TELEOPERATOR MANEUVERING SYSTEM

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TELEOPERATOR MANEUVERING SYSTEM

The Teleoperator Maneuvering System (TMS) will perform a variety of missions as a mini-tug/upper stage. Operating out of the Orbiter, it may be controlled either from the AFD (Aft Flight Deck) or from the ground.

Typical missions are: Payload Placement, Retrieval, Servicing (module exchange or refueling) Viewing and large space systems assembly support.

TELEOPERATOR MANEUVERING SYSTEM (TMS) PROGRAM

OBJECTIVES

- PROVIDE A REMOTELY CONTROLLED, FREE-FLYING, MINI-TUG ORBITAL SERVICE VEHICLE CAPABLE OF PERFORMING A WIDE RANGE OF REMOTE SATELLITE SERVICES MISSIONS.
- ENHANCE THE ORBITER'S CAPABILITY AND EFFICIENCY IN THE DELIVERY OR RETRIEVAL OF PAYLOADS TO HIGH ALTITUDE ORBITS.

TMS MISSION APPLICATIONS

- HIGH ALTITUDE PAYLOAD DELIVERY/ RETRIEVAL
- SATELLITE MODULE REPLACEMENT/ SERVICING
- SPACE DEBRIS CAPTURE/DISPOSAL
- LARGE STRUCTURES ASSEMBLY SUPPORT
- PAYLOAD PLANE CHANGES
- SATELLITE REFUELING
- REMOTE PAYLOAD VIEWING (TV)
- MULTI-PURPOSE PROPULSION MODULE UTILITY

TMS PROJECT SCHEDULE

The major activities and phasing of the ongoing TMS project are reflected by the facing schedule.

Phase "A" activities are currently in process which are intended to drive out the system requirements and to define systems concepts in sufficient depth as to initiate the formal RFP for Phase "B".

Authority to proceed is being sought for FY-1985 for the primary system capability (i.e. delivery and subsatellite support) which would have first beneficial use in 1987. Subsequent authority in FY-1986 for the retrieval kit would enable spacecraft retrievals to begin in 1988. Authority to design and construct the Servicer Kit in the same general time period would enable the TMS to repair disabled spacecraft on-orbit and to reboost them to their operational orbit for an extension of life by 1988.

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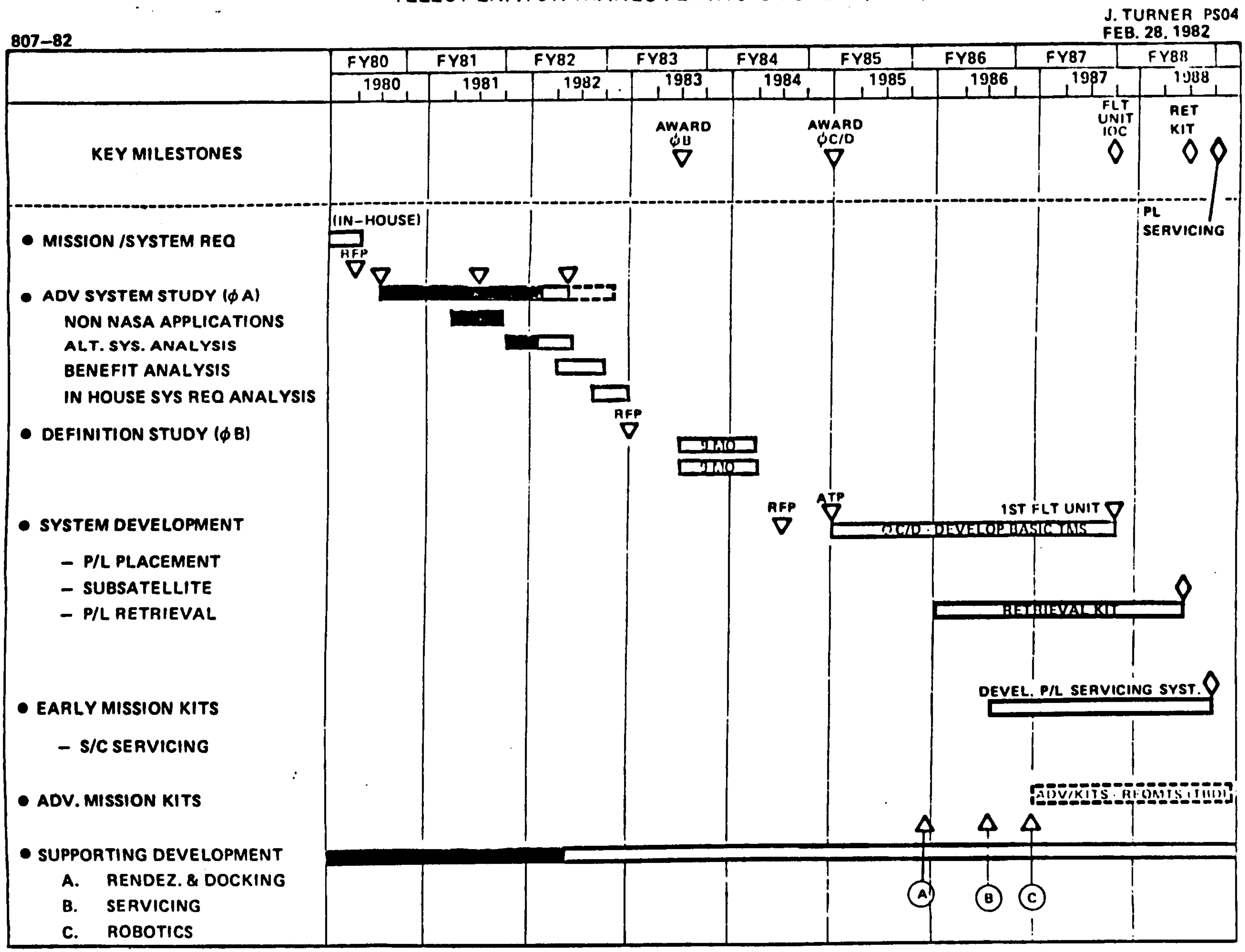
TELEOPERATOR MANEUVERING SYSTEM (TMS)



PROJECT PHASING

The design phasing is reflected by this chart which shows three distinct phases of capability.

ERA-1 capability will consist of payload placement, retrieval and sub-satellite support.

ERA-2 capability will be obtained by the addition of advanced mission kits. These specialized kits will enable the TMS to support large space systems and spacecraft servicing by direct module exchange as a logistic vehicle or the transfer of fluids and modules via remote manipulators.

ERA 3 capability will extend TMS operations to geosynchronous orbits when delivered by an OTV. This era will require longer system duration times, orbital storage, and higher degrees of autonomy.

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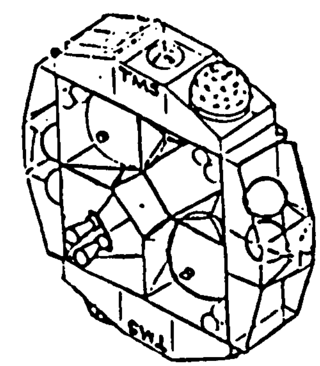
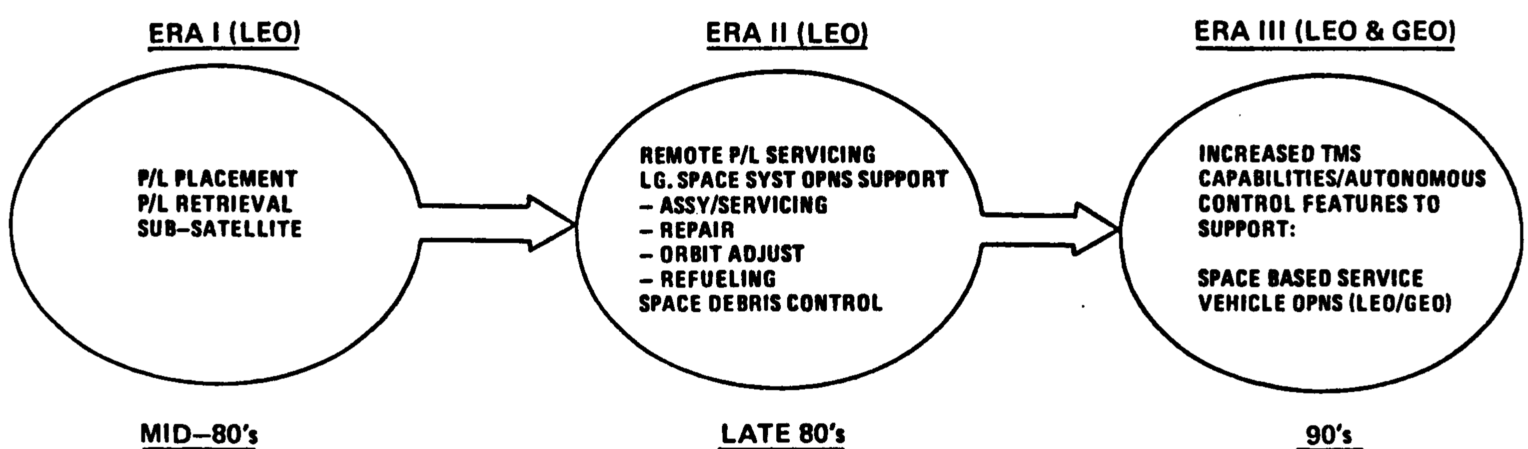
TELEOPERATOR MANEUVERING SYSTEM (TMS)



TMS:
- SMALL, REMOTE–CONTROL PROPULSION & SERVICE UNIT TO EXTEND SHUTTLE CAPABILITIES
- TMS CAPABILITIES TO BE INTRODUCED IN INCREMENTAL FASHION



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DESIGN PHILOSOPHY

A building block philosophy/methodology is planned; thus permitting the evolution of capability as it is needed and delaying cost as much as possible.

The system is being designed with a wide range of applications in mind to maximize its application and to minimize the transportation cost.

Other factors being considered are: standardized interfaces, safety, contamination, and system reusability.

TMS Design Philosophy

• A Building-Block Approach	A basic core vehicle with propulsive communication, and servicing kit add-on to evolve with mission needs
• Minimize Early-Year Costs	1985-1986 missions with core vehicle
• Multipurpose	Enhance/augment STS by providing flexibility in payload delivery altitudes inclinations, manifesting, and support operations
• Reduce User Charges	Minimize weight and length in configuration trade studies
• Control Flexibility	Mix of autonomous and man-loop control in orbiter and appropriate ground stations for periodic or real-time control of TMS
• Standardize Interfaces	Minimize complexity of interfaces between payloads, the orbiter and launch facilities.
• Safe and Contamination-Free	TMS designed to the safety aspects of the man-rated Shuttle and to avoid STS and payload contamination
• Cost-Effective	Reuseable with goal for 10-year life with limited refurbishment and maximum use of developed hardware

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TELEOPERATOR MANEUVERING SYSTEM

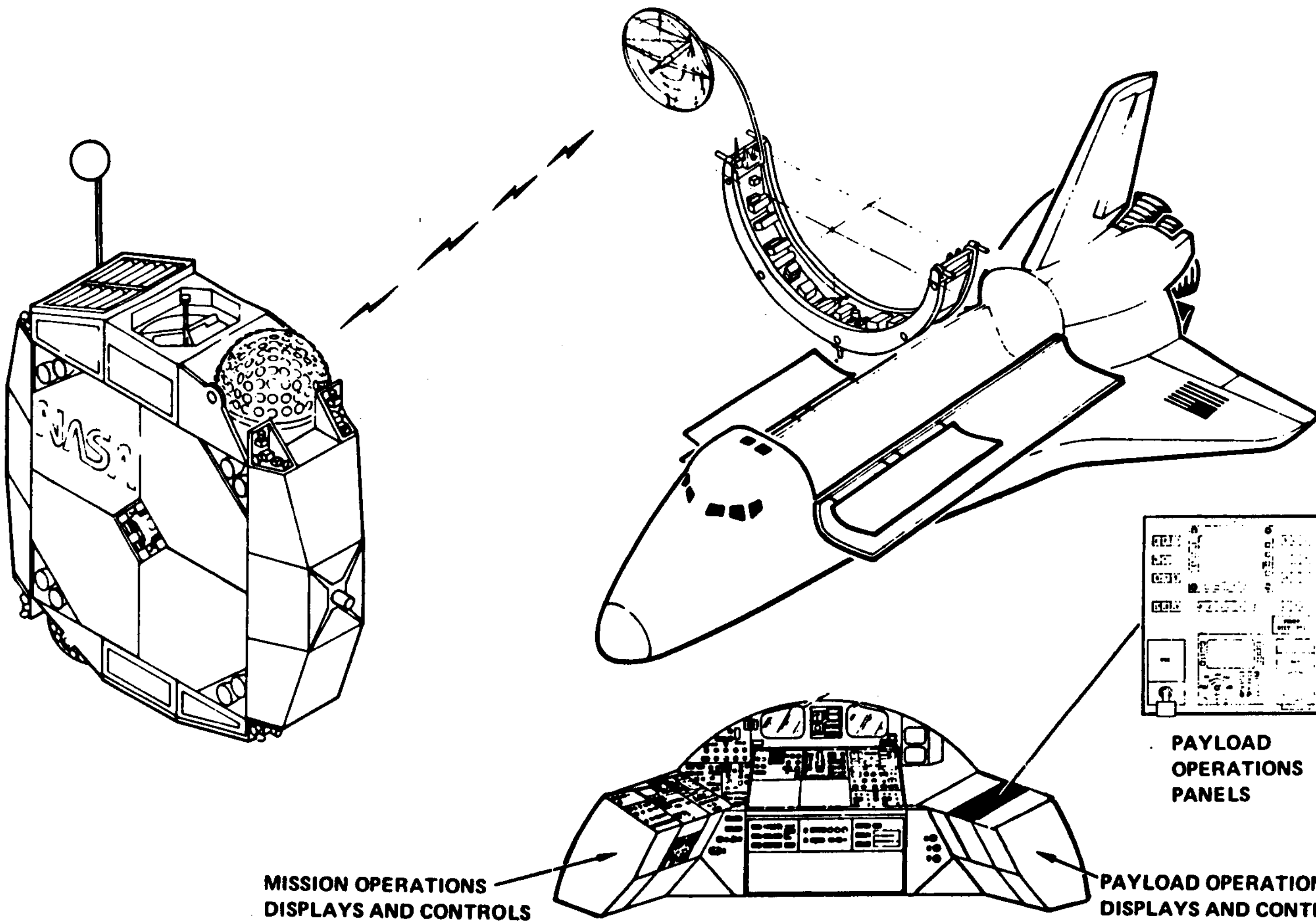
The TMS consists of three segments: the vehicle, the Shuttle Orbiter payload bay cradle with Airborne Support Equipment (ASE), and the Aft Flight Deck (AFD) control station.

- The 13 foot diameter, 37 inch thick vehicle is a reusable remotely controlled free flying vehicle capable of satellite servicing, placement and retrieval. The TMS flies preprogrammed trajectories as well as being controlled or reprogrammed from the AFD or the ground. Approximately 1 million lb-sec of energy are available from the hydrazine propellant with an option to upgrade to 1.6 million lb-sec of N_2O_4/MMH bipropellant.

- The lightweight ASE cradle may be conveniently positioned along the payload bay length where it is attached using the standard sill and keel fittings. The cradle supports the TMS during the launch and reentry phases and houses the antennas, communication, video and other avionics ASE necessary for vehicle man-in-loop (MIL) control from the Orbiter's AFD.

- The equipment on the AFD is located at console L-11. It consists of a set of hand controllers for TMS proximity operation maneuvering and two cathode ray tube (CRT) screens and keyboards. Data is displayed for vehicle checkout and health status and video display is provided for docking and servicing. All of the data are reconstructed and processed by the cradle ASE prior to receipt at the AFD. The AFD installation is mission dedicated; however, the entire TMS operation is autonomous to the Orbiter systems except for in-bay power and guidance initialization through the Orbiter multiplex bus. Recorded data will also be stored by the Orbiter.

Teleoperator Maneuvering System



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TMS - AFT FACE

This is a perspective view looking at the aft face of the TMS with the subsystem components and other items identified. Vehicle dimensions and weights are listed. The Remote Manipulator System (RMS) grapple fixture is the standard interface for the RMS. The TMS is deployed from and replaced in the payload bay by the RMS. Two (2) 30 inch diameter Electronically Steerable Spherical Array (ESSA) antennas operating on S-Band are located diametrically opposite on the TMS to provide 4 steradian coverage. Twenty-four 15 pound thrusters comprise the RCS which provides roll attitude control during main burn and rotational and translational control during rendezvous and man-in-the-loop operations. Helium gas is used to pressurize the propellant tanks. The spherical pressurant tanks are located on each side of the vehicle. A multi-use compartment is also located in this area as contingency volume. Three trunnion fittings are present (one on each side and one on the bottom) on the TMS for attachment to the ASE cradle. Avionics compartments are on the upper and lower segments of the TMS. Thermal control louvers are used to dissipate heat from the electronic equipment. The aft end of the docking port is shown. A device such as an RMS end effector extends forward when docking with a spacecraft. The eight (8) throttleable thrusters are located in a square pattern. Four or eight thrusters can be operated between the 25 and 125 lbf level with the total thrust range varying from 100 lbf minimum to 1000 lbf maximum.

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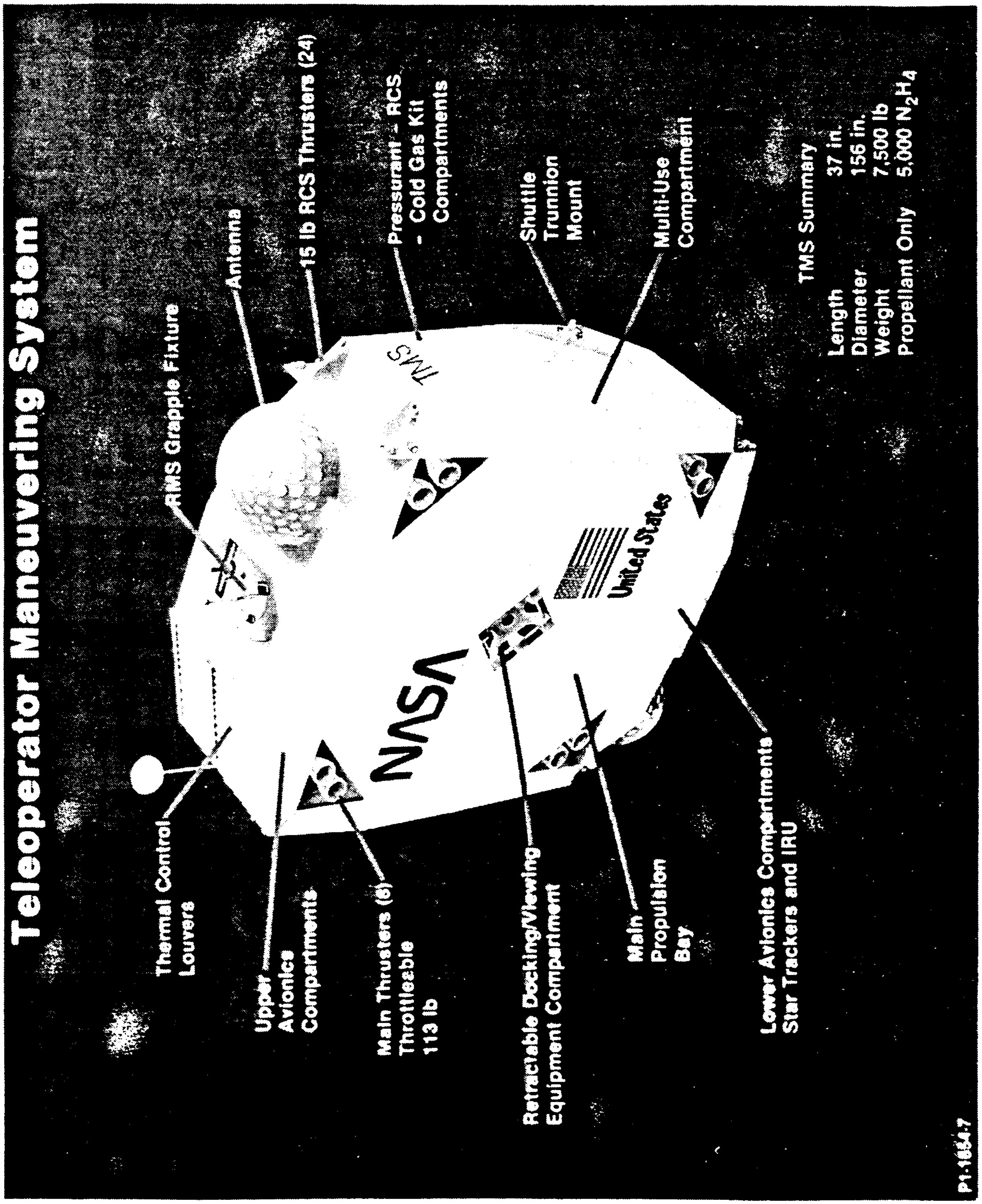

TMS - FORWARD FACE

This is a perspective view of the forward face of the TMS. The docking adapter can be seen in its fully extended positon, 24 inches. The end effector is identical to the Shuttle Orbiter RMS end effector although other types may be incorporated. The video and lighting system are located as shown and are used for docking, viewing, and servicing. Also required in the docking kit is the range/range rate radar which has a 9 inch diameter antenna shown deployed outward from the TMS body. Star tracker field of view ports are shown in the lower avionics bay. The lower keel fitting has been offset to not obstruct their field of view. A multi-layer insulation blanket will cover the TMS to maintain thermal balance.

The monochrome TV camera provides a redundant video imaging system capable of viewing a target during rendezvous and final docking operations. One of the cameras is mounted on a pan/tilt base to aid in acquisition and provide additional viewing flexibility.

Flood lights are provided for dimly lit or night scenes illumination.

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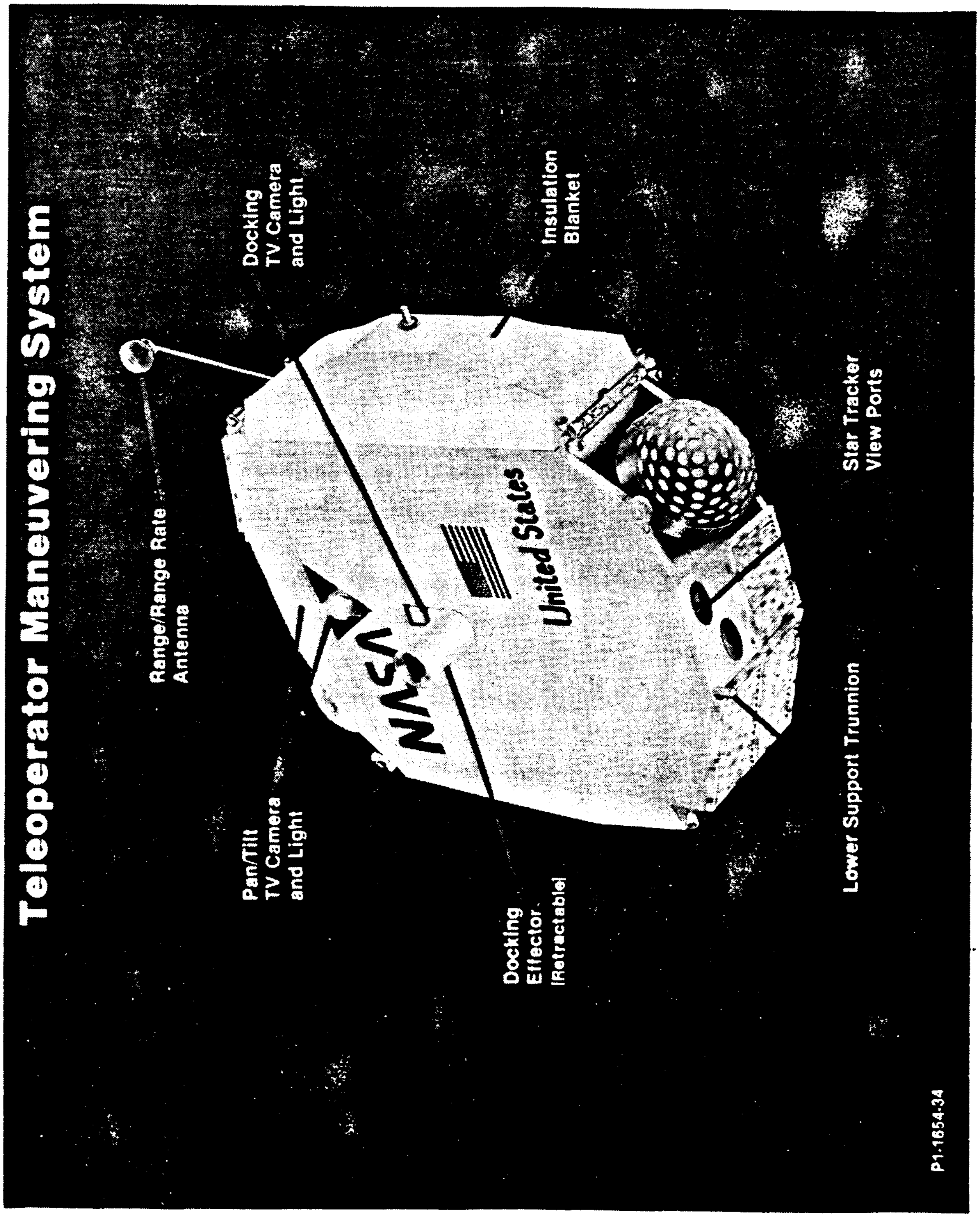
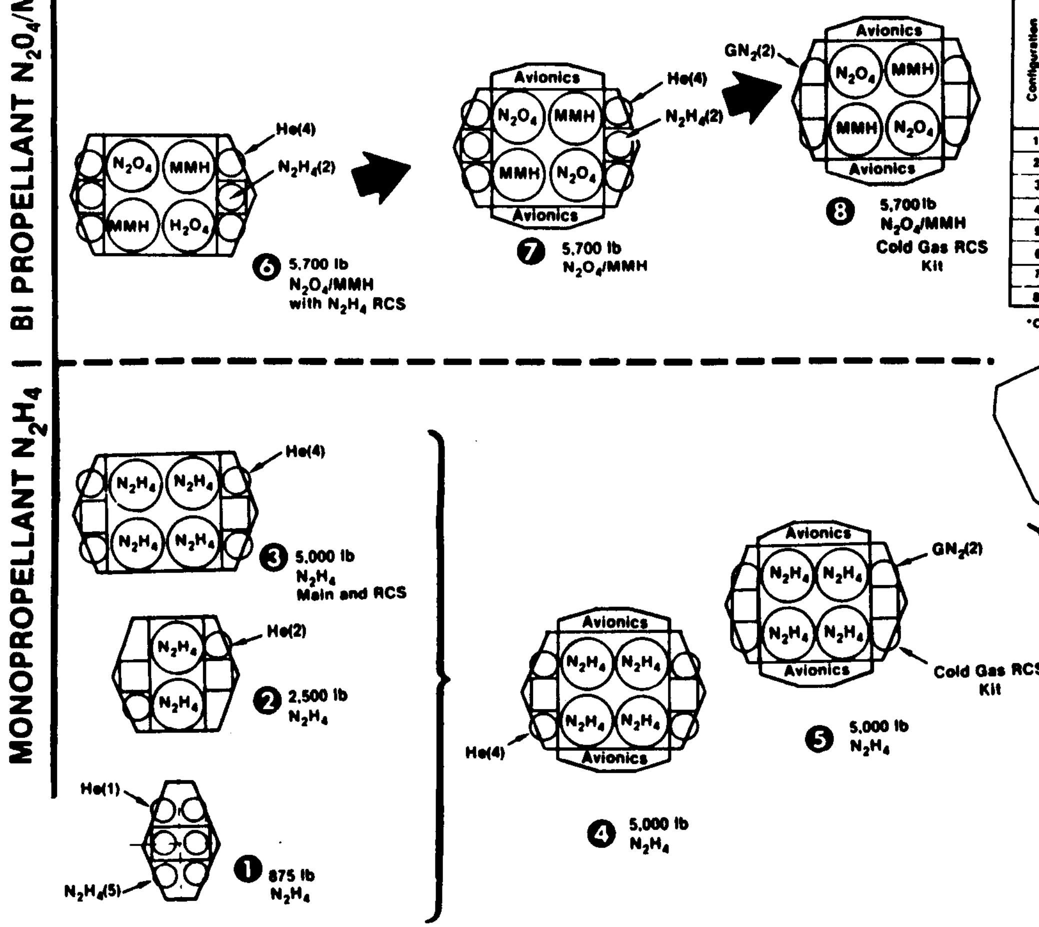


TELEOPERATOR MANEUVERING SYSTEM EVOLUTION

The design philosophy of a building-block approach is reflected in the lower half of this chart and the commonality matrix at the upper right. The standard or baseline TMS is denoted as number 4. Modular compartments of this baseline may be used up-front to build various sized propulsion modules with hydrazine propellant quantities of 875 pounds, 2500 pounds or 5000 pounds as required. Incorporation of the avionics brings the vehicle to its full capability, and even that can be done progressively. For example, docking kit equipment such as range/range rate radar and TV system with video bandwidth compression may be added to the placement capability at a later date when needed. If cold gas RCS is needed because of contamination considerations, it can also be added in kit form. Examples of subsatellite operations and satellite servicing are shown to the right where subsatellite solar arrays and servicing kits are added to the basic vehicle.

The baseline uses monopropellant hydrazine. Comparing monoprop and biprop results in a "toss up" between the two propellants. Monoprop was selected because of acceptable performance in the required energy regime, lower development costs and risk and user familarity. However, in order to be responsive to changing requirements, the monoprop vehicle has been designed to easily switch to a biprop system as shown in the upper half of the chart. The propellant tanks would remain unchanged except to substitute surface tension devices for bladders and the required plumbing changes. The vehicle would hold 5700 pounds of biprop. The RCS would remain monoprop or cold gas. These concepts are shown in configurations numbered 6 through 8.

Teleoperator Maneuvering System Evolution



COMMONALITY

Configuration Number	Main Structure	RCS Module Structure	Avionics Modules	Main N_2H_4 Tanks	N_2O_4/MMH Tanks	GN_2 Cylinders	He Spheres	N_2H_4 Spheres	N_2H_4 RCS Thrusters	N_2H_4 Main Thrusters	N_2O_4/MMH Thrusters
1		X					X	X	•	•	
2		X		X			X		•	•	
3	X	X		X			X		X	X	
4	X	X	X	X			X		X	X	
5	X	X	X	X		X				X	
6	X	X			X		X	X	X		X
7	X	X	X		X		X	X	X		X
8	X	X	X		X	X					X

*Optional

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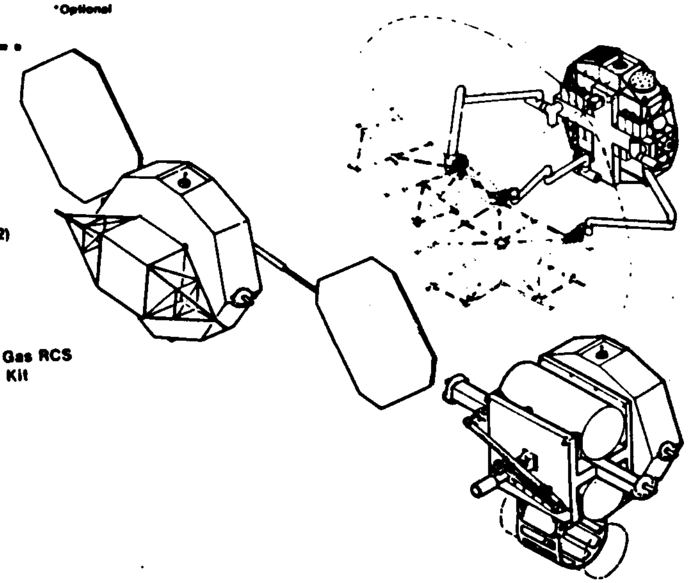

PROPULSION MODULES

- Placement, Reboost, Controlled Reentry
- Subsatellite (Short Range Free Flyer)

REMOTE SATELLITE SERVICES

Retrieval (Satellite or Payload/Experiment)

Long Range Subsatellite Operations

Maintenance, Servicing and Repair

Structure Assembly

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TMS APPLICATIONS

A wide range of TMS applications are shown and implied on the facing page.

Basic Shuttle payload delivery flexibility is greatly enhanced. Multiple payload delivery to various orbital altitudes may be readily accommodated.

Launch window make-up is possible as well as considerable plane change. Some representative combinations of plane change and delivery capability are shown - also, representative retrievals which make servicing and debris removal possible.

The capability matrix is further enhanced by viewing and logistic support.

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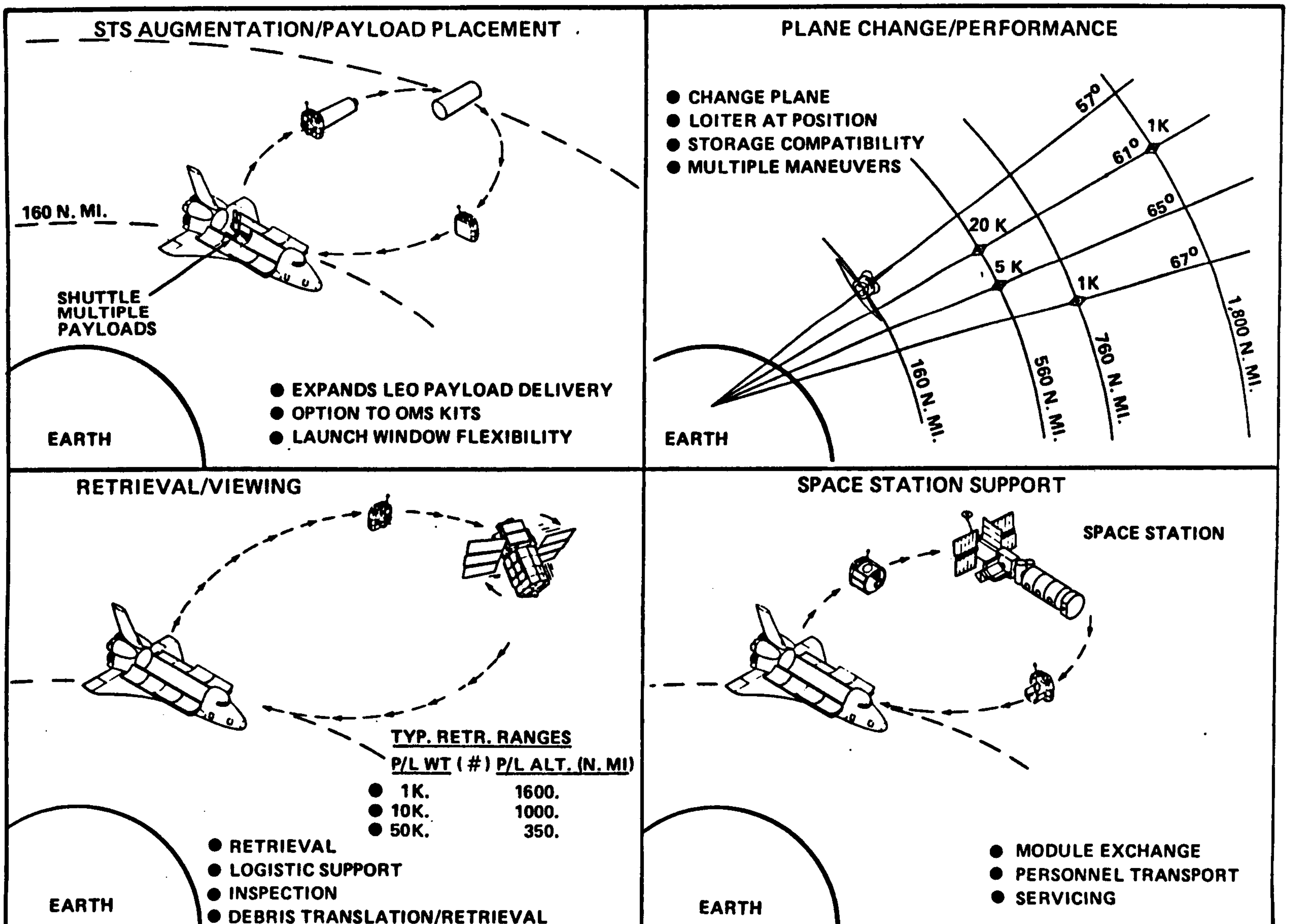
TELEOPERATOR MANEUVERING SYSTEM (TMS) APPLICATIONS



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TYPICAL TMS PERFORMANCE ENHANCEMENT OF STS

The chart presents performance as cargo weight which can be transported to circular orbit altitude. The dashed curves represent Shuttle capability with integral OMS, and with 1, 2 or 3 OMS kits. The solid curve is TMS performance staged from the Shuttle at 160 nautical miles. TMS performance is shown for the baseline 4-Tank vehicle. The curve represents net payload weight which can be transferred from 160 nautical miles to higher circular orbits. The beginning of the TMS curve to the left represents zero TMS fuel. Fuel is added along the straight portion of the curve until full fuel is reached where the curve breaks downward. At this point payload is reduced to achieve higher altitude.

The chart demonstrates the efficiency of staging a TMS/Payload from the Orbiter at 160 nautical miles versus direct ascent to altitude by the Orbiter. The example point (within the diamond) shows the Orbiter requires two OMS kits to take 20,000 pounds to 425 nautical miles. In contrast, an off-loaded 4-tank TMS can take 20,000 pounds to 425 nautical miles, and on the same flight to 160 nautical miles the Orbiter can bring up an additional payload in excess of 31,500 pounds.

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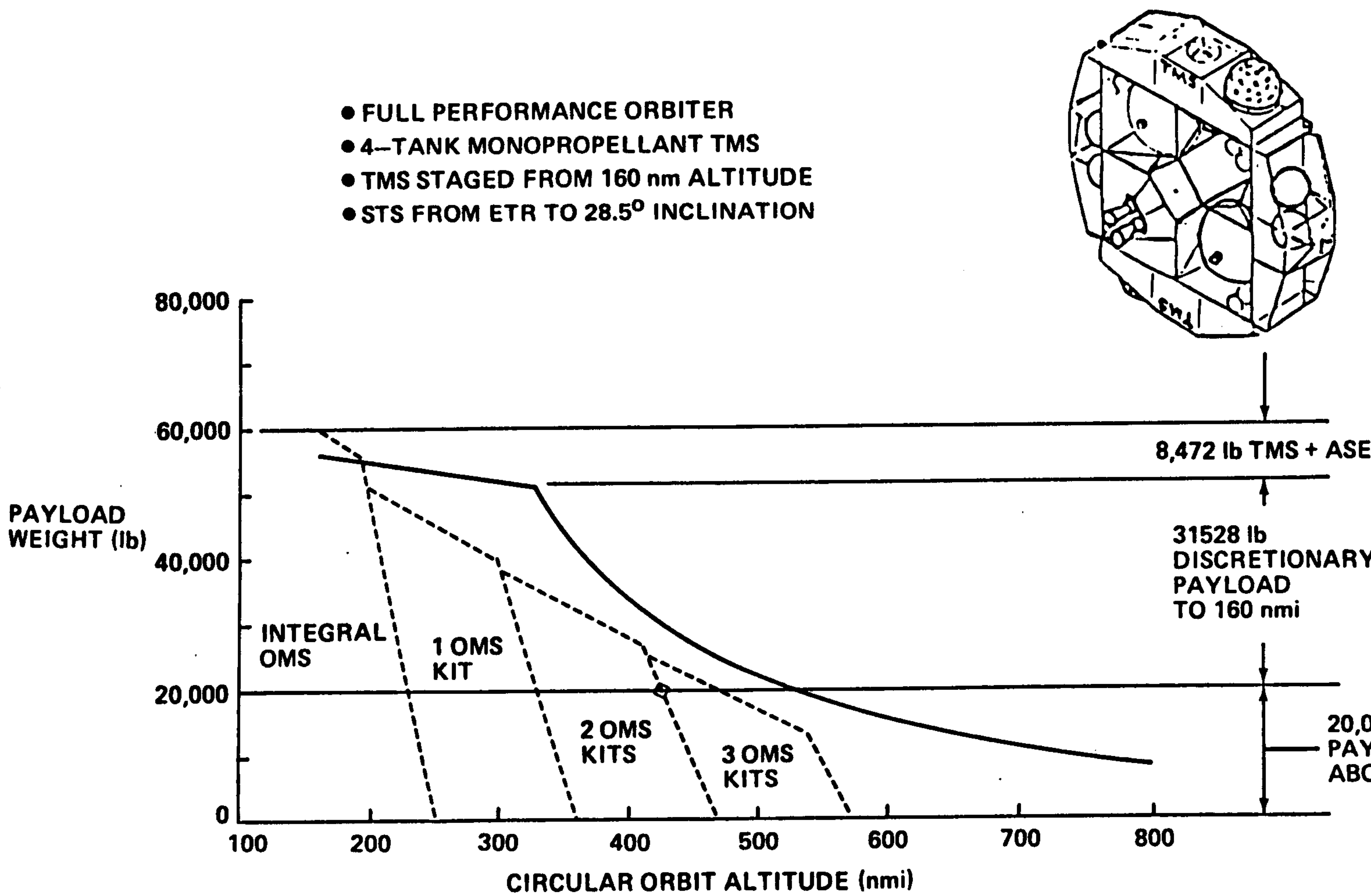
TYPICAL TMS PERFORMANCE ENHANCEMENT OF STS

- FULL PERFORMANCE ORBITER
- 4–TANK MONOPROPELLANT TMS
- TMS STAGED FROM 160 nm ALTITUDE
- STS FROM ETR TO 28.5° INCLINATION



TMS PERFORMANCE ENHANCEMENT OF STS

(BIPROP TMS)

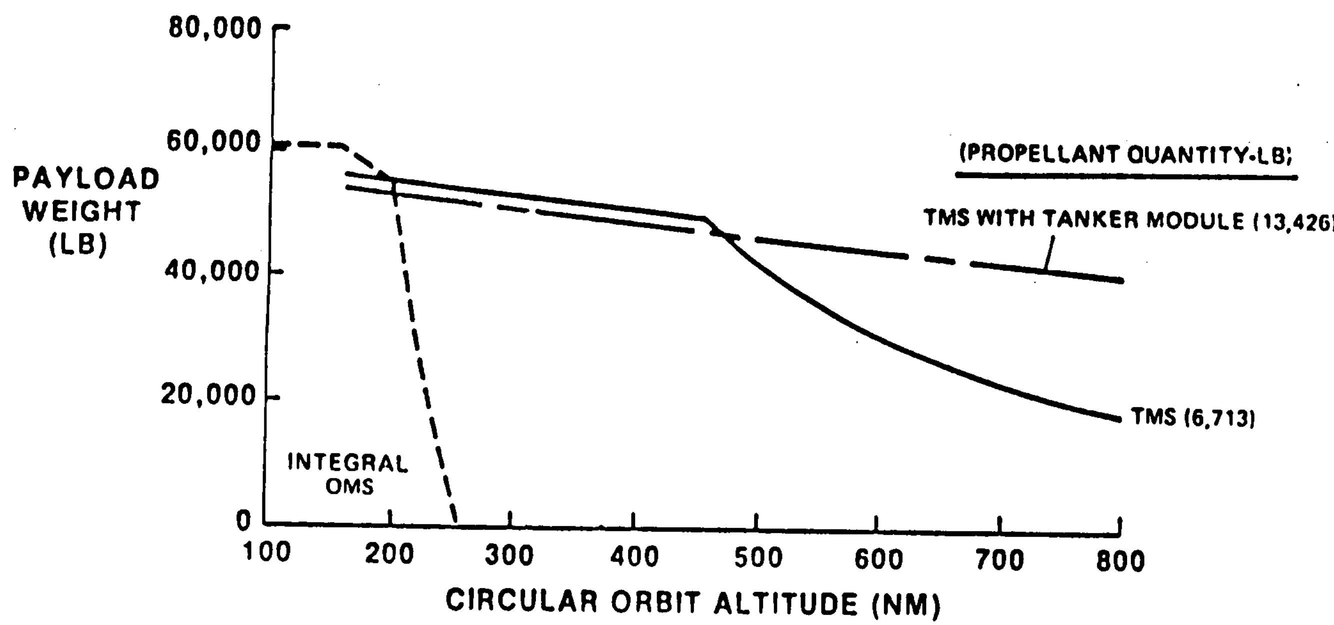
The facing page shows the Orbiter delivery capability increase which is possible utilizing a stretched version of the TMS capable of carrying 6,713 lb. of bipropellant (N_2O_4/MMH).

Some interest has been expressed in a vehicle in this size class. This system is approximately four inches longer than the baseline system.

Also shown is the performance capability of a configuration consisting of a TMS plus a second set of tanks (13,426 lb. propellant).

TYPICAL TMS PERFORMANCE ENHANCEMENT OF STS

- NEAR-TERM PERFORMANCE ORBITER
- 6713 LB BIPROP/10,401 LB IGNITION WEIGHT TMS
- TMS STAGED FROM 160 NM
- STS FROM ETR TO 28.5° INCLINATION WITH STD MECO (ET IN INDIAN OCEAN)



RATIONALE FOR A TELEOPERATOR MANEUVERING SYSTEM

The chart presents a rationale for adding a Teleoperator Maneuvering System (TMS) to the STS. The Orbiter carries its largest payload to low earth orbit (LEO) in the range of 150 to 220 NM. Ascent to higher altitudes with integral OMS fuel or with OMS kits decreases the total payload delivered to orbit. Additional cost is also involved when using OMS kits. Since a majority of payloads (71%) require placement above 220 NM, the most efficient means for this placement will minimize user cost. Staging a payload from low altitude with a TMS maximizes payload brought to orbit (maximum sharing) and avoids the cost of OMS kits to reach the higher altitudes desired by a large number of payloads.

RATIONALE FOR A TELEOPERATOR MANEUVERING SYSTEM

ORBITER TRANSPORTS LARGE MASS TO LOW EARTH ORBIT

- LOW ALTITUDE (150-220 N.M.) MAXIMIZES PAYLOAD
- HIGHER ALTITUDE DECREASES PAYLOAD
- OMS KITS ARE INEFFICIENT AND INCREASE USER COST IN 220-680 N.M. ALTITUDE RANGE

FEW PAYLOADS AT LOW ALTITUDE IN 1985-1995 ERA

150 - 220 N.M.	5%
220 - 1500 N.M.	71%
1500 - GEOSYNCHRONOUS	24%

CONCLUSIONS:

- MEDIUM ALTITUDE IS INEFFICIENT USER COST DOMAIN FOR ORBITER, OR BEYOND ITS CAPABILITY
- TMS REDUCES USER COST BY ALLOWING MORE PAYLOAD SHARING AND EXPANDS CAPABILITY OF STS BEYOND SHUTTLE/OMS KITS

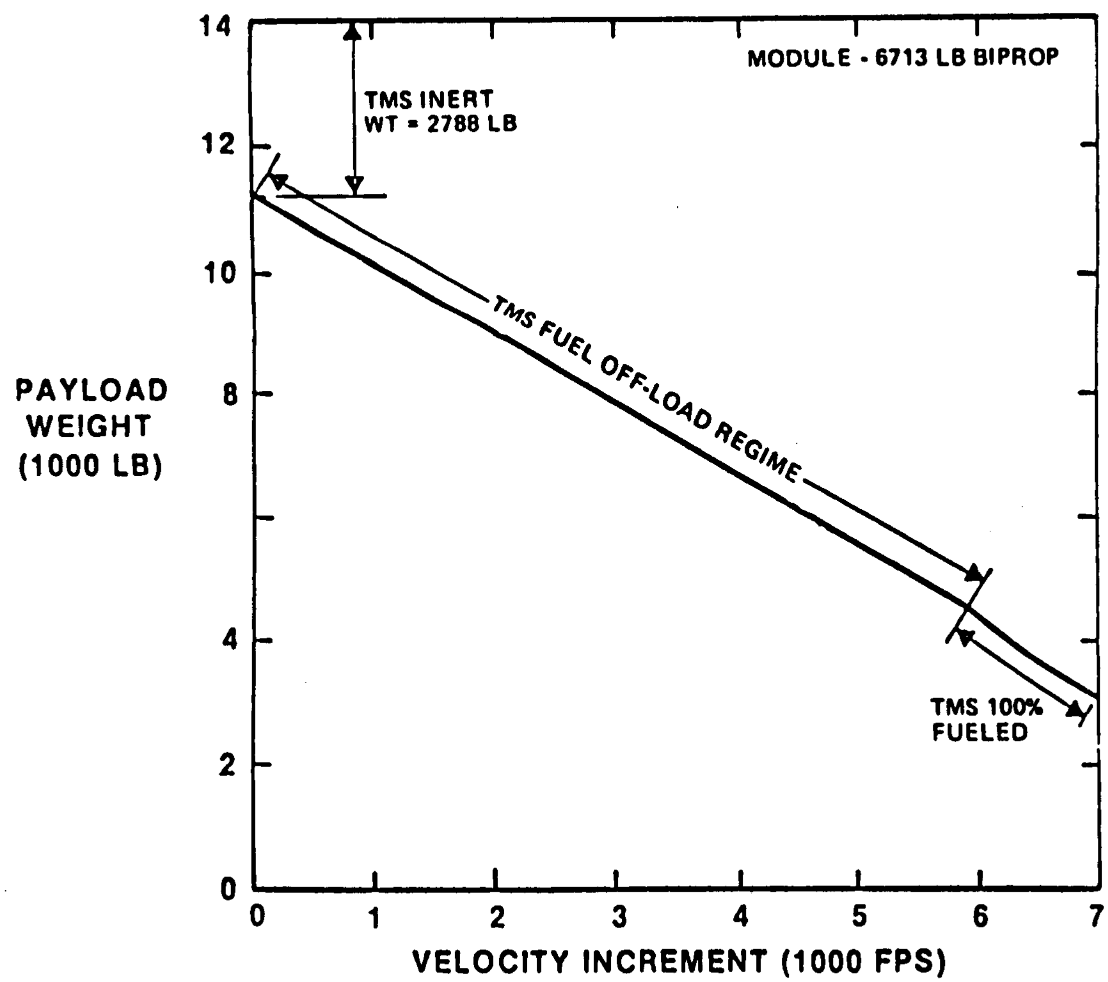
TMS MANEUVER CAPABILITY AT GEO

The facing performance chart reflects the TMS geosynchronous maneuver capability when delivered by an OTV vehicle.

Current study efforts are focusing on the feasibility of long term geosynchronous TMS storage.

In such role the TMS could become a valuable aid to servicing and assembly support to major orbiting systems and as a logistic/refueling system to fleets of GEO spacecraft.

TMS MANEUVER CAPABILITY AT GEOSTATIONARY ORBIT



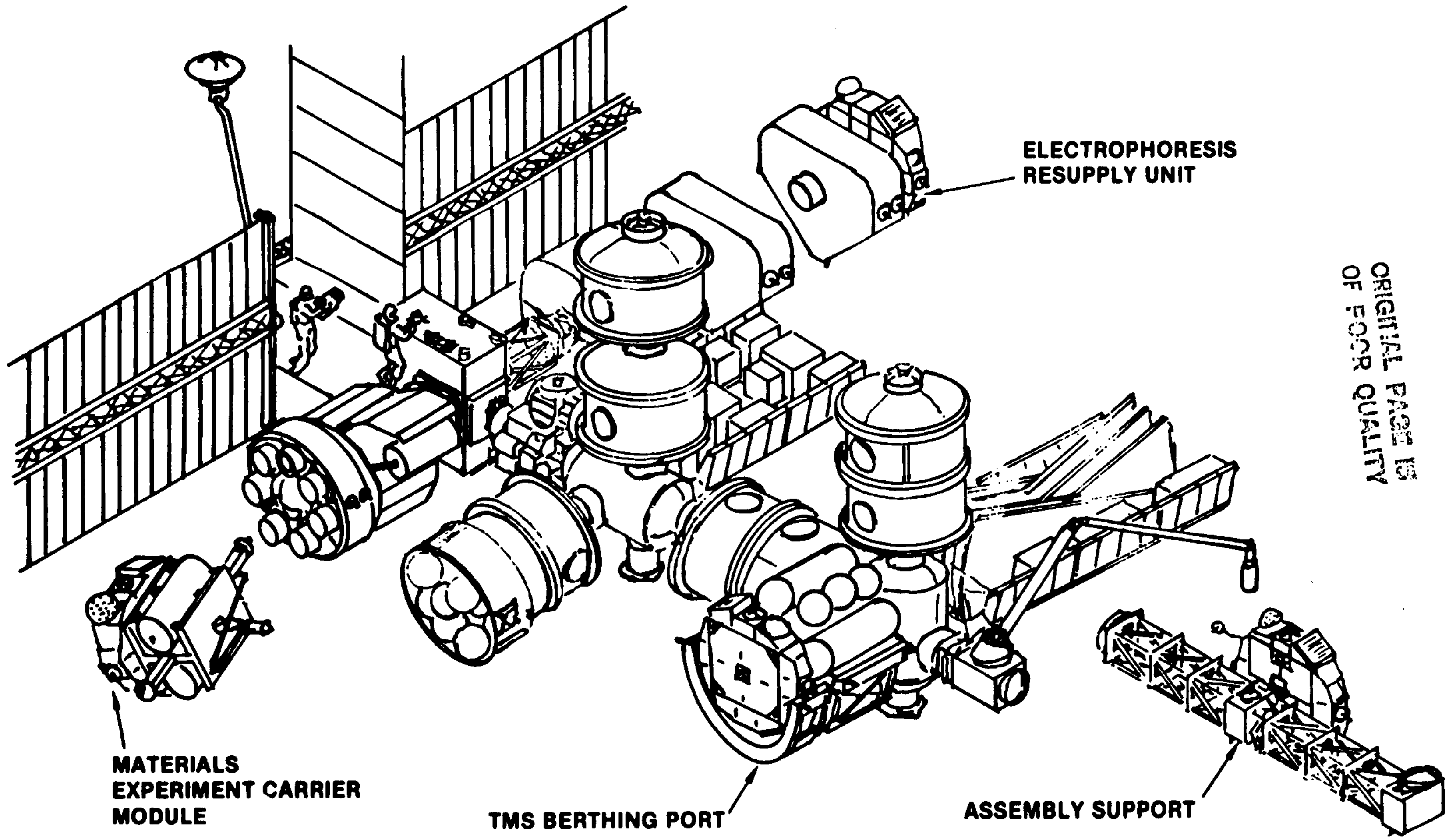
ASSEMBLY SUPPORT

An important role of the TMS is the assembly support of a space platform or space station. The TMS is shown bringing a structural module to the platform for installation by an onboard space crane or RMS. In this scenario the module was delivered by the Orbiter to a lower altitude, deployed, and subsystems verified before the TMS transports it to the platform. After handoff to the platform RMS, the TMS is available to aid the assembly and to observe and inspect overall operations.

The TMS is also shown in a servicing role by delivering electrophoresis resupply units and Materials Experiment Carrier modules. These units are transported between the platform and the Orbiter.

The TMS can be space-based at the platform as depicted at the berthing station. TMS is shown berthed in a cradle similar to the Orbiter ASE cradle, which provides dedicated communications and checkout equipment. At this location the TMS can be refueled and have the batteries charged for continuing operations. Docking at the port would be accomplished with the platform RMS. Space-basing provides a quick-response capability for exploratory inspection, debris control, and rescue contingencies.

Platform Assembly Support and Servicing



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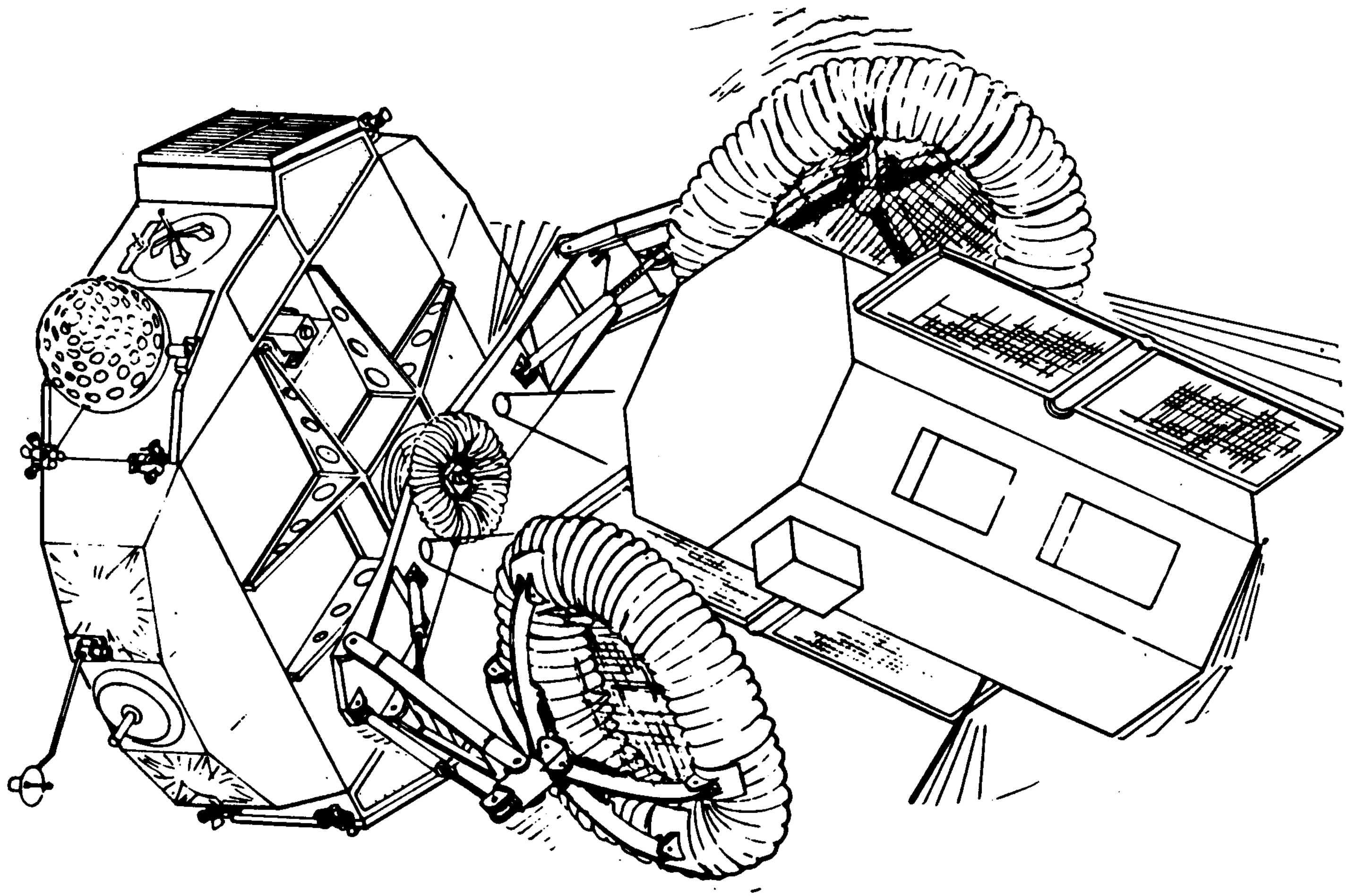
TMS DEBRIS CAPTURE

The control of space debris is becoming extremely important because the debris population is growing rapidly and personnel/equipment hazards are increasing due to expanding space operations and activity in the debris zones. The TMS offers an opportunity to control large debris through its capture and removal from space. Controlled re-entry will help ease the debris hazard by removal of spacecraft at the end of the mission.

This view shows a stabilized spacecraft captured by the TMS. The capture device, which is readily attached to the TMS as a kit, may also be used in uncooperative retrieval where the spacecraft may have uncontrolled motion. The inflatable pads would allow retrieval of the spacecraft with a minimum of structural damage. Compartmentation of the rings enhances their compliance and localizes loss of pressurization in case any compartment is punctured, as shown. This device may also be used in a rescue application.

TMS DEBRIS CAPTURE



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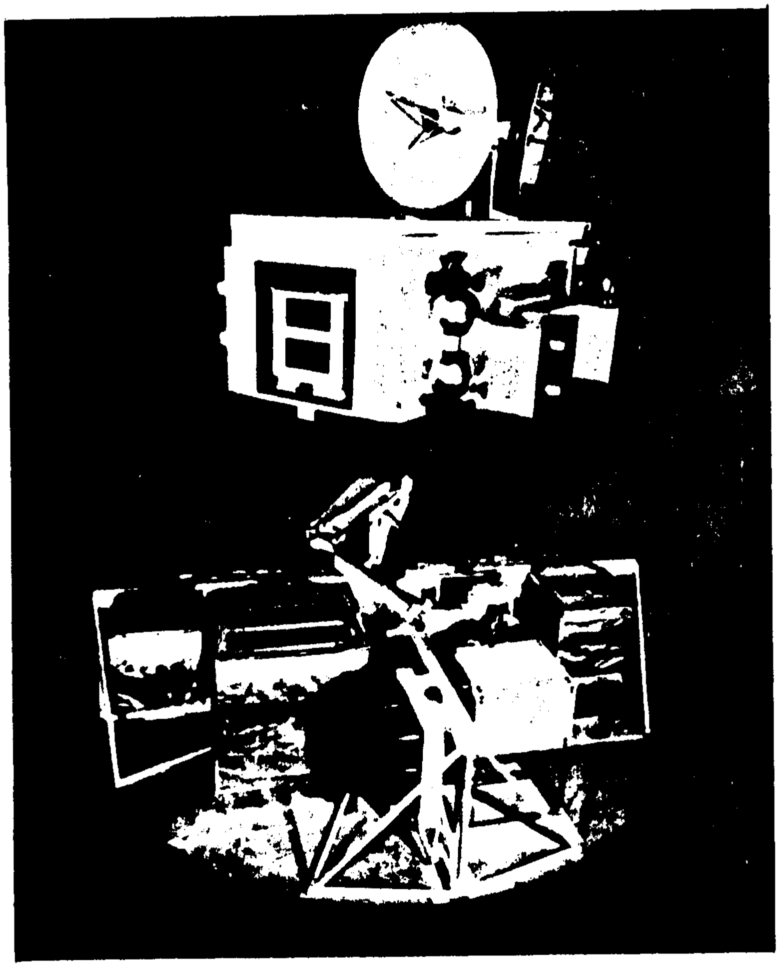
SPACECRAFT SERVICING

An engineering test unit of the Integrated Orbital Servicing System (IOSS) which is currently being tested and evaluated at MSFC is shown on the facing page.

This system is capable of removing and replacing major system modules by remote computer control. The system consists of a docking probe, spare module rack and a six degree of freedom manipulator system. In addition, a subtle part of the system is the system of spacecraft interface mechanisms which support the modules structurally and which make and break the electrical and fluid connectors of the spacecraft/module interface when powered by the servicer end effector.

This system is planned as the first major kit to the TMS. With the addition of this kit (and the assumed compatible spacecraft designs) the TMS will be capable of performing maintenance in a free-flying mode remote from the Orbiter.



SPACECRAFT SERVICER AND STORAGE RACK

AXAF SERVICING

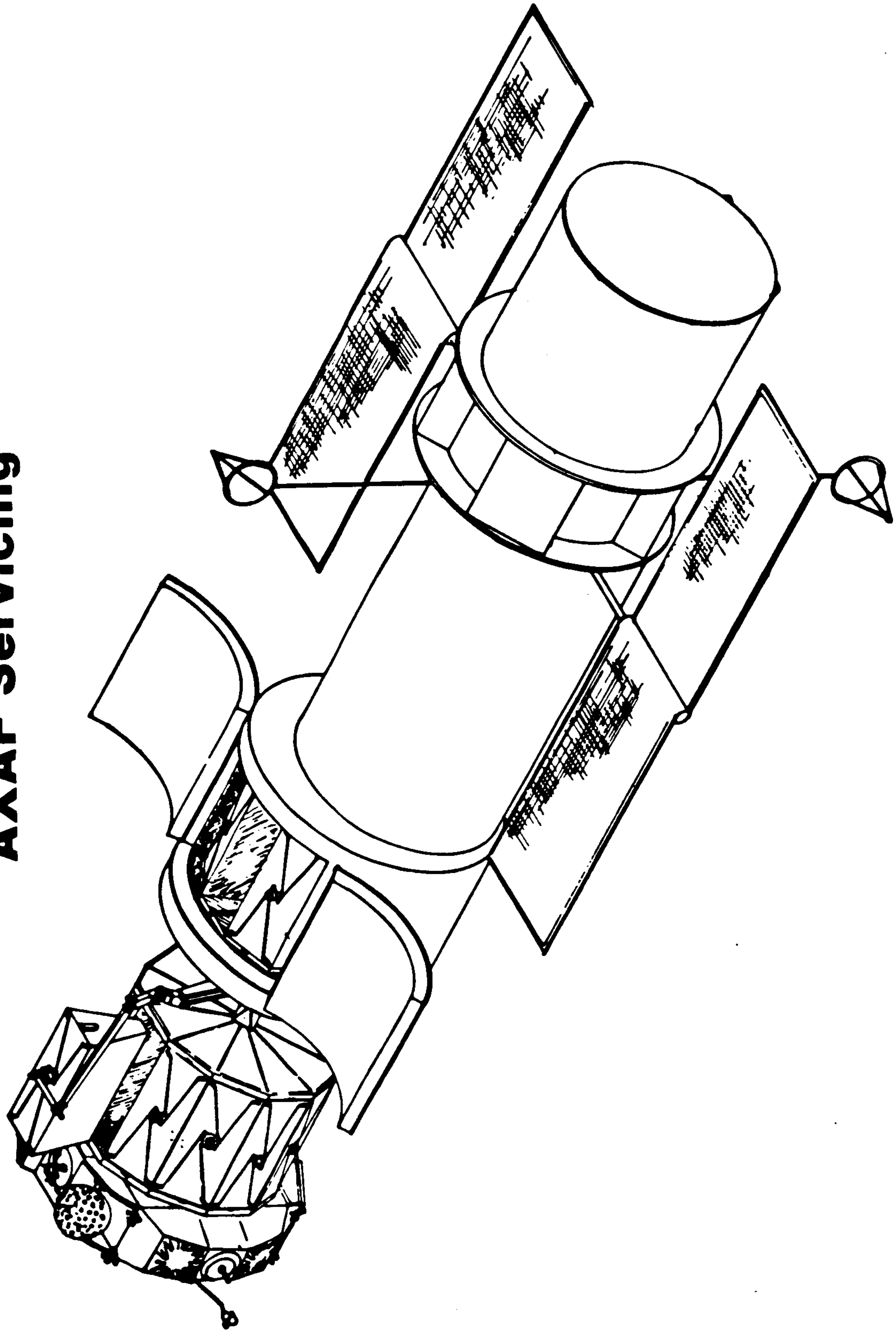
The Advanced X-Ray Astrophysics Facility (AXAF) is shown here configured for servicing. In order to achieve the primary goal for continuity of observations over a 10 year period, the capability for exchange of instruments on an "on-condition" maintenance basis is "designed in". Although presently planned for return to the Orbiter cargo bay for maintenance operations most of the instrument exchange functions could be performed by TMS.

This chart shows TMS, docked to the aft end of AXAF, equipped with an instrument storage rack and the Integrated Orbital Servicing System (IOSS). The access doors of the AXAF instrumentation compartment have been opened and IOSS has removed one of the instrumentation modules from the carousel for placement in the instrument storage rack. In this illustration the instrument modules have been altered to include a centrally operated system of latches.

It is also considered feasible for TMS to exchange support systems modules mounted between the ring frames near the forward end of the spacecraft, but this would require additional docking provisions.

A specially configured storage rack would be required to accommodate the four support system modules, each approximately 40 x 40 x 20 inches. Provisions for re-stowage of the solar arrays would also be necessary.

AXAF Servicing



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SUMMARY TMS BENEFITS

The facing chart briefly lists some rather compelling statements for the near term development of a TMS system.

In summary the TMS has the promise of vastly increasing the flexibility of the Shuttle Transportation System.

Summary of TMS Benefits

- Payload placement by TMS vastly expands shuttle capability-flexibility-utility
- Opportunities for 1985-1995 estimated at 305
- Modular TMS will evolve to broad range of mission applicability
- TMS modularity provides opportunity for near-term reboost controlled reentry kits
- Staging TMS from orbiter permits significant discretionary payload increases to 160 nmi orbits
- TMS permits economical consideration of retrieval with STS
- TMS favorably influences escalating STS user charges
- Development/recurring costs for TMS could be 1/3 cost of alternatives
- TMS payoff resides in flexibility, servicing and reusability

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