Apr 1st, 8:00 AM

# MTFF Operational Design Features

H. Friedrich
*MTFF Study Manager MBB/ERNO, Bremen/W. Germany*

A. J. Thirkettle
*Columbus Module Projects Manager ESA/ESTEC, Noordwijk/Netherlands*

# MTFF OPERATIONAL DESIGN FEATURES

H. Friedrich, MTFF Study Manager
MBB/ERNO, Bremen/W. Germany

A. J. Thirkettle, Columbus Module Projects Manager
ESA/ESTEC, Noordwijk/Netherlands

## Abstract

This paper describes the main design features incorporated in the European Space Agency's Man-Tended Free Flyer which enable the MTFF to be operational on-orbit for a 30 year period via servicing and maintenance. The MTFF is to be serviced at the Station or by Hermes every 6 months in one of two ways - using man in the Pressurized Module and using robotics for the external equipment of the PM and the Resource Module. EVA is a contingency back-up to the latter. Crew servicing inside the PM is enhanced by the proper attention to design details allowing good access to the payload and subsystem equipment in the same manner as for the Attached Modules of the Station, that is by mounting all equipment in standard racks to which the crew have easy access. Servicing of the external items is achieved by mounting them in Orbital Replacement Units (ORU's) which are compatible with the Station and/or Hermes manipulator arms. The ORU's have standardized interface provisions for end effectors and also for attachment to their parent Spacecraft. There are also non-standard ORU's such as solar arrays and comms antennae. The MTFF has attitude/orbit control, stability and position features, has RVD sensors and propulsive capabilities for orbit maintenance, transfer and rendezvous functions.

# MTFF Operational Design Features

## MTFF Main Features

The COLUMBUS Man Tended Free Flyer (MTFF) presently being studied in COLUMBUS Phase B 2, represents a free flying micro-gravity laboratory for material science, fluid physics and life science payloads. It consists of a 2 segment Spacelab-type Pressurized Module (PM-2) and an unpressurized Resource Module (RM) which provides 5 kW of 120 VDC Power for payloads.

Payload (P/L) operation will be by automated processing in the free flying mode while P/L processing set-up and P/L servicing, such as material resupply is conducted by astronauts in a shirt-sleeve environment when the MTFF is connected to a servicing base. The MTFF design concept provides compatibility with the following servicing bases:

ISS or
HERMES or
NSTS.

Here also the MTFF spacecraft and its subsystems will be serviced. To enable this, the MTFF has to be designed for in-orbit replacement of P/L and of subsystem assemblies or components and for resupply of consumables.

Fig. 1 depicts the flight configuration of the MTFF, showing the Resource Module (RM) with the deployed 20 kW solar array (end of life power) and antenna and also the main thrusters for orbit transfer manoeuvres. Connected to the RM is the Pressurized Module (PM-2) with body mounted thermal radiators. The radiators reject via a fluid loop the waste heat of the PM-2 and of the RM.
The radiator also contributes to the meteoroid and debris protection of the PM-2. The internal environment of the PM-2 is the same as that of the ISS, of HERMES and of the NSTS, i.e.
1 atmosphere shirt sleeve.

To enable berthing and physical connection of the MTFF to the respective servicing base, the free flyer provides a pressurized docking port at the PM-2, an unpressurized berthing interface at the opposite end,(i.e. at the RM) and various grapple fixtures on both the PM-2 and RM.

Also on Fig. 1 the main features of the MTFF are listed. The P/L mass of 2000 kg applies to the MTFF launch and can be increased to 5000 kg by installation of additional P/L facilities during on-orbit servicing. The 900 kg propellant also applies to the launch case. More propellant can be loaded on-orbit to increase the refuelling intervals. The launch configuration, shown in Fig. 2 indicates that the MTFF is launched by ARIANE 5 in one shot, fully integrated and with the RM located on top of the PM-2.

Mission Scenario

The mission orbit profile of the MTFF is arranged such that the free flyer orbit remains on average co-planar with that of the ISS, allowing rendezvous with the ISS for Payload servicing at intervals of 180 days. After each servicing event the MTFF performs a boost-up manoeuvre with a subsequent free drifting flight without doing any further orbit corrections. In this way it is possible to achieve the undisturbed micro-gravity environment of levels down to $10^{-6}$ g (< 1 Hz). In the HERMES servicing scenario, the MTFF will also fly co-planar with the ISS in order to allow servicing at the ISS in a contingency and/or mixed mode situation. The mission profile for a MTFF mission period of e.g. 180 days is shown on Fig. 3.

The MTFF carries out the orbit transfer manoeuvres and rendezvous operations by means of its attitude and orbit control system which incorporates also RVD sensors (rendezvous and docking) and cold gas propulsion for proximity operations with manned vehicles.

While the MTFF is designed to support P/L servicing at intervals ranging from 30 to 180 days, scheduled MTFF-spacecraft (i.e. subsystem) servicing is intended to take place at longer intervals, of 2 or more years. The propellant tanks are sized to carry fuel for more than 2 years mission operation between refuelling.

MTFF Design for On-Orbit Servicing

The MTFF design concept is based on an on-orbit life requirement of 30 years. Particular measures have therefore to be applied to achieve this life. The respective measures are summarized in Table 1. The primary structure of the free flyer elements (PM-2 and RM) will be designed and the material selected in accordance with the 30 years life requirement. Also repair methods have to be applied and proper access to critical areas provided to enable the correction of damage, stemming from for example meteoroid impact.

Functional components such as computers, gyros and in particular batteries, cannot be designed for 30 years life. On-orbit replacement must therefore be possible. Equipment accommodated inside the PM-2 is accessible by astronauts and will hence be designed for replacement by IVA. Standardized replacement units in the form of P/L or S/S racks are widely used to facilitate the maintenance activities.

The RM equipment cannot be replaced by IVA since it is located in unpressurized areas. In order to avoid excessive EVA during maintenance, the external ORUs should be replaceable by robotic means i.e. by manipulators. For this reason most of the RM equipment is accommodated in "standard", manipulator-compatible ORUs. Some of the components of the MTFF, e.g. radiators of the PM-2, the solar array and antenna of the RM cannot be made to fit a standardized ORU packaging due to their size and shape. They are also of complex mechanical design. These components are also replaceable on-orbit but will need EVA as a back-up during replacement. The partitioning of the RM into standard and non-standard ORUs is shown on Fig. 4.

MTFF Serviced at the ISS

The final attitude for ISS manipulator pick up of the MTFF is depicted on Fig. 5. The free flyer performs active rendezvous with the ISS until pick-up by the station's manipulator arm. The final approach of the MTFF is to the same position to which the NSTS flies when it visits the station. After pick-up, the MTFF is transfered by the ISS manipulator to its berthing/docking node to which it is connected. The free flyer in its final servicing position is shown in Fig. 6. All appendages (e.g.solar array, antenna) are retracted and the MTFF gets its resources from the ISS through functional interface connectors, provided in the pressurized docking/berthing adapter.

During rendezvous operations the position and velocity of the MTFF relative to the ISS will be determined by the use of the following means provided by the free flyer:

- Long range: Differential GPS (Global Positioning System) measurements
- Medium range: Laser sensor
- Short range: Camera

Range and range rate information of the MTFF will be transmitted to the ISS crew to allow monitoring and if necessary safe interruption of the rendezvous manoeuvre.

Internal servicing of the PM-2 is indicated in Fig.7. The location of the MTFF at the ISS is adjacent to the station's Logistic Module. Thus no working area has to be passed through when transfering items from or to the PM-2. Crew servicing inside the PM-2 is enhanced by the proper attention to design details, allowing good access to the P/L and S/S equipment in the same manner as for the Columbus Attached Module of the station, that is by mounting, as already explained, in standard racks. The size of these racks allows the transfer of single as well as double racks from the MTFF through the hatch of the docking port into the Logistic Module.

For external servicing (i.e. RM servicing) the MTFF may be moved to the station's servicing bay where the external standard ORUs can be replaced by the remote manipulator of the ISS, or it may be possible to remove/replace the ORU's by manipulator at the logistics module node. Refuelling of MTFF propellant can be done by exchange of the two propulsion ORU's, also using the station's manipulator.

MTFF Servicing by HERMES or NSTS

For the rendezvous with HERMES the MTFF is converted into a passive but cooperative mode with HERMES performing the active rendezvous function.

The rendezvous approach configuration for PM-2 servicing is shown in Fig. 8.

The resupply material for the P/L as well as the P/L and (internal) S/S spares are transported by HERMES in a "HERMES dedicated" pressurized Logistic Module (LM). Since the HERMES airlock port size is different to that of the PM-2 (ISS) the LM, having two different port sizes, is used as an adapter between the HERMES airlock and the PM-2 docking adapter.

In the docked mode the MTFF provides electrical power to HERMES during most of the servicing time. The combined MTFF/Hermes assembly will be stabilized in its attitude by cooperative attitude control, i.e. using the Hermes computer as the master which then commands actuators, located in Hermes as well as in the MTFF.

Transportation of P/L or S/S racks from PM-2 to the HERMES LM is depicted in Fig. 9. As can be deduced from this figure, the inline arrangement of the MTFF and the LM has the advantage that racks need not to be moved around corners.

As already mentioned under the headline "Mission Scenario", MTFF-Spacecraft servicing will not be performed at nominal P/L servicing events. At intervals of 2 to 3 years, the S/Ss will be serviced and the MTFF refuelled via a dedicated HERMES flight. The MTFF/HERMES configuration for RM servicing is shown in fig. 10. The free flyer is mounted on a telescopic mast which is located behind the HERMES cabin. The mast provides +/- 180° rotation in 90° steps to enable the HERMES manipulator to reach all ORU's around the RM. The telescopic mast is sufficiently long to give proper clearance to the HERMES airlock, allowing EVA in case it will be required. Fig. 11 shows the exchange of standard ORU's. All non-standard ORU's of the MTFF are also HERMES compatible. As the propulsion subsystem is accommodated in two standard ORU's, refuelling can be conveniently accomplished by ORU replacement.

FEATURES:
2 SEGMENTS: PRESS. MODULE + RESOURCE MODULE
SERVICE VEHICLE: HERMES OR USSS OR NSTS
MASS: 16250 kg LAUNCH
2000 kg P/L
900 kg FUEL AT LAUNCH
POWER: 9,6 kw TOTAL
5,0 kw TO P/L
ORBITS: 490 - 463 km OPERATIONAL
28° INCL.
463 km; 28,5° SERVICING
BY HERMES OR NSTS
490 km; 28,5° SERVICING
BY USSS
MICROGRAVITY: $10^{-6}$ g ($\leq$ 1 Hz)

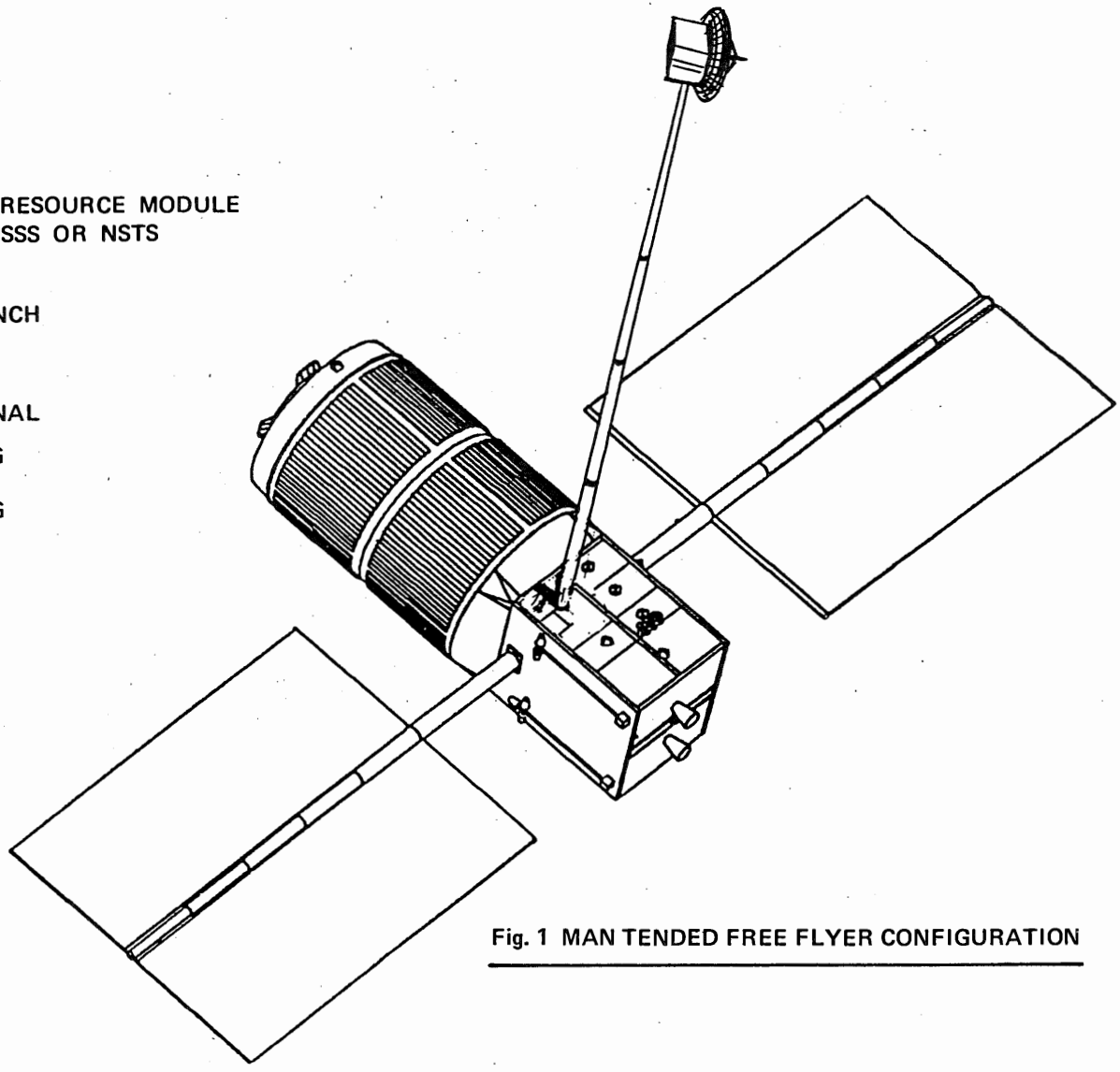


Fig. 1 MAN TENDED FREE FLYER CONFIGURATION

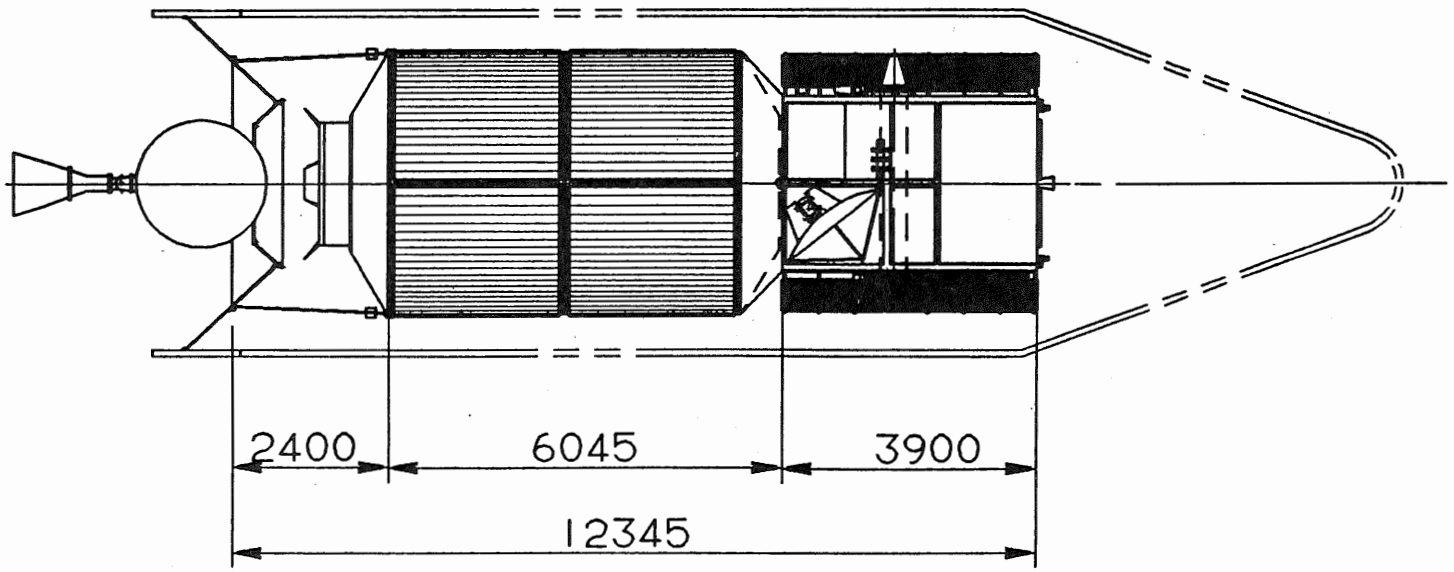
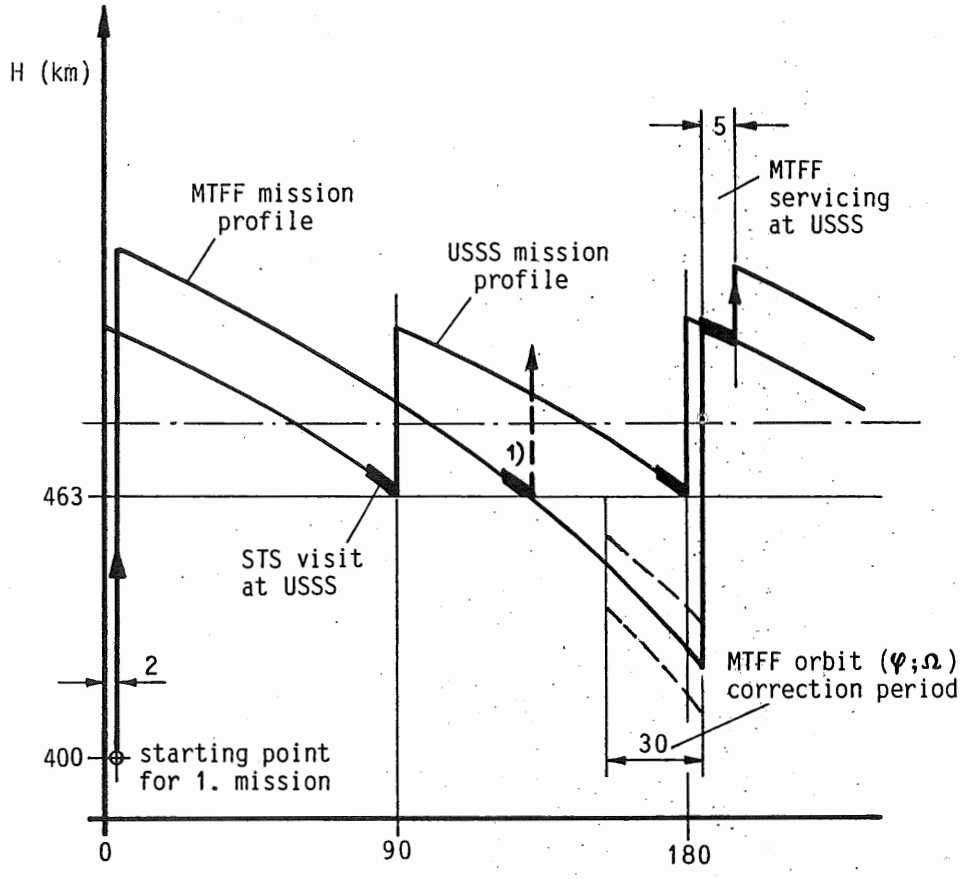



Fig. 2 MTFF LAUNCH CONFIGURATION




1) alternative servicing by Hermes or NSTS

**Fig. 3 MTFF MISSION SCENARIO**

## Table 1: Measures to achieve 30 years Operational Life

- Design of primary structure for 30 years on-orbit life. Provide access to critical areas (e.g. internal surface of pressure shell) to enable on-orbit repair.

- Accommodation of all functional assemblies/components as "Orbital Replacement Units"
  → ORU
  - Standard ORUs:
    -- Racks for P/L and S/S in PM-2 → replacement by astronauts
    -- Drawer type units in RM → replacement by manipulator

  - Non-Standard ORUs:
    -- Radiators on PM-2
    -- Solar Array; Antenna on RM
    } → replacement by manipulator with EVA back-up

Standard ORUs contain equipment of higher replacement frequency

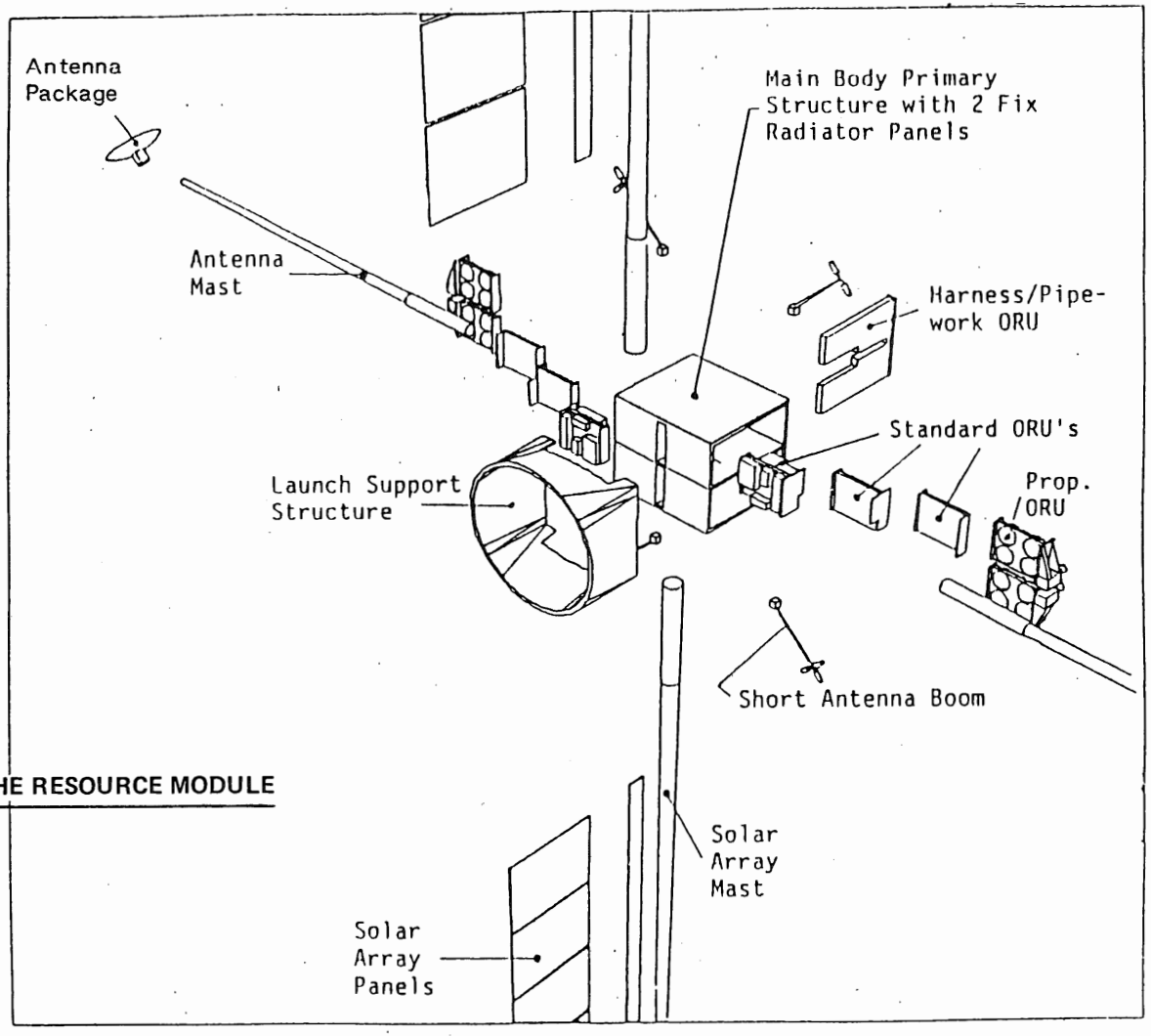



**Fig. 4 ORU PARTITIONING OF THE RESOURCE MODULE**

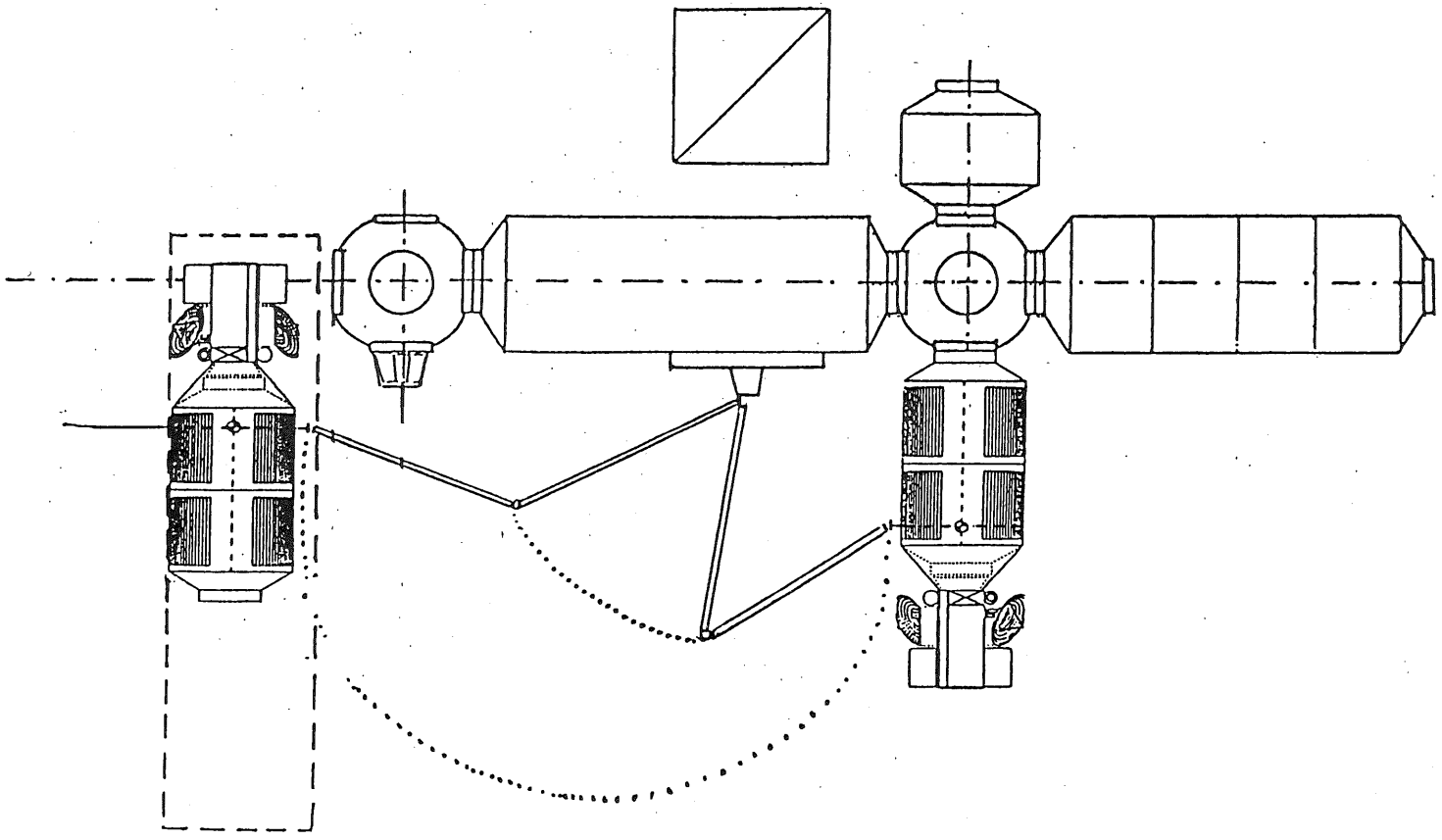


Fig. 5 MTFF FINAL ATTITUDE FOR STATION MANIPULATOR PICKUP

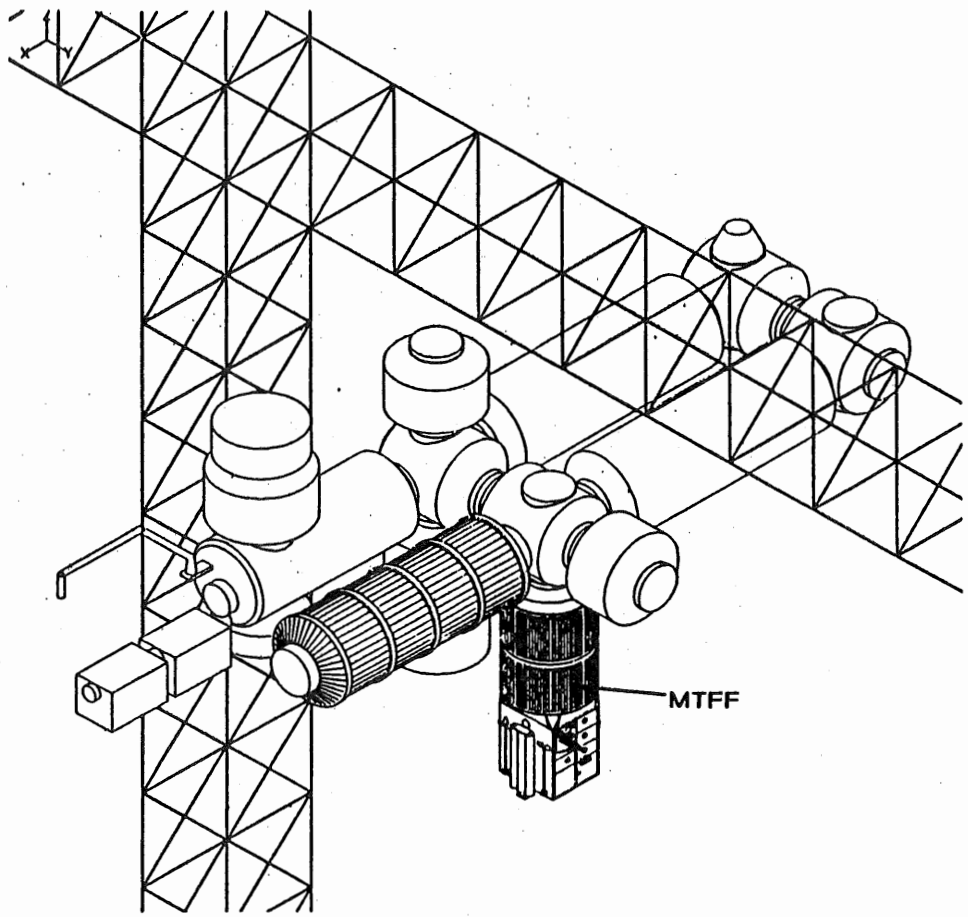



Fig. 6 MTFF DOCKED TO USSS

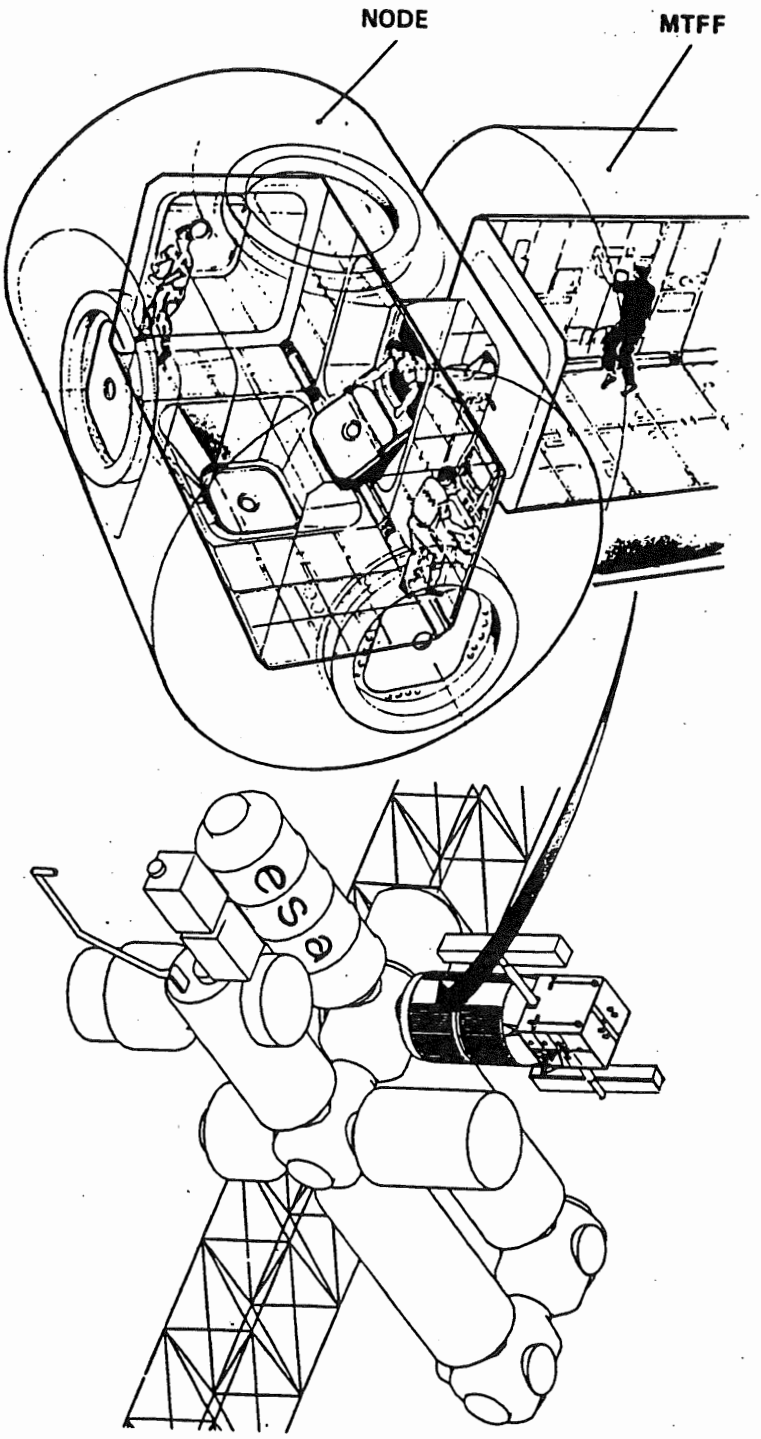



Fig. 7 MTFF DOCKED TO USSS NODE

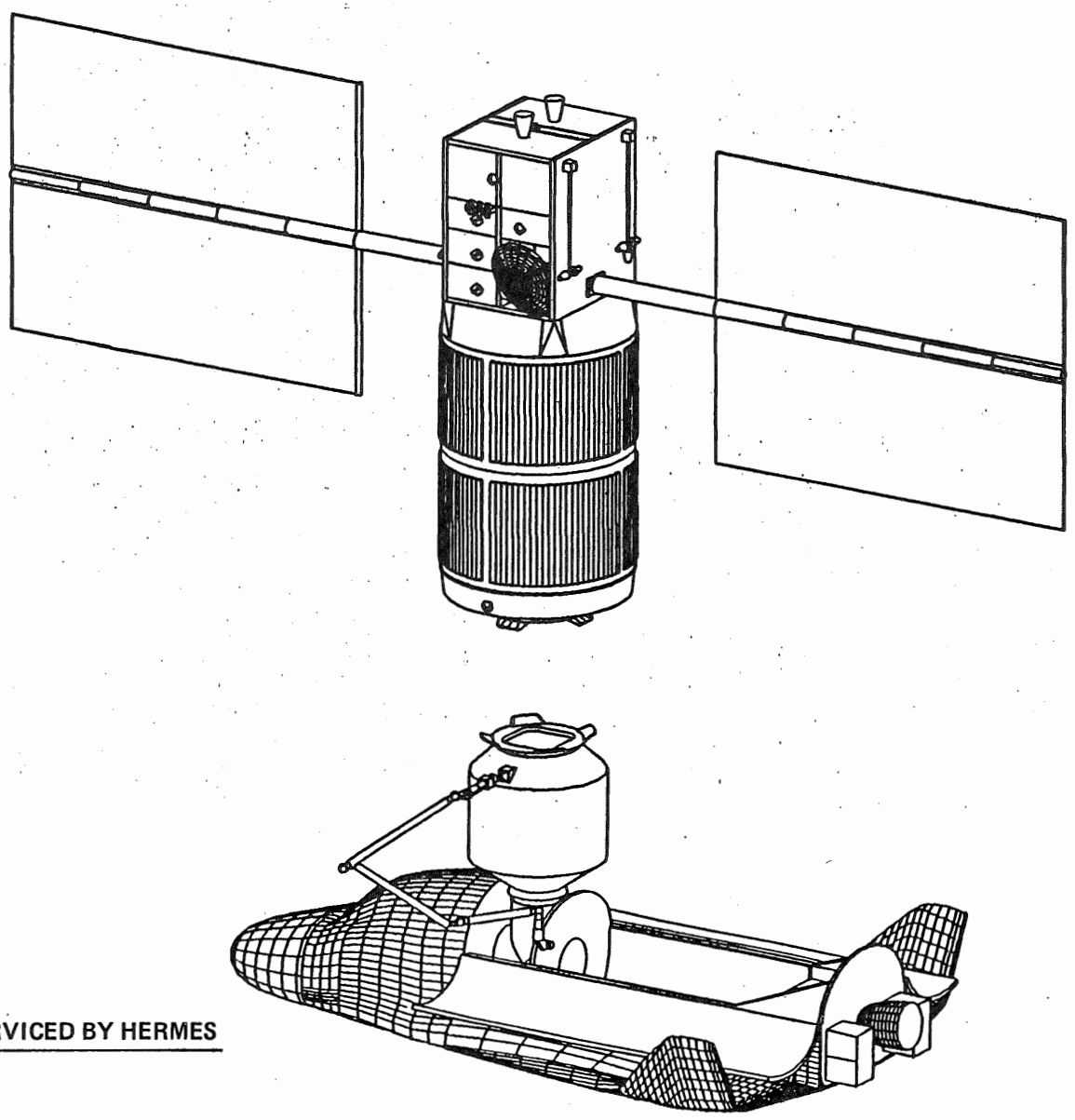


Fig. 8 MTFF SERVICED BY HERMES

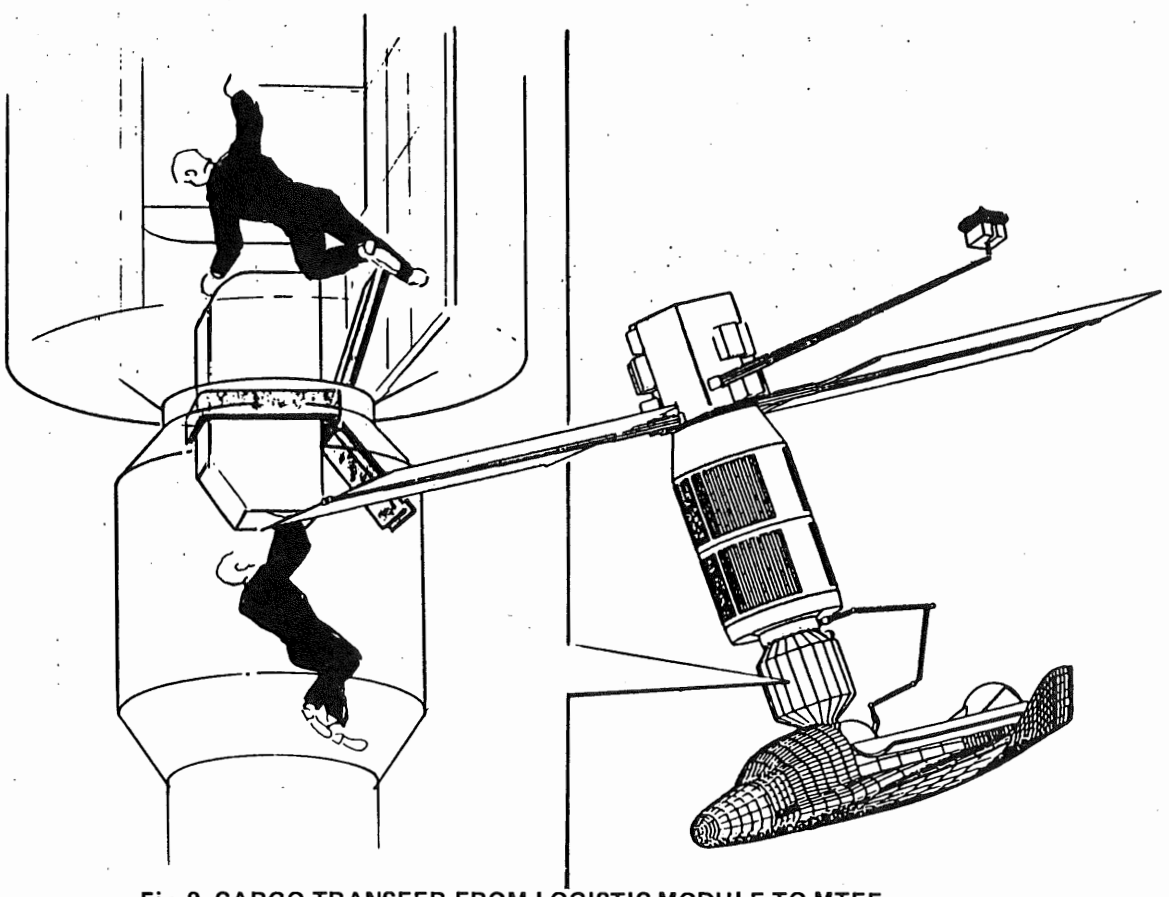


Fig. 9 CARGO TRANSFER FROM LOGISTIC MODULE TO MTFF

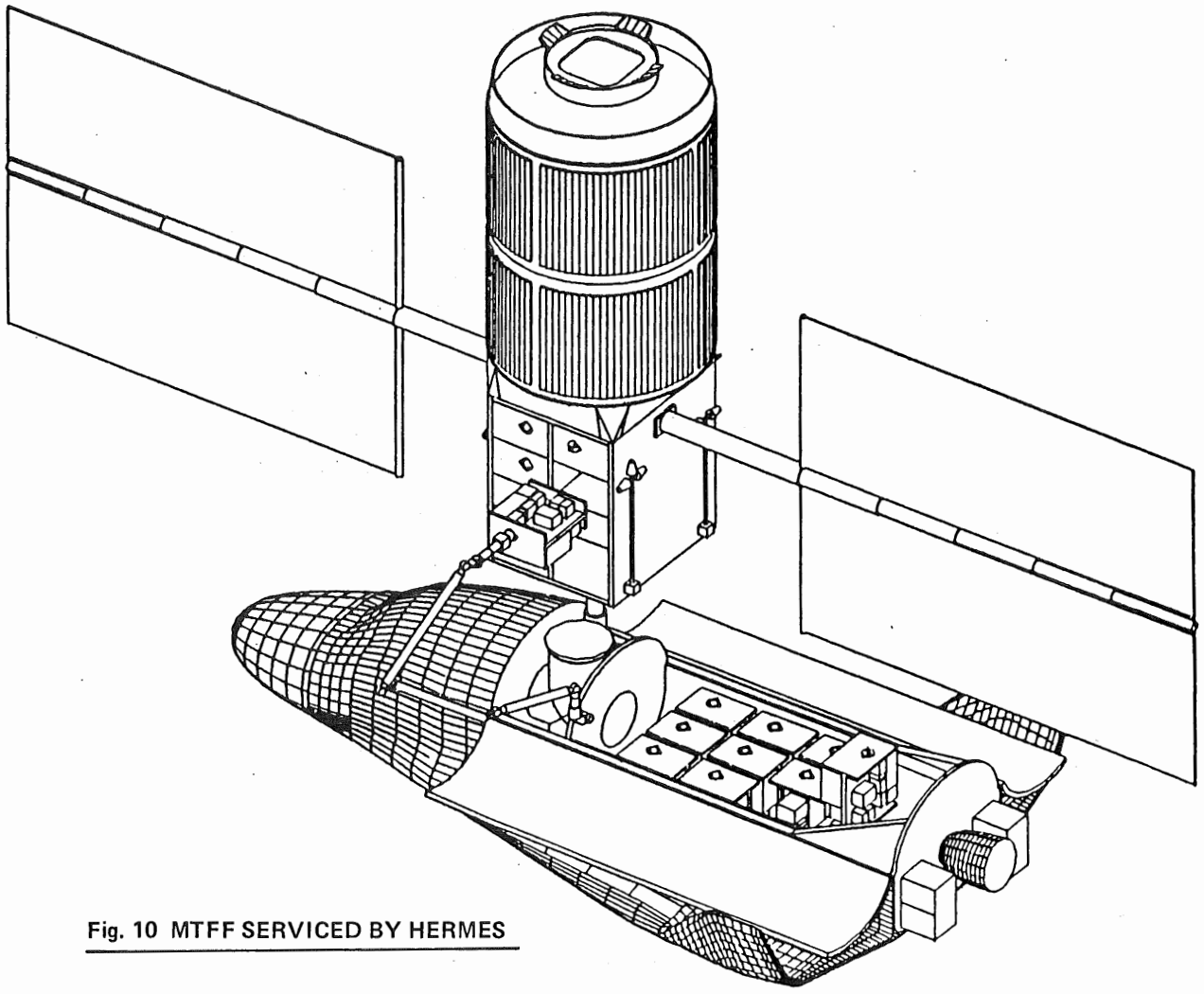


Fig. 10 MTFF SERVICED BY HERMES