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Teleoperator Maneuvering System (TMS) Mission Applications and Benefits

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ABSTRACT

The Teleoperator Maneuvering System (TMS) is a Shuttle-launched, free-flying, remotely controlled, reusable orbital support vehicle capable of providing a wide range of placement, maneuvering, retrieval, and maintenance/repair "user" services for future satellites and for large space systems being planned for the late 80's and beyond. The TMS will greatly extend the operating range and altitudes provided by the basic Space Transportation System (STS) in low Earth orbit; similar capabilities are also provided at geosynchronous altitudes when the TMS is delivered to that location with the Centaur or alternative upper stages.

Basic TMS capabilities for both long duration and short term orbital missions, including Space Station support operations, will be described. The combined utilitarian, performance, and economic benefits offered to the user community by the TMS program will also be presented.

INTRODUCTION AND SUMMARY

Now that the Shuttle system has become operational, the benefits offered by the use of a "mini," or "harbor" tug (TMS) operating in concert with the Shuttle orbiter have become clearly evident. Studies conducted by MSFC have shown that the "sphere of influence" of the Shuttle can be substantially increased and cost of payload operations decreased with the use of a TMS. When the TMS is delivered by the Orbiter to the standard 160-nautical-mile parking orbit, the TMS can perform ΔV maneuvers to deliver and retrieve payloads up to 2,000 nautical miles. Further, for high energy missions up to and including geostationary orbit, the TMS propulsion stage will augment the Transfer Orbit Stage (TOS) recently proposed for commercial development in providing an effective low-cost second-stage system for delivering intermediate sized payloads to geosynchronous orbit (GEO). Similarly, a TMS with an attached payload delivered to GEO by a Centaur upper stage provides an effective delivery and on-orbit support capability for a larger class of payloads. Operating as an unmanned remotely controlled free-flying system, the TMS will provide a wide range of remote satellite services beyond basic placement and retrieval functions, including payload viewing, payload repositioning/phase changes, sub-satellite science support, automated satellite servicing via major module or element exchange, satellite refueling, large space structures assembly support, and logistics support to low earth orbit spacecraft or platforms. When a space station becomes a reality, the TMS will provide a wide range of "workhorse" tasks in support of the space station and its associated unmanned free-flying platforms/payloads, as described later.

The TMS will be developed in a modular way which permits adding "mission kit" capabilities as they are needed; or, conversely, readily removing them when not needed for a specific mission. Early TMS missions will involve payload placement, retrieval, viewing, or the use of the TMS propulsion module for spacecraft maneuvering or upper stage performance augmentation. Later missions will involve servicing operations, and the possible capture, controlled re-entry, or reboost of space debris/malfunctioning satellites. Mission kits, including radar, television systems, docking devices, and specialized manipulator arms will all eventually become part of the TMS inventory.

MSFC is investigating a number of mission and configuration needs essential to TMS program success, and is ready to proceed with specifications and procurement actions for definition and development activities leading to TMS availability in the 1987-88 time period.

TMS PROGRAM SCOPE AND OBJECTIVES

Operating out of the shuttle cargo bay, from a space station, or on top of an upper stage like Centaur, the TMS is being configured to perform a wide range of remote satellite service missions. As outlined in Figure 1, the TMS will enhance and complement the orbiter's capability in many areas. If development authority is obtained in FY 85, the TMS could bring to the Space Transportation System (STS) program a remotely controlled satellite placement and retrieval capability in the 1987-88 time period. The initial TMS delivered to orbit by the Shuttle will permit placement and retrieval of satellites in orbits that are beyond the Shuttle's reach. It will also provide a capability to perform as a maneuvering sub-satellite in orbits remote from the Shuttle, and will be able to view payloads with its TV cameras to assess their status or detect potential problems in the case of equipment/appendage malfunctions. The early TMS propulsion module will also provide many direct uses to attached payloads, or in conjunction with a Transfer Orbit Stage (TOS) or Centaur Upper Stage, may provide mission orbit applications out to and including geostationary orbits.

As shown in Figure 2, the TMS will be a remotely operated, reuseable vehicle, with man-in-the-loop control from several possible control station location alternatives. Although initial basic control is assumed to be from a ground control station, some degree of control may also be provided from the orbiter aft flight deck if needed for mission support reasons. If a space station program becomes a reality, the TMS may very well become a space-based mini-tug, operating in and out of the Space Station, and controlled by the Space Station crew.

As the TMS mission requirements expand in the late 80's to early 90's, the basic system will be augmented by add-on mission kits to support more advanced capability needs associated with satellite maintenance and repair, space station operations/logistics support, remote satellite refueling operations, retrieval of unstabilized satellites, large structure assembly support and orbital debris management. The entire spectrum of TMS mission applications envisioned for the 1987-1990's period is summarized in Figure 3. Operating directly out of the Shuttle, TMS provides payload delivery or retrieval out to 2,000 nautical miles, with plane changes up to 10°. Logistics resupply operations between the space station and the Shuttle are also planned. For providing long-duration on-orbit support to payloads, the TMS will be equipped with solar array power kits necessary to support mission needs. TMS interfaces will be made compatible for use with the TOS or Centaur upper stage systems, for support to high energy orbit missions. In such missions, the TMS can operate as a propulsion module, remaining attached to the spacecraft, or it can separate to operate as an independent free-flyer to support multiple mission objectives. Every effort will be made to structure the TMS program in a modular way to accommodate the diverse range of mission needs in a cost effective manner.

TMS MISSION APPLICATIONS AND BENEFITS

The fundamental classes of design reference missions the TMS will be required to perform are pictured in Figure 4. Use of the TMS with TOS provides a low-cost two-stage vehicle capability for attached payloads in the 4,000 to 5,000 lb range. The Centaur will deliver larger class payloads (TMS and spacecraft weights up to 13,700 lb) for more demanding missions at geostationary orbit. A TMS tanker system is planned as a future mission kit to serve two primary functions: It can serve as a supply source from which to remotely refuel the propellants and gases on future spacecraft and can also be used as an added source of propellants to augment the basic TMS performance capabilities.

The performance capabilities provided by a TMS with tanker, using bi-propellants, are shown in Figure 5. Typically, when the Shuttle is launched at 57°, this TMS system can deliver a 20,000 lb payload to an altitude of 960 nautical miles and give it a 4° plane change, then return to the orbiter for retrieval and reuse. In a similar mission profile, a 1,000 lb spacecraft can be placed at altitudes over 2,000 miles, with a 4° plane change. The basic theme of STS performance augmentation for payload placement or retrieval is also conveyed in Figure 5. By flying the orbiter to 160 nautical miles and letting the TMS perform the payload delivery/retrieval operations at altitudes beyond the Shuttle efficient operating range, the maximum benefits for use of the combined system are achieved. Much more cargo can be delivered to the LEO position, thereby permitting the manifesting of more payloads or cargo on each Shuttle flight. This manifesting benefit offered by the use of TMS is more clearly conveyed on Figure 6. For example, at the Eastern Test Range (ETR), it would take a dedicated Shuttle launch to deliver a 20,000 lb payload to an altitude of 300 to 400 nautical miles (reference dotted lines). The user/payload developer would then have the full user charge costs for a dedicated Shuttle flight. However, if a TMS were used, the story would be much different. A typical TMS, weighing around 10,700 lb fully fueled, could deliver the 20,000 lb payload from the 160 nautical miles Shuttle parking orbit, to 750 nautical miles, and then return to the orbiter for reuse (reference solid line – TMS performance). Taking away the weight of the TMS, the orbiter could deliver an additional 34,000 lb to the lower altitude. This approach maximizes use of the orbiter's delivery capability (65,000 lb) to the lower altitude, and would permit sharing of the Shuttle launch cost between the 20,000 lb payload developer, and the other payload(s) using the remaining cargo space/payload (34,000 lb) left over. Nominal use fees for the TMS on any given mission will be small compared with the user savings realized by this new mode of operation.

A similar analogy/case is also shown for the Western Test Range (WTR) on Figure 6. In this case, the STS performance drops off rapidly at altitudes above the 250 to 350 nautical mile range, depending upon insertion technique used. The TMS performance greatly extends the altitude range and delivery capabilities at WTR. Another way to demonstrate the benefits of TMS utilization is described in Figure 7. For a typical payload 27,000 lb requiring delivery to 320 nautical miles, a dedicated orbiter launch is required to perform this mission, and in doing so, also incurs the cost of consuming 22,000 lb of maneuvering propellant. Doing the same job with a TMS consumes only 2,570 lb of propellant, and permits the possible use of up to 29,700 lb of additional discretionary payload made available by flying the orbiter only to the lower altitude. This discretionary benefit, of course, may not be completely available on any one given flight, if the cargo bay volume is not available to permit taking advantage of the added payload delivery capability. This is a function of co-manifested payload volume/length requirements in the bay, and must be assessed on a flight-by-flight basis. At any rate, the benefits offered by the TMS, both in STS performance enhancement and in providing payload manifesting alternatives resulting in lower user launch costs, are clearly evident.

A typical TMS timeline for a routine retrieval mission is shown in Figure 8. Allowing for the maximum possible required phasing times at orbiter altitude (up to 7 to 8 hours), the total mission can be accomplished in about 17 hours. By turning much of the control of the mission sequence over to the TMS onboard control computer supported by a ground control station, the orbiter crew can then be freed to handle other mission assignments. A typical TMS control station, with man-in-the-loop hand controllers, is shown in Figure 9. This is the actual hardware once developed by MSFC to control the Teleoperator Retrieval System (TRS) for reboosting the Skylab. (As the reader may recall, the TRS development program was terminated in December 1978 when it became known that the Skylab would re-enter sooner than predicted, and prior to Shuttle-TRS availability.) The period of time since then has permitted MSFC to reassess a broader range of future mission requirements, and to structure a more capable and optimized TMS design concept to meet the Agency needs of the future. The control station design for TMS will take advantage of the lessons learned from the TRS development efforts; a number of ground-based and space-based (STS or space station) control station concepts are being defined and evaluated.

Opportunities for TMS use in support of large observatory programs are being considered in current and planned MSFC contractor and in-house studies. Figure 10 displays a typical mission profile for the TMS support to an Advanced X-Ray Astronomy Facility (AXAF) servicing mission. As shown, TMS flies from the orbiter standard altitude (160 nautical miles), retrieves AXAF at 205 nautical miles (the predicted decay altitude AXAF will have obtained after three years on orbit), and brings it back to the orbiter for repair and servicing. After servicing is completed, the TMS then reboosts the AXAF back to an operational altitude of 320 nautical miles, and then returns to the orbiter for retrieval/reuse on a subsequent mission. The benefits of using the STS-TMS combination for this mission instead of the orbiter by itself are shown in Figure 11. Over a 12-year period, six Shuttle launches are involved to support the program if TMS is used. Ten Shuttle launches are required to do the same job without TMS. The reason is that the Shuttle cannot reboost the AXAF as high on each revisit mission for servicing (i.e., it reboosts AXAF from an estimated 205 nautical miles to 260 nautical miles). The orbit decay rate is higher at these lower altitudes, and more frequent STS launches for reboost would therefore be required. Use of the TMS saves this program the equivalent of four dedicated STS launches over the 12-year period, resulting in a substantial operations benefit and cost savings to the project. Similar savings/benefits are being evaluated for a number of programs considered as candidates for TMS support.

Another type of TMS service mission is demonstrated in Figure 12. Delivered by a Centaur to geostationary orbit, the TMS can be configured to interface with a satellite or large geostationary platform (GSP) to provide services involving propellants/gases resupply, battery changeout, and, perhaps automated exchange of a payload/subsystem module. Servicing techniques and prototype systems to demonstrate the technology of automated servicing have been under study at MSFC for a number of years; future efforts will be directed toward ground and orbital flight experiments to demonstrate the technology to candidate users, and to establish a standardized and simplified interface approach between the TMS and future spacecraft that will permit the utilization of remote servicing capabilities now in hand with minimum impact to the payload developer. More advanced TMS capabilities anticipated for the future are shown in Figure 13. Advanced viewing capabilities, including the use of stereo video, may eventually be needed. Long duration mission capabilities with support to attached payloads (i.e., materials processing) may dictate the sizing of a TMS solar array power kit to sustain the mission. Servicing of cryogens or the exchange of cryogenic devices on scientific payloads is anticipated as a TMS mission capability to be needed downstream. Problems inherent with space debris and derelict/tumbling/out-of-control satellites have been with us for some time. A TMS mission requirement for "space debris" capture could occur at a moment's notice, and most likely will be a capability needed in the future to cover unpredictable situations, including the retrieval of a high value malfunctioning satellite for repair and reuse, or the reboost of a space derelict into a higher orbit where it will not be a hazard to other satellites/space systems. Another TMS mission capability option for space debris retrieval is to place the debris on a controlled reentry trajectory into a safe area for deep water impact, as shown in Figure 14. In such mission profiles, the reuseable TMS separates from the object being de-orbited at around 100 nautical miles for "pullout" and return to the orbiter for retrieval. The TMS guidance and control system provides the reentry trajectory accuracy needed to assure a controlled and predictable reentry corridor and limited impact dispersion footprint in the selected deep-water ocean disposal area.

Once a space station program comes into being, the TMS will perform a number of "work-horse" or harbor tug functions in support of the space station's operational mission, as depicted in Figure 15. Included are payload support functions and space-station/Shuttle logistics resupply support. The implications of a space-based TMS operating from a permanently manned space station will be discussed further later in this paper.

TYPICAL TMS CONCEPTS

MSFC has investigated a wide range of TMS configurations to support the mission/user needs identified for the program, some of which are shown in Figure 16. Both monopropellant and bi-propellant configurations are being evaluated; new designs, and concepts which can be evolved from existing hardware programs are being considered. Propulsion systems being defined in study programs external to the MSFC TMS study are also being considered for possible application to TMS. MSFC is currently deriving a baseline design concept from this on-going activity and preparing a comprehensive set of mission and system performance specifications and operations requirements applicable to an emerging Request for Proposal (RFP) for preliminary design (Phase B) efforts proposed for FY 84.

Most TMS concepts are being configured to take full advantage of the orbiter cargo bay diameter. Such a configuration is highly desirable, since many of the payloads in the NASA mission model are length-sensitive; i.e., their STS transportation charges/user fees are determined by their length as opposed to weight. Considering the wide range (combinations of payloads with which the TMS may be paired), this short disk-type configuration should tend to minimize transportation costs. This minimum-length approach also is more applicable to the TMS use with upper stages. On the other hand, should the TMS become used in a space-based mode, and be refueled on orbit, these STS charge-policy-related length considerations become less significant. These and other factors are being assessed in current MSFC-Rockwell International/TMS Benefit studies to help guide future TMS design criteria determinations. A representative TMS concept defined by the Vought Corporation for MSFC is shown in Figure 17. Both mono-propellant (N_2H_4) and bi-propellant (N_2O_4/MMH) alternatives have been studied by Vought.

In operation the TMS can fly a preprogrammed trajectory with the use of its onboard computer, and can be manually controlled or reprogrammed from the control station on the ground. (Control options also exist from the orbiter or a future space station.) The TMS communications system can transmit or receive status data, commands, and video signals between the TMS and control station either directly or via the Spaceflight Tracking and Data Network (STDN) or Tracking Data Relay Satellite System (TDRSS) networks. The TMS is equipped with a payload illumination and TV viewing system which will be used for spacecraft viewing and as a vital element of the rendezvous and docking system. It consists of a payload illumination light and a dual TV camera system. One camera is rigidly mounted and equipped with a fixed lens; the other one has a zoom lens and pan-tilt capability to provide scene information for remote payload observations/viewing. The viewing system may be used in conjunction with a range/range rate radar sensor (requirements – TBD) and a docking mechanism for interfacing with payloads. Power is provided by both primary and secondary batteries; for long duration missions, a solar array power kit will be added. Other significant features are called out on the figure.

TMS configurations with propellant capacities ranging from 3,000 lb to 14,000 lb are being considered in MSFC's current trade study assessments. Figures 18 and 19 represent candidate concepts defined by Martin Marietta for MSFC. These concepts reflect a heritage from the Mark II propulsion system; and, as with the Vought concepts, incorporate tried and proven technologies/subsystems developed and demonstrated in other programs. Figure 20 represents another configuration recently defined by Vought to provide a high degree of modularity in the basic design, down to and including the capability to use the TMS tankage system to supplement the orbiters Orbital Maneuvering System (OMS). (This use of the TMS tankage to serve as an OMS kit for the orbiter is only conceptual at this time, since no decision has been made to implement OMS kits for the orbiter to augment its performance.) As shown, Figure 20 represents the largest bi-propellant configuration evaluated to date (6,700 lb propellant); this configuration, with an add-on tanker kit of an additional 6,700 lb propellant offers a substantial performance capability to meet future growth mission needs. Ultimate TMS "sizing" decisions will be based on a thorough review of future mission needs now being reassessed at MSFC.

PERFORMANCE SYNOPSIS

Representative performance curves for a mono-propellant TMS (5,000 propellant), a bi-propellant configuration (6,700 lb propellant), and a bi-propellant configuration with tanker module attached are shown in Figure 21. These curves represent the TMS ability to place or deliver payloads to an altitude above the orbiter, and then return itself to the orbiter for retrieval and reuse. Typical NASA payloads are plotted for reference purposes, showing that the TMS could perform all the payload delivery missions on a "one at a time" basis. However, this criteria alone cannot necessarily be used to size the TMS. Future growth mission needs, the implications of combining multiple missions on a single TMS flight, and the implications of space basing/refueling of a TMS on orbit will have to be considered in arriving at an optimum solution. Plane-change requirements imposed on top of a payload delivery mission are extremely demanding on TMS performance. TMS capabilities offered for a range of altitudes and plane changes are shown in Figure 22 for a nominal bi-propellant TMS and a growth version with tanker set. User requirements for payload delivery altitudes and plane changes beyond the standard orbiter mission profiles are being assessed to establish the TMS "design reference mission" driving requirements in this area.

SPACE BASING IMPLICATIONS

The TMS can play an important role in support of the initial assembly/buildup of a low earth orbit space station. During this buildup phase, the TMS could be permanently based at the space station berthed in a cradle, or support fixture similar to the orbiter cargo bay interface, provided to the TMS. At this location, the TMS could be refueled and have its batteries charged for continuing operations. Berthing of the TMS at the space station could be supported by a station-based manipulator similar to the Shuttle's RMS. Space-basing the TMS at the station could provide a quick response capability for exploratory inspection, debris control, and contingency missions. The wide range of TMS potential mission capabilities in the space station era are summarized in Figure 23. Multiple logistics support functions between the space station and Space Shuttle are anticipated. TMS service support missions between the space station and co-orbiting unmanned platforms are currently projected. If future OTV's become operational in a space-based mode out of the space station, TMS support could be needed during the OTV retrieval operation, bringing it back into a berthed/ hangar location for maintenance, refueling, and checkout.

The control from the space station can be accomplished with an avionics system as schematically shown in Figure 24. A hardwire link would provide the communications link whenever TMS docks at the station. This link could also provide the means of testing and verifying the TMS subsystems and further be used for launch control of the TMS. An RF link would be required to communicate command information from the space station to TMS, and for the TMS to transmit telemetry and video to the space station. It is currently estimated that this link can utilize S-Band frequencies, with telemetry data rates as high as 8 KBPS and compressed video data rates of 346 KBPS.

The areas where TMS and spacestation interfaces must be compatible are shown in Figure 25. These interfaces would permit the space station personnel to perform the functions of checkout, launch, control, monitoring, rendezvous/ docking the TMS, and TMS-related maintenance. TMS-related requirements to provide space-station-based operations are summarized in Figure 26; space station requirements are outlined in Figure 27. These emerging requirements will be further quantified as a result of on-going and planned TMS-space station basing studies.

Major trade-off studies will be required yet to determine the best approach to "storing/maintaining" the TMS at the space station, i.e., "shirt sleeve" versus EVA on-orbit maintenance. A typical "hangaring" concept for servicing and maintaining a TMS is shown in Figure 28. This approach also shows initial docking of a TMS to a deployable mast, thus minimizing any potential hazard which may be inherent in TMS maneuvering in the proximity of the space station. Although an approach for handling a "fleet" of differently configured TMS vehicles is shown, use of a single TMS with multiple end effectors/mission kits which can be changed out on orbit at the space station to support the wide range of TMS mission applications will probably be a more cost-effective way to proceed in the early years of space station operations. As shown in Figure 28, the TMS's are berthed in cradles around the perimeter of the RMS reach envelope. The cradles are mounted on a large area base platform for EVA storage of the TMS vehicles, but the TMS can also be placed by the RMS into a pressurized hangar or enclosure for extensive servicing/mods. Detailed trade-offs of these and other arrangements must be made by space station designers to determine the optimum arrangement.

PROGRAM EVOLUTION AND DEVELOPMENT MILESTONES

A cursory review of future payload mission models, as summarized on Figure 29, reveals a large number of mission opportunities possible for a TMS vehicle. These are certainly not commitments or requirements at this time, but a clear indication of the potential utility of a TMS vehicle once it becomes available to the STS inventory. Efforts are underway to update this opportunity model based on current user plans; needs and requirements for a space-station-based TMS must also be better understood and reflected in future TMS project plans.

Based on mission model requirements known to date, the TMS program uses may evolve as shown in Figure 30. Early missions will involve payload placement, viewing, and propulsion module operations (possibly in conjunction with a Centaur Upper Stage and attached payload). By the 1988-1990 period, payload retrieval missions, along with missions using a TMS in a space-based mode (refueled by the Orbiter), may emerge. By 1990 and beyond, more advanced TMS capabilities for remote servicing, satellite refueling, space debris retrieval, and space station operations support will be needed. The TMS will evolve in a modular way to meet these needs; a typical range of configuration alternatives which match the scenario outlined in Figure 30 are shown in Figure 31. Although TMS is not now an approved program, a project schedule compatible with providing a nominal TMS capability in the late 1987-88 time period is shown in Figure 32. To meet these availability dates would require completion of Phase B preliminary design efforts in FY 84, and an authorization to proceed with hardware development in FY 85.

CONCLUDING REMARKS

As summarized in Figure 33, the TMS program offers a wide range of services that are projected to be needed in the late 80's. If authorization to proceed is received for a development go-ahead in FY 85, a nominal TMS capability can be made available in the time frame compatible with these future mission needs.

TELEOPERATOR MANEUVERING SYSTEM (TMS)

- TMS IS A REMOTELY CONTROLLED, FREE-FLYING, ORBITAL MINI-TUG VEHICLE CAPABLE OF PERFORMING A WIDE RANGE OF REMOTE SATELLITE SERVICES MISSIONS

- TMS ENHANCES THE ORBITER'S CAPABILITY & EFFICIENCY:
  - DELIVERY TO OR RETRIEVAL OF PAYLOADS FROM HIGH ALTITUDE ORBITS
  - MANEUVERING OR REPOSITIONING (PLANE CHANGE) OF P/L'S
  - SUPPORTS P/L'S FOR LONG DURATION ORBITAL STORAGE MISSIONS
  - REMOTE P/L VIEWING (TV), REFUELING; SERVICING; SPACE STATION SUPPORT
  - PERMITS EFFICIENT CO-MANIFESTING OF P/L'S ASSIGNED TO DIFFERENT ALTITUDES (MAXIMIZES USE OF STS CARGO DELIVERY CAPABILITY TO LEO)

FIGURE 1

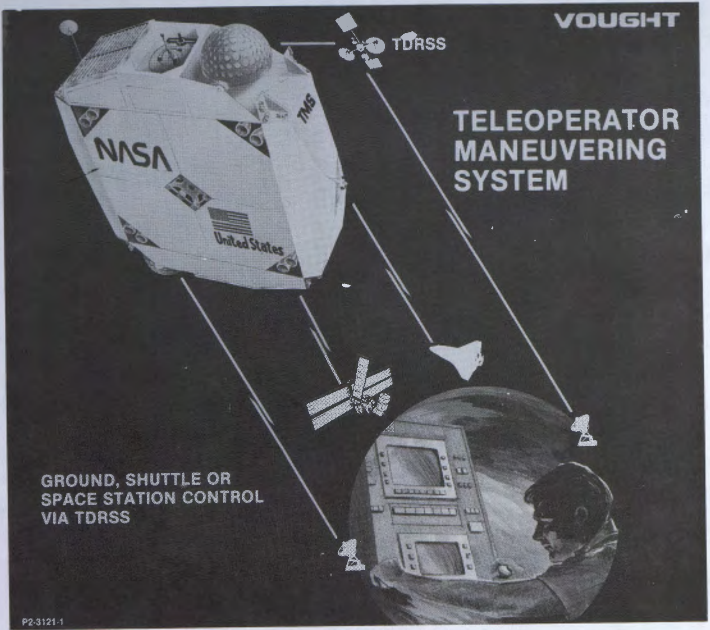

VOUGHT
TDRSS
TELEOPERATOR
MANEUVERING
SYSTEM
NASA
TMS
United States
GROUND, SHUTTLE OR
SPACE STATION CONTROL
VIA TDRSS
P2-3121-1

FIGURE 2

TMS Applications Overview

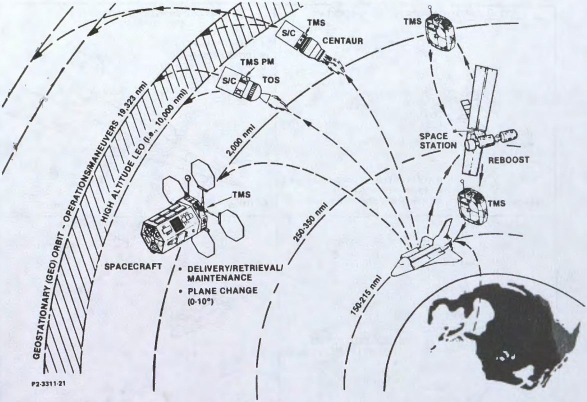


FIGURE 3

Typical Teleoperator Maneuvering System (TMS) Uses

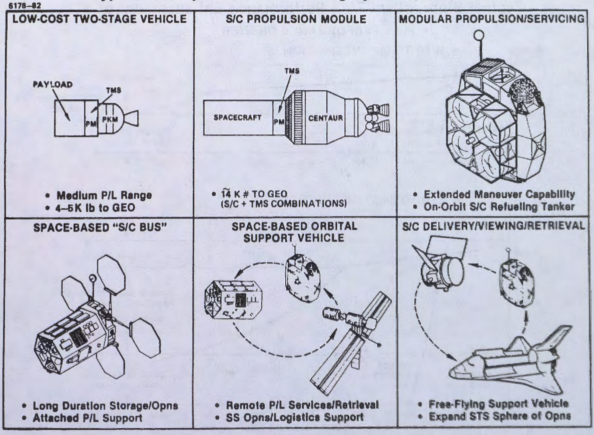


FIGURE 4

TELEOPERATOR MANEUVERING SYSTEM (TMS) APPLICATIONS

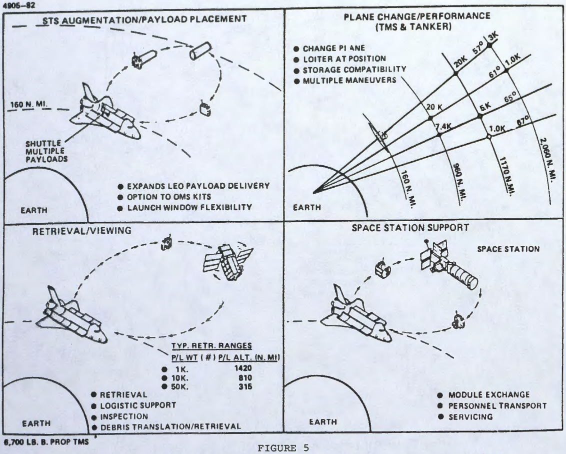


FIGURE 5

Typical Bipropellant TMS Performance Enhancement of STS

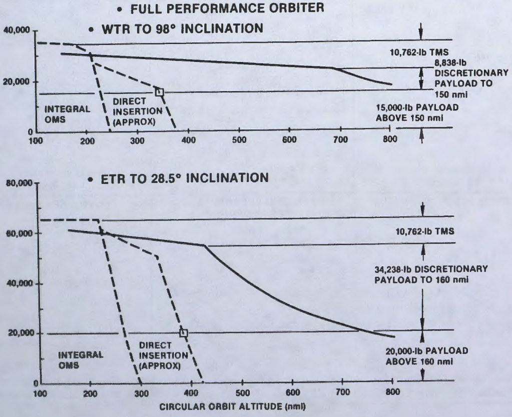


FIGURE 6

ECONOMICS OF SATELLITE PLACEMENT

EXAMPLE: 27,000 LB PAYLOAD TO 320 NM

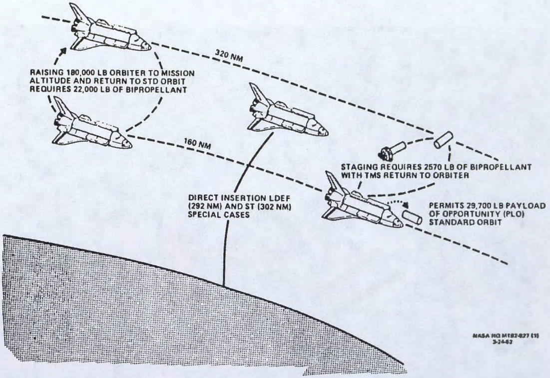
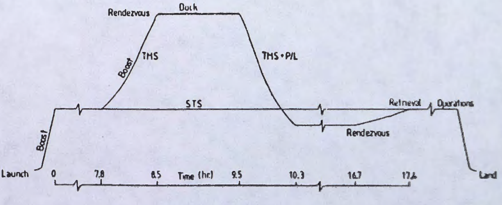


FIGURE 7



- o SHUTTLE DELIVERS TMS TO 160 NM
- o TMS DOCKING WITH P/L - 1 HOUR
- o TMS + P/L RETURN VIA PHASING ORBIT (100 NM)

FIG. 8 TYPICAL TMS RETRIEVAL PROFILE

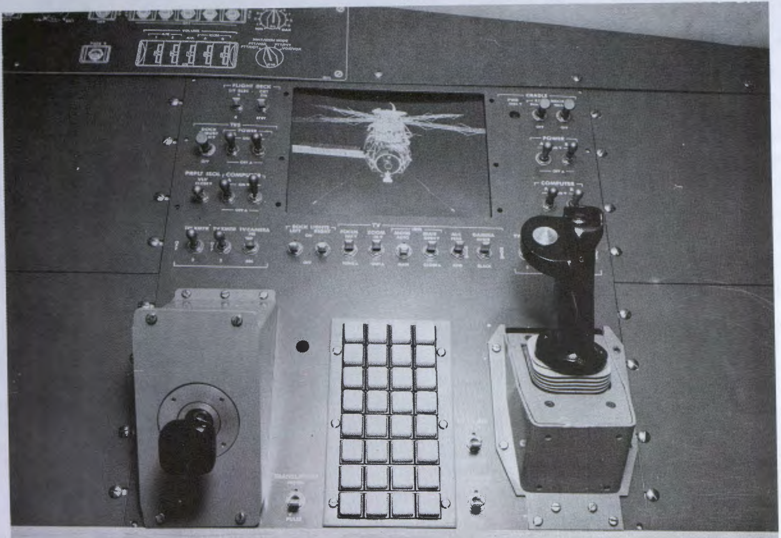


FIGURE 9

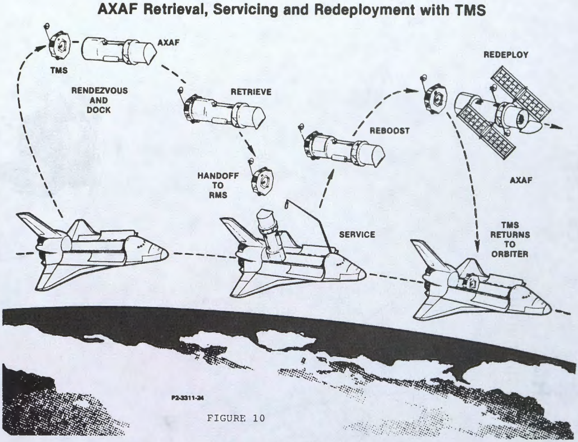


FIGURE 10

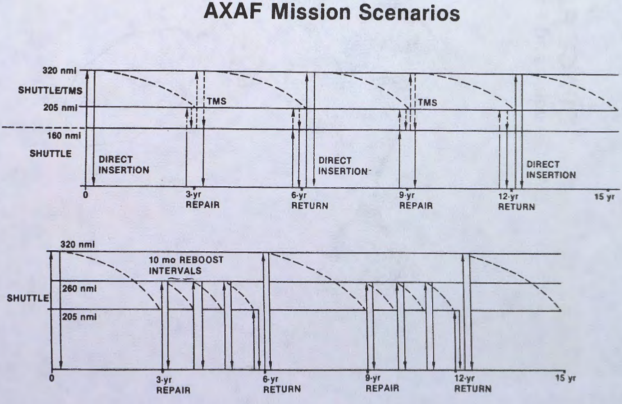


FIGURE 11

VOUGHT

SPACE PLATFORM
TMS Servicing and Refueling Configuration

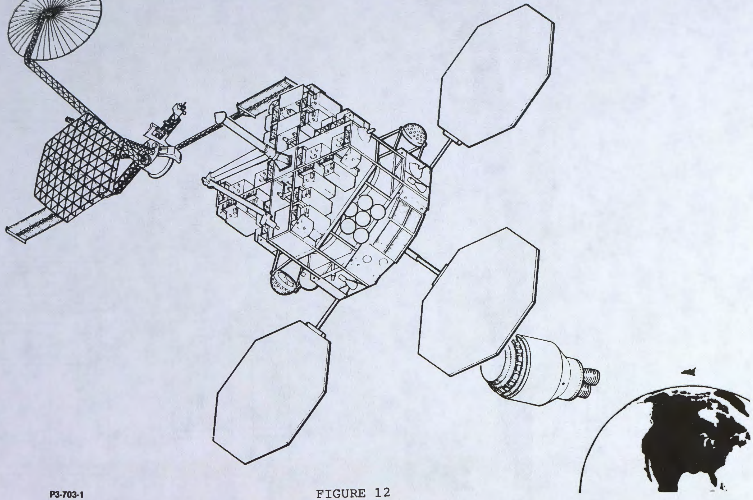


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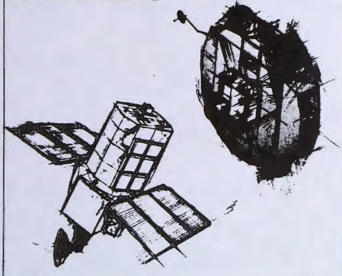
FIGURE 12

TMS SERVICES

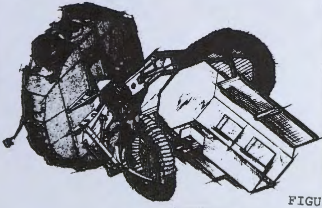
VOUGHT

SATELLITE VIEWING



MATERIAL PROCESSING SUBSATELLITE

DEBRIS CAPTURE



CRYOGEN SERVICING

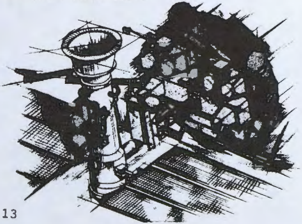
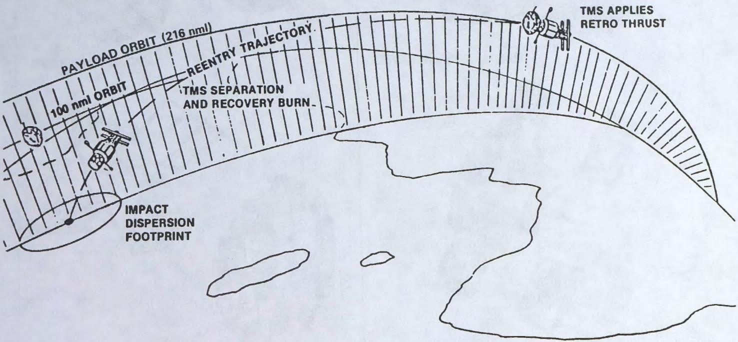


FIGURE 13

0567–83



TYPICAL TMS MISSION PROFILE (P/L CONTROLLED REENTRY)

FIGURE 14

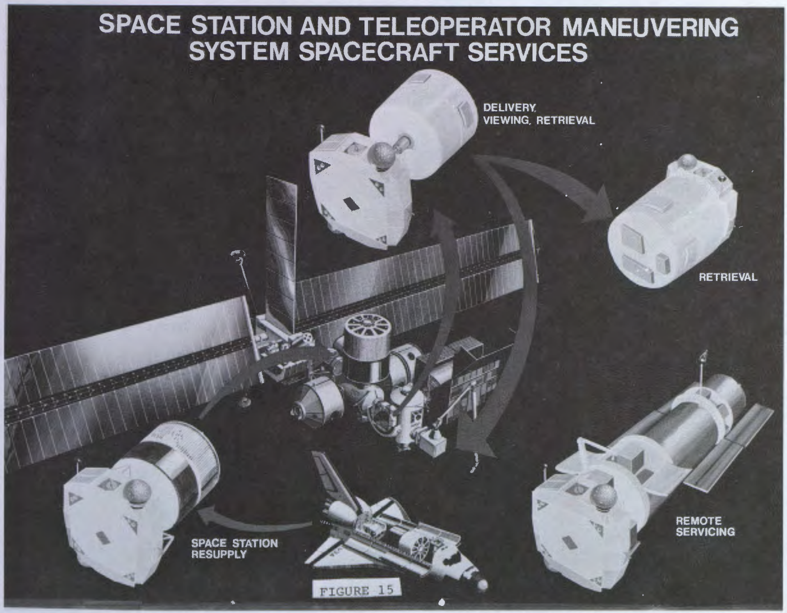
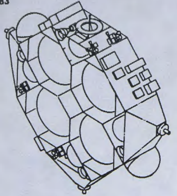

SPACE STATION AND TELEOPERATOR MANEUVERING SYSTEM SPACECRAFT SERVICES
DELIVERY, VIEWING, RETRIEVAL
RETRIEVAL
REMOTE SERVICING
SPACE STATION RESUPPLY

FIGURE 15

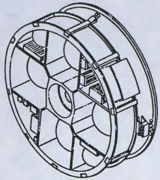
TMS CONCEPTS

0441–83



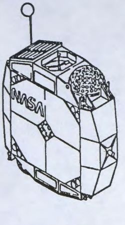
- LENGTH 37"
- PROP 6,700 N_2H_4/MMH
- INERT 3,011 LBS.

MSFC DESIGN REF. CONCEPT



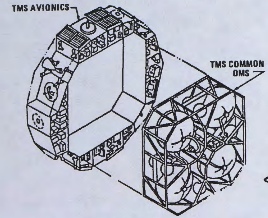
- LENGTH 40"
- PROP 3,800 (LBS) N_2O_4/MMH
- INERT WT. 1600

GEN. DYNAMICS (SMM)
SPACECRAFT MANEUVER MODULE



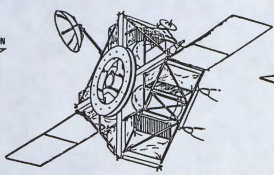
- LENGTH 37 IN.
- PROP 5,000 LBS N_2H_4
- INERT WT. 2,545 (LBS)

VOUGHT BASELINE



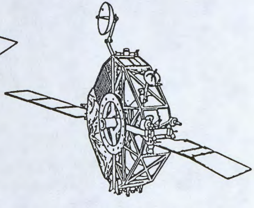
- LENGTH 37 IN.
- PROP 6,700 (N_2O_4/MMH)
- INERT 4,776 (LBS)

VOUGHT (BI PROP)
(OMS COMPATIBLE)



- LENGTH 7 FT.
- PROP 5,500 LBS N_2H_4
- INERT 2,956

MARTIN MARK II/TMS
(MINIMUM MODS)



- LENGTH 41 IN.
- PROP 5,500 LBS N_2H_4
- INERT 2,670

MARTIN MARK II /TMS
(OPTIMIZED)

FIGURE 16

VOUGHT

TMS External Arrangement

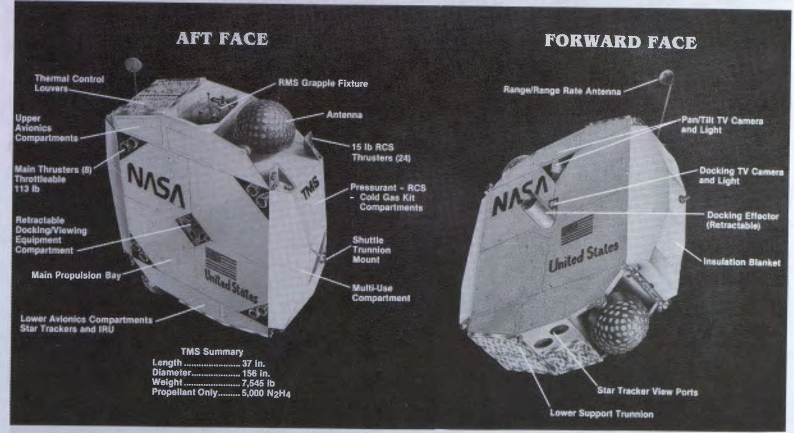


FIGURE 17

P2-3121 2A

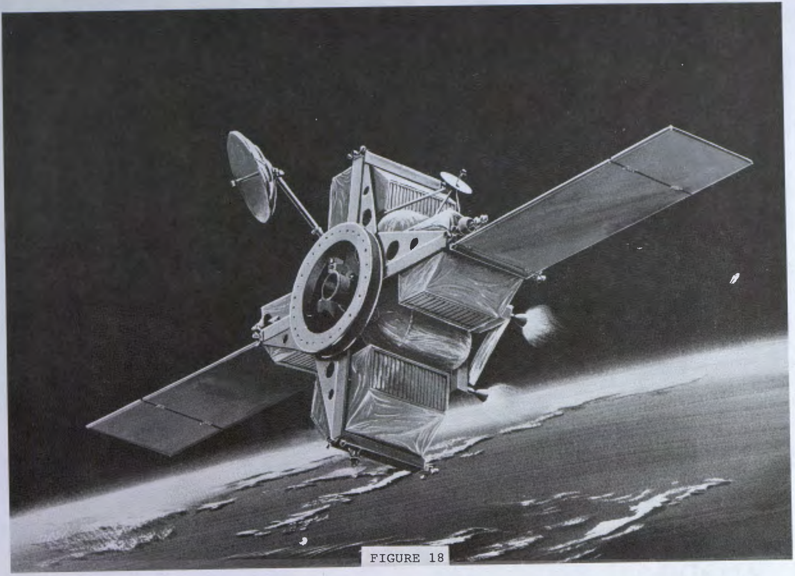


FIGURE 18

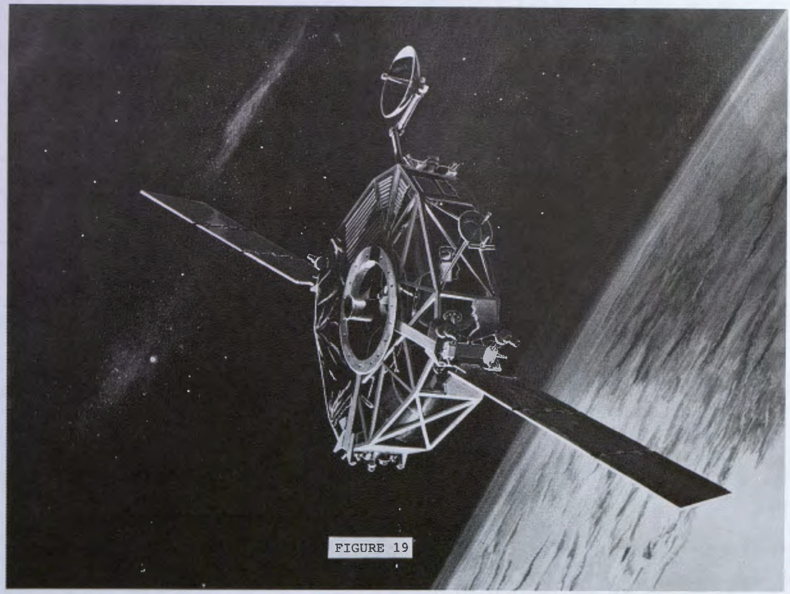
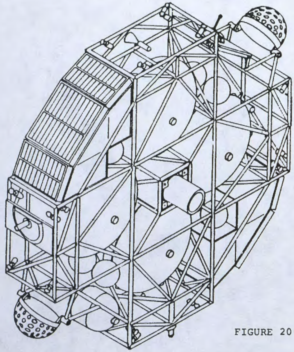


FIGURE 19

OMS / TMS CONFIGURATION # 3



TMS Weight Summary.	Lb
Structure	1218
Avionics	388
Power (Ag Zn)	408
Thermal	180
Propulsion Syst (Main & RCS)	1217
Contingency	137
Expendables (Useable)	7091
Main 6713	
RCS 350	
Press 28	
Subtotal	10639
Docking Kit	423
Total	11062

FIGURE 20

TMS Performance Capability — NASA Payloads

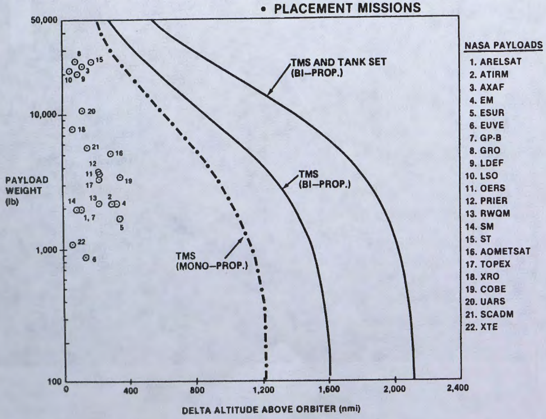


FIGURE 21

TMS Plane Change Performance Capability

- BIPROPELLANT TMS
- PLACEMENT MISSIONS

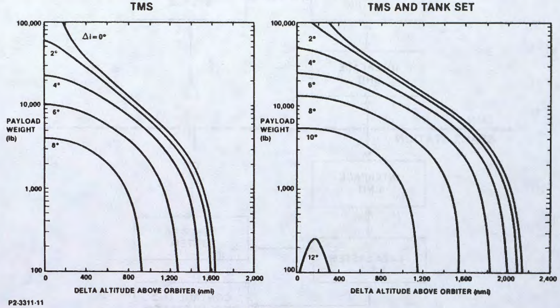


FIGURE 22

0304–83

TMS in the Space Station Era

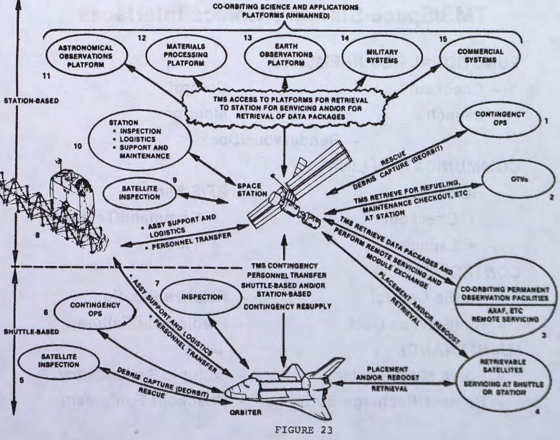


FIGURE 23

TMS/Space Station Avionics Interfaces

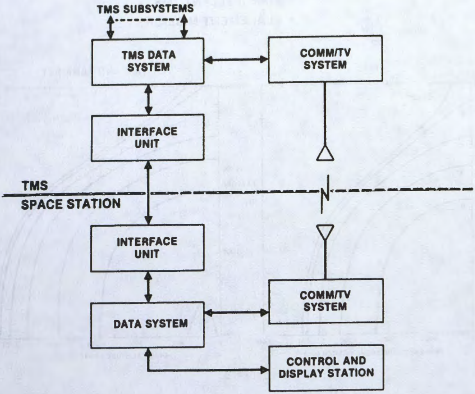


FIGURE 24

TMS/Space-Station Avionics Interfaces

FUNCTIONAL REQUIREMENTS

- Checkout
- Launch
- Control
- Monitor
- Rendezvous/Dock

COMMUNICATION LINK

- Hardwire
  - Checkout
  - Launch
- RF/S-Band
  - Command/Telemetry
  - Video

CONTROL/SAFETY

- Traffic Control
- Rendezvous Dock
- Relative Position
- Predictable Failures

MAINTENANCE

- Spare Modules/Parts
- Replace/Recharge Batteries
- Multiple Redundancy
- Checkout Equipment

FIGURE 25

TMS SPACE STATION BASED OPERATIONS

TMS REQUIREMENTS

- O COMPATIBLE INTERFACE PROVISIONS FOR ACCESS TO RELATED FREE-FLYING UNMANNED PLATFORMS:
  - SERVICING
  - MODULE/PALLET EXCHANGE
  - EXPENDABLES RESUPPLY
- O ACCESS PROVISIONS FOR ON-ORBIT SERVICING AND MAINTENANCE OF SPACE-BASED TMS
- O PROVISIONS FOR ON-ORBIT REFUELING
  - PROPELLANT AND GASES
  - UMBILICALS AND DISCONNECTS
- O PROVISIONS FOR EXTERNAL POWER UMBILICAL CONNECTION AND BATTERY RECHARGE
- O PROVISIONS FOR CONTROL AND CHECKOUT FROM SPACE STATION

FIGURE 26

TMS SPACE STATION BASED OPERATIONS

SPACE STATION REQUIREMENTS

- O RMS OR EQUIVALENT FOR TMS HANDLING/RETRIEVAL
- O BERTHING PROVISIONS FOR TMS
  - STS CARGO BAY SURROGATE OR EQUIVALENT
- O CONTROL STATION AND COMPATIBLE COMMUNICATIONS FOR TMS C/O AND CONTROL
- O FACILITY PROVISIONS FOR TMS SERVICING
  A. BATTERY RECHARGE B. STORAGE AND TRANSFER OF PROPELLANTS/GASES
- O STOWAGE OF SPECIAL TMS SERVICING ADAPTERS/MISSION KITS
- O TMS BERTHING/HANGAR/MAINTENANCE FACILITY NEEDS (TBD)
  A. EVA B. SHIRT SLEEVE C. BOTH?
- O PROVISIONS FOR STANDBY AND RAPID DEPLOYMENT OF TMS

FIGURE 27

Alternate Station Arrangement Concept for TMS Servicing and Maintenance of a Fleet of TMSs

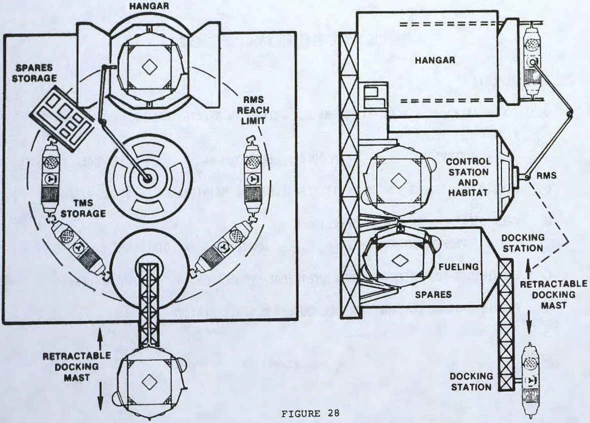


FIGURE 28

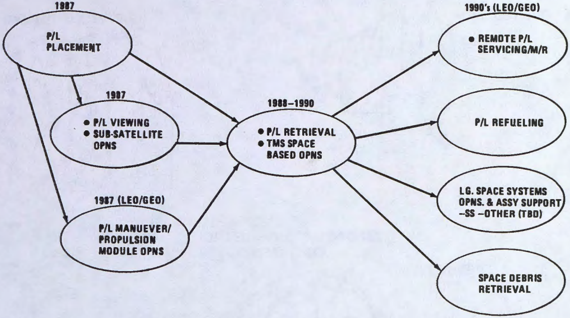
TMS Opportunity Model

	85	86	87	88	89	90	91	92	93	94	95	NASA Total	• Possible DOD Total
Placement	1	5	4	8	12	9	10	6	7	4	5	72	82
Retrieval	2	—	1	1	1	2	2	4	2	3	4	22	25
Subsatellite	3	3	3	2	1	1	1	1	1	1	—	17	10
Servicing	—	—	1	4	7	6	8	6	8	7	7	54	62
Total	6	8	9	15	21	18	21	17	18	16	16	165	179

- ● NOMINAL SPACE STATION LOGISTICS SUPPORT FLTS. INCLUDED
- ● ADDED FLT. OPNS. FOR A SPACE STATION BASED TMS NOT INCLUDED

FIGURE 29

SCOPE OF TMS REMOTE SATELLITE SEVICES



RELATED TMS MISSION KITS OR GROWTH OPTIONS

- TV VIEWING & LIGHTNING KIT
- GROUND CONTROL STATION
- LONG DURATION PWR KIT
  - ARRAYS – BATTERIES
- PROPULSION STAGE VERSIONS
  - MODULARITY FEATURES
- L. R. COMM SYST,
  - COMMAND – TLM
  - VIDEO (DATA COMPRESSION)

- COLD GAS RCS KIT
- TANKER MODULE (ΔV PERFORMANCE AUGMENTATION)
- TMS ORBITAL REFUELING & M/R KIT
- DOCKING PROBE(s)
- NAVIGATION AIDS
  - GPS – TRACKERS
- RENDEZ RADAR
- ORBITER CONTROL STATION (OPTION)
- ORBITER ASE

- DEDICATED P/L SERVICER MECHANISM FOR PLANNED M/R
- TMS – P/L REFUELING TANKER MODULE
- 7 DOF MANIPULATOR ARM
  - SPECIAL TOOLS
  - END EFFECTORS
  - SENSORS

  DEBRIS CAPTURE MECHANISM & CONTAINMENT TECHNIQUES
- STEREO TV
- AUTONOMOUS DOCKING SYST

FIGURE 30

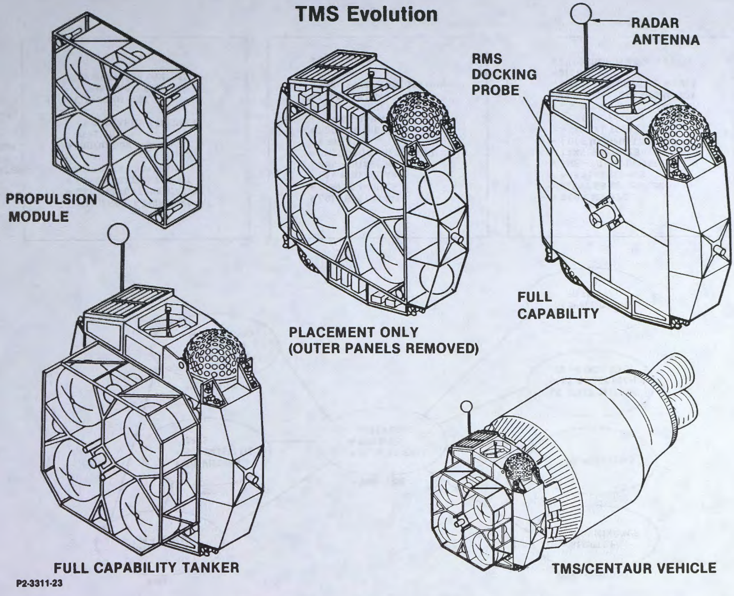

TMS Evolution
PROPULSION MODULE
PLACEMENT ONLY (OUTER PANELS REMOVED)
RADAR ANTENNA
RMS DOCKING PROBE
FULL CAPABILITY
FULL CAPABILITY TANKER
TMS/CENTAUR VEHICLE
P2-3311-23

FIGURE 31

TELEOPERATOR MANEUVERING SYSTEM (TMS)

J. TURNER PS04
JANUARY 7, 1983

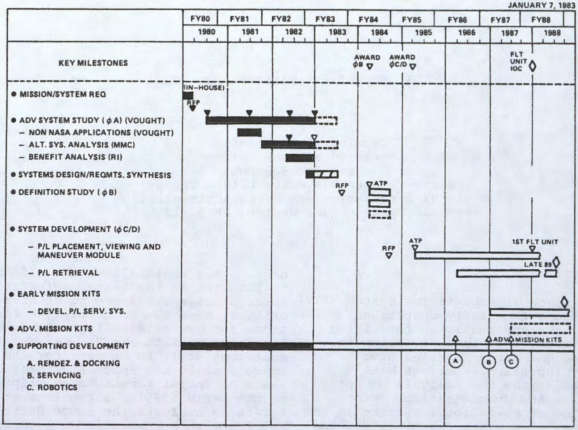


FIGURE 32

CONCLUDING REMARKS

- THE TMS, WITH MODULAR GROWTH POTENTIAL AND MULTI-PURPOSE MISSION KIT SUPPORT FEATURES, WILL COST EFFECTIVELY COMPLEMENT AND EXPAND THE PAYLOAD SERVICES OFFERED BY THE SPACE TRANSPORTATION SYSTEM

- OPERATING IN CONJUNCTION WITH PLANNED UPPER STAGES, THE TMS OFFERS A WIDE RANGE OF SERVICES TO P/L'S, OUT TO & INCLUDING GEOSTATIONARY ORBITS

  - PROPULSION MODULE APPLICATIONS
  - SERVICING APPLICATIONS

- IN THE SPACE STATION ERA, TMS WILL PROVIDE A NUMBER OF PAYLOAD AND ORBITAL SUPPORT FUNCTIONS ESSENTIAL TO OVERALL SPACE STATION MISSION OBJECTIVES

- IF AUTHORIZED AS AN FY85 START, INITIAL TMS CAPABILITIES CAN BE BROUGHT ON LINE IN THE LATE '87 - EARLY '88 TIME PERIOD.

FIGURE 33