to the SSF mobile transporter. During berthing, the UBA trunnions mount into payload retention latch assemblies in the orbiter payload bay. For these initial five assembly flights, the orbiter to SSF mating will be unpressurized and crew transfer is not required. During mated operations, extra-vehicular activity (EVA) is possible from the berthing system. The time required for rendezvous to the completion of the berthing operation is approximately 90 minutes.

Berthing Modifications

The following paragraphs describe the Space Shuttle orbiter hardware and software modifications which are required to support berthing the orbiter to the SSF.

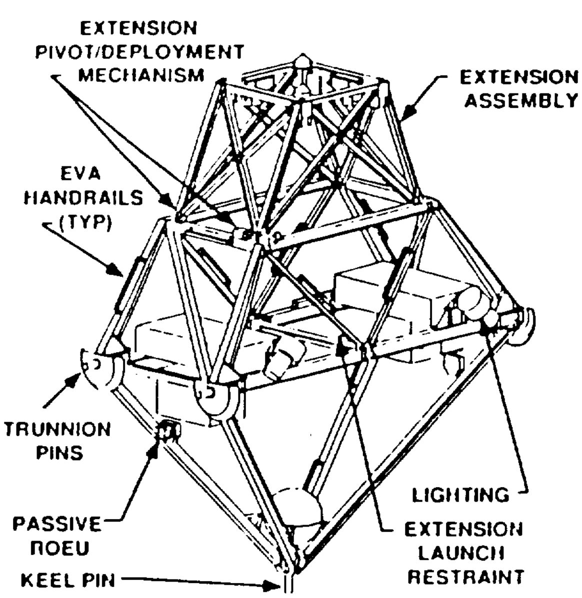
Shuttle Remote Manipulator System Upgrades

The SRMS is designed and certified for the retrieval of payloads up to 32,000 lbs. and deployment of payloads up to 65,000 lbs. In order to berth the SSF and Shuttle orbiter, the SRMS must be certified to maneuver payloads up to 270,000 lbs. Therefore, modifications are required to the SRMS hardware and software.

Hardware modifications are required to the SRMS joint electronics, or Servo Power Amplifiers (SPA). The SPAs must be upgraded to implement programmable servo gains to provide sufficient command authority for heavy payload handling. Command authority margins provided by high gains in the SPA are required for safety and consistent operation.

Software upgrades are required for implementing the Position Orientation Hold Selection (POHS) Submode to control uncommanded motion during berthing. The POHS can maintain attitude or position in five axes while driving in the sixth axis. This upgrade will reduce crew work load during the handling of large payloads. It will also reduce both the berthing and assembly operation timelines.

After these upgrades are complete, the SRMS will require recertification.



Unpressurized Berthing Adapter

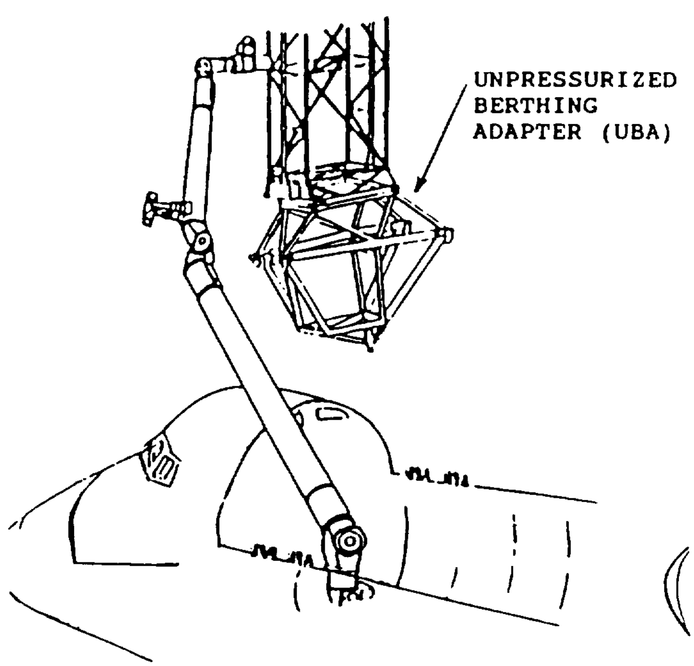


Figure 1 - Berthing System (MB-2 - MB-5)

Retention System

The retention system for the Unpressurized Berthing Adapter is comprised of standard payload retention lightweight starboard and port longeron active latches, keel latch, bridges, and V-guides. The V-guides may require modification to accommodate SSF loads.

Berthing Aids

Space Shuttle orbiter hardware which aids the berthing operation includes a keel closed circuit television (CCTV) camera which may require relocation. Also, a Crew Optical Alignment Sight (COAS) target is to be mounted on the SSF. Exterior lighting will utilize existing forward payload bay (Xo 576) bulkhead and payload bay lights.

Resource Transfer Hardware

The following Space Shuttle orbiter modifications will be required to facilitate resource transfer after the Shuttle orbiter is berthed to the SSF.

Electrical and Data Transfer Hardware

The Remotely Operated Electrical Umbilical (ROEU), Figure 2, will provide electrical and data interfaces between the orbiter and SSF. It can be mated and demated on command from the orbiter aft flight deck. The ROEU mounts on the bridge rail of either the port or starboard side of the orbiter payload bay.

Power Transfer Hardware

For SSF assembly missions MB-2 and MB-3, the Space Shuttle orbiter will be required to provide the electrical power for initial SSF power-up. The Auxiliary Power Control Unit (APCU) is required to convert orbiter 28 volt DC power to SSF 120 volt DC power. Two APCUs will be located in the orbiter payload bay and will transfer power using the ROEU.

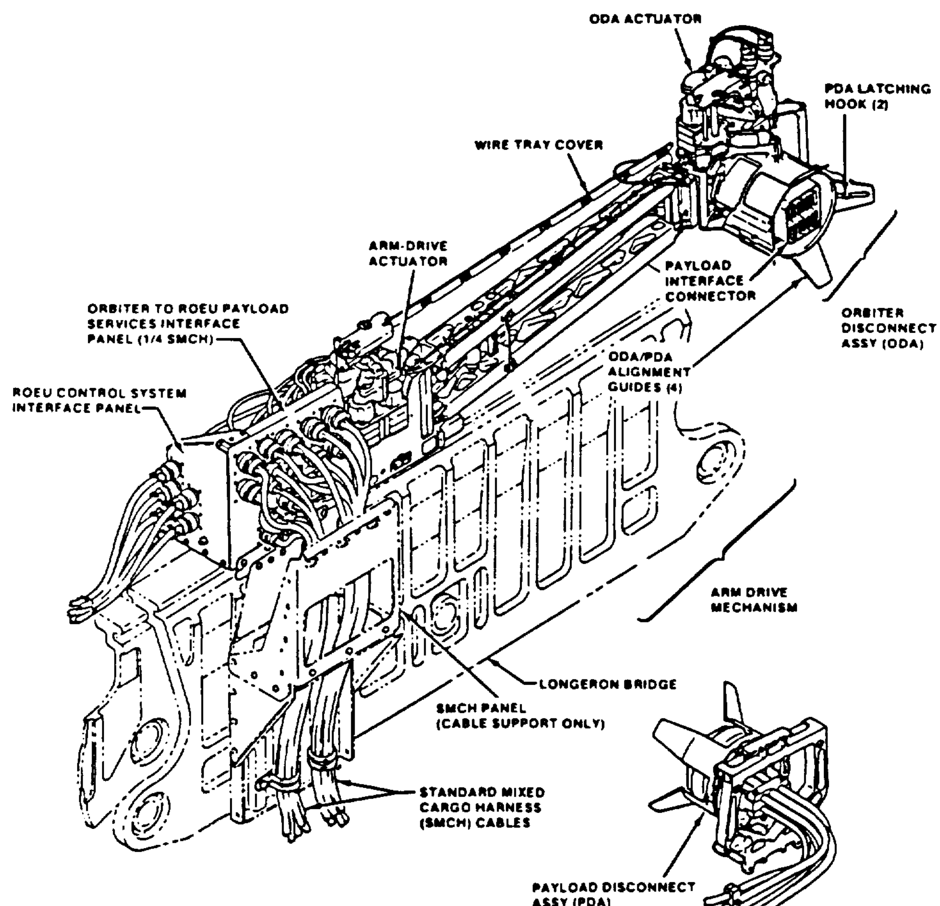


Figure 2 - Remotely Operated Electrical Umbilical

Docking

Docking is the joining of two spacecraft together at a specified structural or mechanical interface, utilizing velocity vectoring for closing the distance between the vehicles until contact. Closing velocities are, therefore, greater for docking than berthing.

Several different types of docking systems were considered by NASA, including the docking systems used for the Gemini and Apollo Programs (probe and drogue) and the Apollo/Soyuz Test Program (ASTP ring latches). The Space Shuttle and SSF Programs have currently baselined the ASTP type ring latch docking system. This system, with the compatible docking mechanism, may also facilitate docking the Space Shuttle orbiter to the MIR Space Station and other space vehicles. The Apollo/Soyuz Test Program (ASTP) type docking system will provide the capability to safely approach, capture, attenuate relative vehicle motions and loads, and rigidly attach the Shuttle orbiter to the SSF. Once mated, the ASTP type docking system with an external orbiter airlock, Figure 3, will provide the pressurized interface between the orbiter and SSF, allowing crew and resource transfer in a shirt sleeve environment.

For SSF assembly flights after MB-5 and utilization flights, the Space Shuttle orbiter will be docked to SSF utilizing a mechanical ASTP type docking system. The primary docking port on SSF will initially be located on Node 2, but will be located on the Lab A module after MB-7. During all mated operations, SSF-based or orbiter-based EVA is possible. The time required to conduct the docking operation, from rendezvous to completion, is approximately 26 minutes.

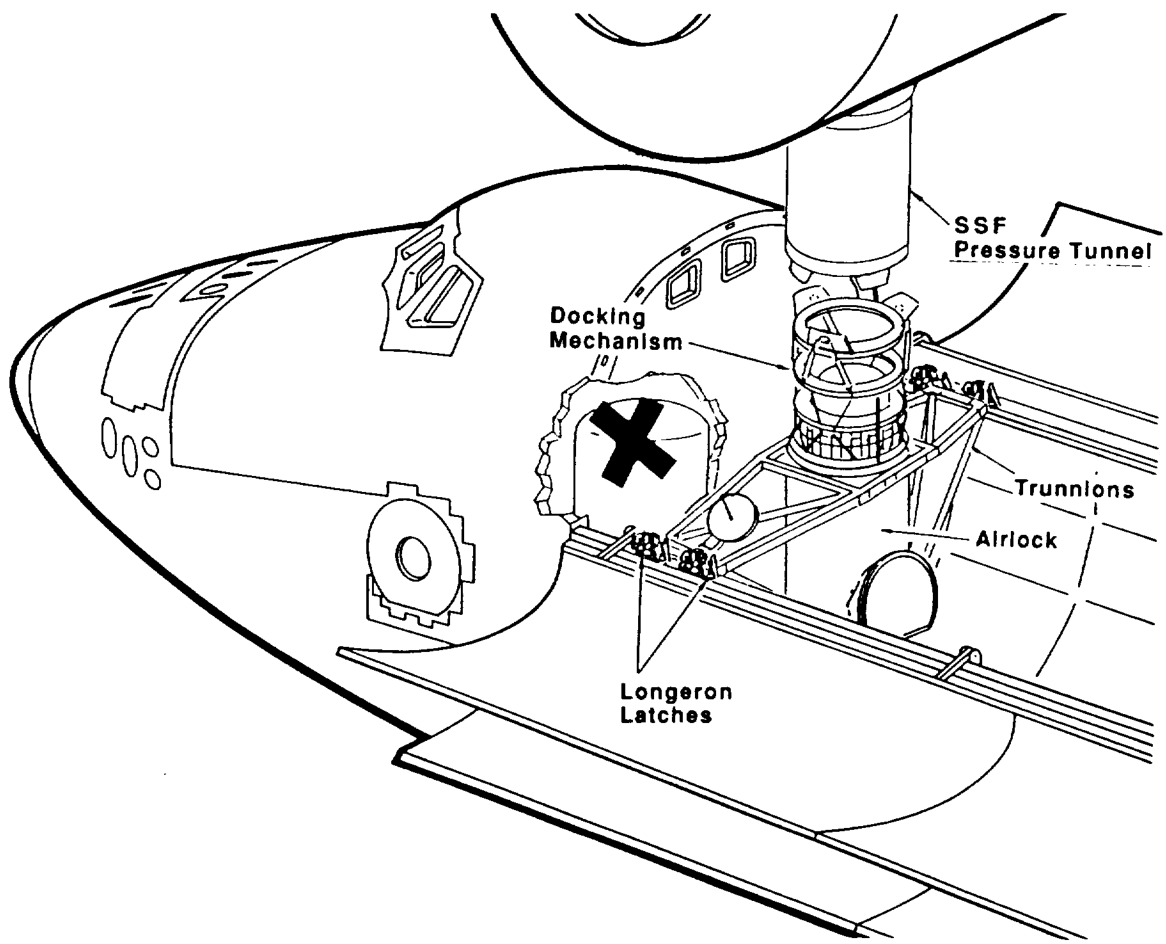


Figure 3 - ASTP Type Docking System External Airlock Configuration (MB-6 - Subs)

Docking Modifications

The following paragraphs describe the Space Shuttle orbiter modifications required to provide the capability to dock the orbiter to the SSF.

External Airlock

In order to facilitate pressurized docking to SSF, the Shuttle orbiter airlock, currently located in the crew cabin, will be removed, modified, and mounted in the orbiter payload bay. The docking mechanism will be mounted on top of the external airlock, Figure 4. The removal of the airlock from the crew cabin will increase the available habitable volume in the crew cabin.

The Shuttle orbiter airlock will require structural modifications to support the docking system and facilitate placement in the payload bay. A trunnion structure will be added to the existing airlock which will carry the docking loads and support the airlock in the orbiter payload bay. A structure will be mounted on the bottom of the external airlock to provide truss attach points and a keel trunnion. A flexible bellows, similar to the current Spacelab design, will be mounted on the orbiter Xo 576 bulkhead and extend to the external airlock. In addition, an adapter ring and "B" type hatch will be mounted on top of the airlock to facilitate crew transfer.

Placement of the airlock aft of the Xo 576 bulkhead, structural enhancements, and the necessary docking hardware comprise an extensive modification to the Shuttle orbiter. These modifications are planned to be performed on each of the four Shuttle orbiters during the scheduled orbiter maintenance and inspection periods or extended vehicle processing flows. The internal airlocks will be removed and refurbished as external airlocks. Three docking mechanisms will be procured and available to support SSF assembly and operations.

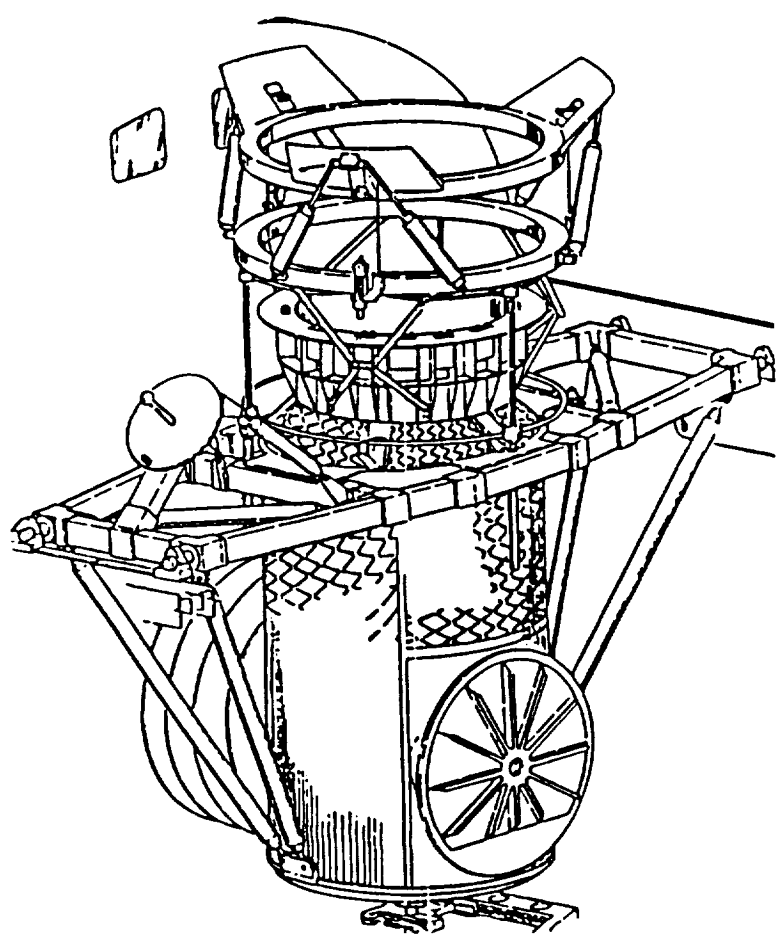


Figure 4 - Shuttle Orbiter External Airlock

Docking Mechanism

The docking mechanism consists of a large attenuation guide ring, capture and structural latches, a mechanical Z-drive, and load attenuators as shown in Figure 5. The mechanism will be mounted on the Space Shuttle orbiter external airlock trunnion assembly. The mechanical Z-drive will be used to extend the attenuators and drive the ring and capture latches up to the SSF docking port. A passive interface ring will be mounted on SSF to mate to the docking system. Following capture, the mechanical Z-drive will then retract the guide ring and the structural latches will be activated. When the structural latches are closed and the umbilical is mated, docking will be complete. The docking mechanism will be designed to withstand closing or opening velocities and lateral misalignments of the orbiter approach to the SSF.

Retention System

The docking mechanism retention system supports the external airlock structure in the payload bay. The retention system will consist of four struts and four trunnions mounted to four bridge passive latches. A keel trunnion at the bottom of the airlock will be mounted into a keel latch.

Avionics

The docking operation will require a docking display and control panel and utilization of existing aft flight deck DC busses B & C.

Docking Aids

The same Space Shuttle orbiter hardware described for the berthing operation will be utilized to aid docking.

Crew Equipment

EVA crew equipment located in the orbiter payload bay will require relocation to facilitate the external airlock. This includes relocation of the Payload Stowage Assembly (PSA), tether reel, and handholds.

Resource Transfer Hardware

The following Space Shuttle orbiter modifications will be required to facilitate resource transfer after the orbiter is docked to the SSF.

Electrical and Data Transfer Hardware

An umbilical mounted on the docking mechanism mating ring will provide the electrical and data interfaces between the Shuttle orbiter and the SSF. The interface will be mated when the docking mechanism is fully retracted. The ROEU will no longer be required; however, power transfer to or from the Space Shuttle orbiter is currently not required after MB-3.

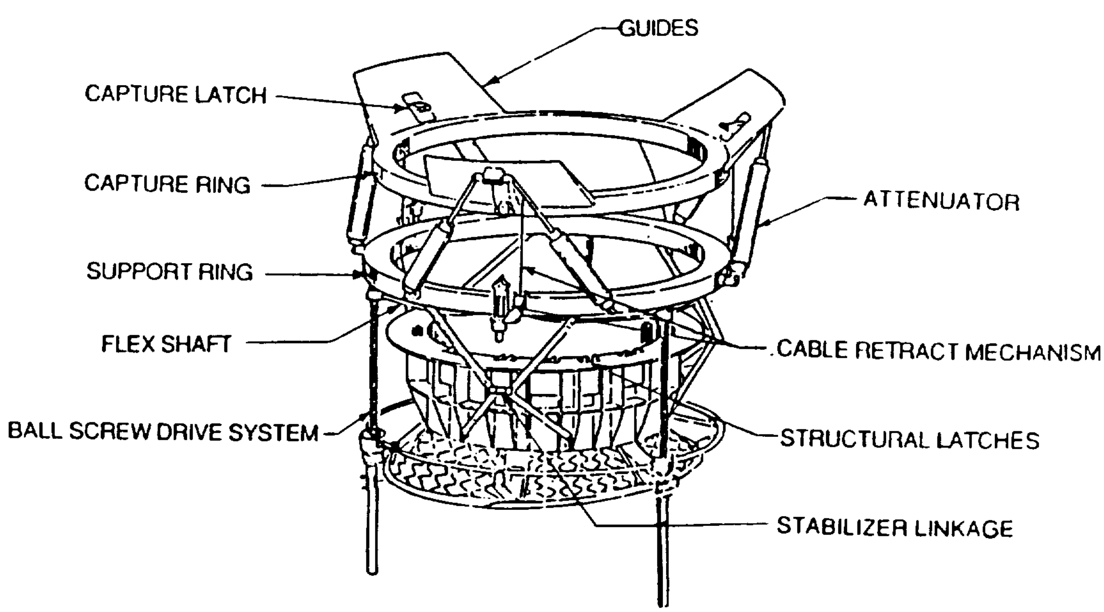


Figure 5 - ASTP Type Docking Mechanism

Potable Water Transfer Hardware

Potable water transfer will be accomplished in the external airlock through a manual intra-vehicular activity (IVA) and EVA connect and disconnect. The Space Shuttle orbiter will require modified piping and the addition of a water shutoff valve.

Extended Duration Mission Modifications

Studies are being conducted to determine the modifications required to support Space Shuttle orbiter to SSF mated operations for up to 45 days. In the extended mated configuration, the Shuttle orbiter would require power from the SSF. The Orbiter Power Conversion Unit (OPCU) would be required to convert SSF 120 volt DC power to orbiter 28 volt DC power. Two OPCUs would be located in the orbiter payload bay and will transfer power using the docking system umbilical. The advantage of an extended duration mission would permit additional SSF utilization from man-tended capability to permanently manned capability.

Spacelab Mission Modifications

The United States/European Space Agency Spacelab module was designed to be mounted in the Space Shuttle orbiter payload bay to provide for microgravity and life sciences research. Spacelab missions require the addition of a tunnel which is mounted to the orbiter Xo 576 bulkhead and connects to the Spacelab module. With the external airlock permanently installed in the payload bay, modifications will be required to the Spacelab tunnel. An additional bellows, connected to the external airlock, will be required to isolate docking loads from the Spacelab module.

Summary

The modifications required to the Space Shuttle orbiter to adequately support Space Station Freedom assembly and operations are extensive. However, the SSF represents a substantial portion of Space Shuttle flights manifested through the next decade. Space Station Freedom is crucial to the United States and international manned space programs. These modifications to the Space Shuttle are fundamental requirements for the success of SSF assembly and operations.