Orbital Maneuvering Vehicle (OMV) Missions Applications and Systems Requirements

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ABSTRACT

The routine delivery of large payloads to low earth orbit has become a reality with the Space Transportation System (STS). However, once earth orbit has been achieved, orbit transfer operations represent an inefficient use of the Space Shuttle. The Orbital Maneuvering Vehicle (OMV) will add a new and needed dimension to STS capabilities. Utilized in a reusable manner, the OMV is needed to deliver and retrieve satellites to and from orbital altitudes or inclinations beyond the practical limits of the Space Shuttle and to support basic Space Station activities. The initial OMV must also be designed to permit the addition of future mission kits to support the servicing, module changeout, or refueling of satellites in Low Earth Orbit (LEO) and Geostationary Earth Orbit (GEO), and the retrieval and deorbit of space debris. This paper addresses the mission needs along with the resulting performance implications, design requirements and operational capabilities imposed on the OMV planned for use in the late 1980's.

INTRODUCTION

The OMV, operating as a remotely controlled free-flying reusable space tug at distances out to 1500 nautical miles away from the Orbiter, provides a substantial augmentation to the range of delivery, retrieval, and reboost satellite services provided by the Space Transportation System (STS). Once developed, the OMV will offer a wide range of both basic and growth capabilities which can be adopted for use by future spacecraft developers with resultant cost savings to the individual projects. It will also be usable as a propulsion module to augment the performance of planned and future high energy upper stages for delivery of payloads to altitudes up to and beyond geosynchronous orbit (GEO). As an essential support element of the future Space Station (SS) program, the OMV system should be operationally demonstrated prior to SS Initial Operational Capability (IOC). In the aggregate of its future uses, the OMV will more than offset its initial development costs. This paper summarizes the mission needs for the OMV program, and the characteristics of a typical/representative design (Figure 1) suited to meeting these needs.

OMV MISSION NEEDS AND OPPORTUNITIES

As a remotely piloted vehicle, its maneuvering controlled by man with hand-controllers from a ground control station, the OMV extends the reach of both the STS and the envelope of man's involvement. It will eventually provide a wide range of new and unique mission capabilities as summarized in Figure 2. The upper portion of this figure addresses mission capabilities that an initial or early OMV will provide; more advanced missions involving SS support and satellite servicing will be accommodated by modularly augmenting the basic OMV with mission "kits" as needed to support these more demanding classes of missions. Early OMV uses will emphasize the delivery of payloads to orbital locations beyond the effective range of the STS. With its TV cameras and a flood-light system, the OMV will be able to view the delivered satellite and verify all sensors/appendages are deployed correctly and are functioning before the OMV returns back to the Orbiter for pickup and reuse. Should the delivered satellite malfunction, the OMV can be remotely controlled to re rendezvous and dock with the satellite for contingency retrieval and return to the Orbiter/ground for repairing. The OMV will also be used for planned retrievals of spacecraft after they have completed their useful mission life or for periodic servicing/updates. The OMV will also provide an efficient means for reboosting large observatory-class payloads (which have no propulsion of their own) back to their desired higher operational orbits after their orbits have decayed. Operating with both primary and vernier (RCS) thrusters, the OMV can be
utilized as a free-flying sub-satellite, transferring attached science payloads or sensors to large separation distances from the Orbiter, followed by later return to the Orbiter for retrieval. The duration of such missions may vary from days to weeks to months; with extended orbital operational times provided by an OMV power augmentation kit. In summary, the initial OMV will be required to:

- Deliver satellite payloads to orbital altitudes or inclinations beyond the practical limit of the existing Space Shuttle.
- Retrieve satellite payloads from orbital altitudes or inclinations beyond the practical limit of the existing Space Shuttle.
- Reboost satellites to original operational orbital altitudes or higher.
- Accommodate mission sharing by providing a means to deliver multiple payloads to different orbital altitudes and inclinations.
- Safely deorbit satellites which have completed their useful life.
- Be readily adaptable to the support of basic Space Station activities by transferring and maneuvering of modules and logistic equipment.

The basic vehicle will be configured in a way that will readily permit the modular add-on of future mission kits or new hardware features essential to supporting potential future mission needs, such as:

- The servicing, module changeout, or refueling of satellites and platforms operating in LEO, GEO, or in formation with a Space Station.
- The retrieval deorbit of space debris which could represent an orbital hazard to future space missions.

In the Space Station era, as shown in Figure 3, it is anticipated that OMV missions will be conducted in two major ways: many will continue to be "based" out of the Orbiter for support to the SS or for spacecraft missions going to orbital locations not involved with or compatible with the SS orbit. Other OMV uses, dedicated to operational support of the SS, will be station-based, where the OMV is serviced, maintained, and controlled from an OMV support facility at the SS. The complete range of OMV basing concepts is shown in Figure 4. Operating out of the Shuttle, in a "Ground-Based" mode, the OMV is delivered to orbit, performs its mission, returns to the same Orbiter for retrieval, and is returned to the ground for servicing, refueling, and subsequent reuse on another Shuttle flight. Operating out of Shuttle, in "Orbit-Stored" mode, the OMV is left on-orbit for extended periods of storage between missions or for the conduct of more missions until its fuel supply is depleted. It will be retrieved by a later Shuttle flight for return to ground or may be refueled and serviced out of the Orbiter to extend its orbital stay time/utility. Operating in a "Space Station-Based" mode, the OMV, once delivered to orbit by the Shuttle, will fly to the SS and remain based there. From the SS location, the OMV will support logistics/payload exchange missions between the SS and STS, and payload services support missions between SS and associated free-flying satellites or unmanned space platforms. The early OMV will be ground-based, but must be readily capable of evolving to the other basing modes as future missions needs and economic considerations dictate. These basing modes will be thoroughly examined during the conduct of OMV Phase B definition studies in CY 1984 and 1985.

Figure 5 addresses the generic class of OMV missions associated with support to large observatories. In this particular mission, the OMV has acquired the target from an initial 10-15 nautical mile separation distance, and then maneuvered to within a safe proximity stand-off distance using a combination of main propulsion and primary RCS thruster burns. The OMV retractable docking probe is then actuated to its extended position and terminal maneuvers performed using a secondary non-contaminating, cold gas RCS system. This phase of the mission is directly controlled by an OMV operator from a ground station, utilizing sensory aids (radar/optical) and TV data transmitted by the associated on-board OMV subsystems. The docking concept involves the use of a payload-mounted fixture and a compatible OMV docking end effector. Several docking configurations and mechanisms are currently being evaluated as part of MSFC's supporting development program. After rendezvous and docking with the large observatory at its pickup altitude (typically 250-275 nautical miles), the OMV will return the observatory to the Orbiter (160 nautical mile altitude) for servicing. Following servicing of the observatory in the Shuttle cargo bay, the OMV will then re-deploy it back to a desired operational altitude which may range anywhere from 320-400 nautical miles. After the observatory is safely deployed and operational, the OMV will then return to the Orbiter.

To meet projected mission needs, the OMV must be capable of effective operations in a number of operating modes, as summarized in Figure 6. Except for control of the terminal rendezvous and docking operations (piloted mode, ground based) the OMV will be capable of automatic operations under programmed control of an on-board computer. It will be capable of executing a primary inertial hold mode to support its
retrieval by the Shuttle/RMS. It will be capable of detecting any onboard anomalous conditions and placing itself into an automatic hold mode (low power) until the situation can be corrected. In the event the OMV cannot be retrieved on the Shuttle flight it was initially delivered by (planned or contingency situation), the OMV will be capable of operating in a powered-down contingency hold mode for up to nine months for retrieval on a later Shuttle flight. Being modular in design, the OMV will also be scarred or readily modified to support extended capability mission modes, such as those associated with storage at the space station, and the control of OMV from a SS control center. Many projected extended capability missions will require the OMV to provide for sustained orbital operations over a long time. Therefore, the OMV will be initially designed to accommodate the future add-on of a supplementary power kit and other support equipment as required to support these growth mission needs.

In summary, OMV mission needs and opportunities are encompassed by the set of generic design reference missions (DRM's) outlined in Figure 7. These DRM's will be used during the definition phase as a basis for configuration sizing and design. It is currently planned that the initial OMV developed will meet the specific requirements identified with early year mission needs (i.e., payload delivery, retrieval, reboost, etc.). Extended capability missions, although not quantifiable in terms of specific needs, will be used to insure that the OMV program can respond to these emerging future missions (satellite refueling, servicing, space debris capture, etc.). The initial OMV will be designed in a modular way to provide these services as the user needs are better developed and defined. Subject to future design studies, it is generally assumed that these growth capabilities will be provided by augmenting the initial OMV with a series of mission kits, added on in modular fashion as required.

OMV PERFORMANCE CAPABILITIES AND BENEFITS

The STS performance capabilities at Eastern Test Range (ETR) and Western Test Range (WTR) are shown in Figure 8 for the standard injection profile and a direct injection profile. The potential for further gains by the addition of an in-bay Orbital Maneuvering System (OMS) kit (not an approved program element at this time) is also shown. Overlaid on these curves is the added performance capability offered by an OMV departing from the standard Orbiter delivery altitude of 160 nautical miles, delivering a payload to a higher orbit, and returning without payload to the Orbiter. As shown, OMV offers a substantial augmentation to the Orbiter's "sphere of influence" relative to attainable payload delivery weights and altitudes. The performance gain at the higher inclinations (WTR) is especially noteworthy. The significance of this STS augmentation is shown in Figure 8 and graphically displayed in Figure 9. Using the Orbiter alone, it takes a dedicated Shuttle flight (no-cost sharing possible) to deliver a 20,000 pound payload to 350 nautical miles. However, using an OMV, this mission can be done in a more efficient and cost effective manner for the users. In this case, the Orbiter delivers the 20,000 pound spacecraft and the 10,000 pound OMV to a 160 nautical mile standard delivery orbit. At this lower altitude, the Orbiter is also able to deliver an added 30,000 pounds of discretionary payload (i.e., a Spacelab/module or other shared mission payload). The cargo bay packaging arrangement for such a potential dual mission manifest is shown in Figure 10. In fact, the OMV could deliver the 20,000 pound spacecraft as high as 750 nautical miles and return back to the Orbiter with fuel remaining. While the OMV (ground-controlled) is doing the delivery mission, the Orbiter crew is free to conduct the Spacelab or support the "discretionary payload" mission. In this scenario, the Orbiter has made full use of its maximum payload delivery potential (50-65K pounds), and has accommodated two payloads. In this manner, the cost of the flight can be shared between the two users. Clearly, the OMV offers a powerful cost-effective means for enhancing the Orbiter's ability to manifest multiple payloads on a single flight.

The low earth orbit performance corridor offered by a typical OMV configuration is shown in Figure 11. Orbital altitudes of 1,400 nautical miles with a 5,000 pound payload are possible. Round-trip plane changes of almost 8° are also provided assuming a payload placement and OMV-only return to the Orbiter. Added performance (if required) is possible by the addition of a propellant tanker kit. Such kitting options will be investigated during the Phase B study analyses. Low earth orbit performance capabilities for several mission profiles are shown in Figure 12. Shown parametrically are the OMV capabilities to deliver, retrieve, transport payloads on a round-trip basis, and to retrieve-redeploy in a double mission. Typically, the round-trip performance curve indicates the OMV's capability to provide contingency return of a payload that fails to operate when deployed. The retrieve-redeploy curve demonstrates the OMV capability to retrieve a spacecraft to the Orbiter or to a Space Station and then redeploy it to its operational altitude after servicing. No orbital refueling of the OMV was assumed, and in all cases, the OMV retains sufficient onboard fuel to return itself to the departure base at the end of the mission. The use of an OMV propulsion module (PM) to augment the performance of high-energy upper stages going to geosynchronous orbit is demonstrated in Figure 13. Applications of an OMV-PM with both a Centaur and a Transfer Orbit Stage
(TOS) are shown. When used with the Centaur, both the OMV and its attached spacecraft are placed in geosynchronous orbit. The OMV then provides maneuvering AV for spacecraft repositioning, altitude changes, etc. When used with the TOS, the OMV-PM provides the apogee circularization burns and plane change maneuver to get the spacecraft into orbit. This leaves the remaining fuel for maneuvering capability. In both cases shown, it was assumed that major avionics functions for the mission (guidance, navigation, power, control, etc.), were provided by the spacecraft and not the PM. Further interface trade studies in this area will be conducted in the definition phase. In summary, the OMV offers a wide range of performance capabilities in support of both the STS and SS programs, both in LEO, and at geosynchronous locations when delivered to this location by a high-energy upper stage.

**BASELINE OMV DESIGN CHARACTERISTICS**

The OMV concept of today has been evolved over a number of years. It's early predecessor program, Teleoperator Retrieval System (TRS), was planned to be used to reboost the Skylab to a safe operational altitude, but was terminated during development in 1978 because of the earlier than expected re-entry of Skylab. This vehicle, shown in Figure 14, was being fabricated using a substantial amount of residual hardware from other programs. It contained approximately 6,000 pounds of hydrazine propellant, used a cluster of 32 thrusters (40 pounds thrust each) for primary propulsion, and was approximately 7 feet in length. It was configured to provide an on-orbit dormant storage capability. From this early design heritage and focused mission objective, a sound data base was acquired on which to derive a more versatile, optimized OMV concept capable of supporting a much broader range of future mission objectives. In the past five years, following TRS, NASA has invested $1.4M in industry Phase A studies to redefine the OMV program (reference Figure 15). This, along with corporate investments of $7.5M and a substantial in-house design/supporting development activity at MSFC has resulted in a sound data base on which to proceed to the next stage of OMV definition (Phase B). A wide range of configuration design approaches emerged from studies to date, some of which are shown in Figure 16. For all Phase A studies, a MSFC configuration utilizes an aluminum tubular structure that mounts directly to the Shuttle cargo bay sill and keel fittings, thereby eliminating the need for a cradle. It has been configured to minimize its length in the Shuttle cargo bay (32''), and can be mounted in any location, thereby enhancing its manifesting potential. It will utilize a redundant onboard computer system, inertial reference units, a global positioning system (GPS) interface, and various sensors for navigation aid (star sensor/sun sensor/horizon sensor or combinations thereof). It will communicate with the ground control station through Tracking and Data Relay Satellite System (TDRSS) networks, using S-Band command-telemetry and video links between OMV and TDRSS for low earth orbit missions. Ground networks will be utilized to support OMV missions at GEO.

The OMV will be powered with primary batteries, but may also require some secondary battery/solar array panels to meet the long-term, on-orbit storage requirements. All critical avionics components are mounted in accessible locations to permit an on-orbit maintenance and repair capability. RF system elements, including surface mounted omni antennas and two (2) deployable highgain antennas (Electronically Steerable Spherical Array (ESSA)) are also accessible for EVA servicing. For main propulsion and primary RCS, both mono-propellant and bi-propellant configuration options are being considered. The MSFC reference design uses 6,700 pounds of storable bi-propellant (monomethyl hydrazine and nitrogen tetroxide) stored in four oblate spherical tanks. Propellants are pressure-fed to the thrusters at 250 psia by a gaseous nitrogen pressurant stored at 4,000 psi in 4 spherical tanks. A nominal thrust level of 800 pounds was established for main propulsion, utilizing 4 thrusters at 200 pounds thrust each. Other thrust levels and thruster combinations are also being investigated. Throttling thrusters and gimbaled thrusters may also be considered further as options to the reference baseline design. Eight RCS modules are provided for OMV stabilization and attitude control. Each module has three thrusters rated at 15 pounds thrust level each. During main propulsion maneuvers, a number of thrust vector control techniques are possible; the reference design utilizes main thrust modulation techniques for pitch and yaw coupled with roll control from the RCS. A cold gas RCS system will also be incorporated for close-in precise OMV maneuvering around contamination sensitive
payloads. The reference design utilizes an extendable-retractable docking probe with an "RMS-type" end effector for docking to a payload for retrieval. Other probe designs are also being evaluated. A radar system is provided to aid in target acquisition, and to provide the OMV operator with precise range and range-rate data during the terminal phases of a man-in-the-loop controlled docking maneuver. Two video cameras will be provided to support rendezvous, docking, and payload viewing operations. One will be bore-sighted along the docking axis; another will be off-set, and will provide pan-tilt-zoom lens capabilities. Docking/fixation lights will be provided to illuminate the payload docking interface. The OMV will also have a standard set of aircraft-type running lights (amber-red-green) to aid the Orbiter or Space Station crews in visually acquiring the OMV during proximity operations, OMV retrieval, and berthing operations. As mentioned earlier, the OMV program will provide a spin-off feature; the availability of a propulsion module (PM) for application to a wide variety of high-energy, upper-stage missions. This PM, shown on Figure 21, will provide only the minimal valve drive electronics/interfacing avionics equipment necessary for control of the propulsion system. It is assumed that all other avionics functions critical to a complete mission are provided by the spacecraft system utilizing the PM. A weight summary for the reference design OMV and OMV-PM is shown on Figure 22, based on a bi-propellant load of 6,700 pounds. From a design flexibility standpoint, the initial ground-based OMV will be properly scarred and configured to permit ready evolution to an extended capability OMV response to accommodating growth missions. For example, it will be scarred to permit on-orbit refueling, battery recharge, and other functions as needed to support long-duration, space-based OMV operations. The derivation of a design approach inherently flexible to evolve "gracefully" as emerging growth missions and new technologies dictate will be a significant challenge to the OMV Phase B contractor teams. While retaining the flexibility for growth, it will also be essential to minimize program development risks and costs through the use of existing and proven hardware wherever possible. An assessment of baseline OMV subsystem requirements (reference Figure 23) indicates a high percentage of the needed capabilities can be met either by existing hardware or modifications thereto. No critical new technology needs have been identified in the OMV planning to date; however, supporting development program efforts relative to rendezvous and docking mechanisms and sensors needs will be accelerated over the next two years to strengthen this critical area.

**OMV Project Status and Plans**

Definition phase studies for the OMV have been approved for FY 1984; MSFC is presently evaluating proposals that will lead to the selection of three or more Phase B study contractors for one-year contracts starting in mid-CY 1984, as shown in Figure 24. Early availability of OMV will obviate the necessity of including integral propulsion in the planning for many new spacecraft. Once an OMV program is approved for development, mission planners and payload developers will rely on OMV availability for placement, retrieval, and maneuvering services. To support payload designers, and planners in their near-term assessments of program options, a close working relationship will be established with the user community to help guide the Phase B contracted efforts. Current OMV project implementation plans are based on an assumed approval for development in FY 1986. This would result in a CY 1990 launch. The OMV functional capabilities are also critical to the Space Station program, and should therefore be demonstrated well in advance of initial Space Station operations. At present, SS-OMV project coordination meetings are conducted on a frequent basis to insure mutual awareness of interface requirements and operational constraints early in the definition phases of the two programs. Major milestones for coordination reviews between the two programs are shown in Figure 25. Space Station participation in the OMV requirements planning, Phase B definition activities, and the conduct of several interactive requirements reviews prior to completion of the OMV "Understanding Phase" (through PDR) of development will assure that space station needs are properly reflected in the initial design and development of OMV flight hardware. Development milestones for the flight hardware are shown in Figure 26. The initial OMV program will most likely encompass the "current program" elements outlined on Figure 27, which also portrays how the program may evolve. As seen now, near-term growth of an initial OMV will be needed to support Space Station-based operations and to demonstrate a capability for the remote refueling of spacecraft or free-flying unmanned platforms. Later growth will involve spacecraft servicing, more advanced manipulative devices for space debris capture/assembly support operations, and spacecraft operations support at GEO locations. As shown on Figure 28, a supporting development program is underway at MSFC to demonstrate the near-term capabilities needed in the rendezvous/docking area. Advanced capability studies are underway in the remote refueling tanker area, and in the area of advanced mechanisms (manipulators/automated spacecraft servicers). Support to the mechanisms area is being provided by Jet Propulsion Laboratory (JPL) in the area of end effectors and sensors. These efforts are establishing the foundations on which future OMV advanced mission kit development efforts will be based.
Near-term MSFC efforts in the rendezvous/docking area will continue to rely heavily on use of a target motion simulator and a six-degree-of-freedom dynamic moving base simulator (Figure 29) to evaluate selected docking mechanisms and terminal rendezvous and contact dynamics (last four feet of closure) and to perform an engineering assessment of vehicle control dynamics. This system will be complemented with another facility to be fully operational by mid-1984, the OMV mobility simulator described in Figures 30 and 31. This facility will be utilized to evaluate a variety of docking techniques, sensors, lighting requirements, video system requirements, and control station needs. Basic elements of the system include a six-degree-of-freedom OMV mobility unit with cold gas thrusters (variable thrust level), and a computer supported navigation/control system slaved to a remote control center via an RF communications link. The mobility unit will operate on a precision epoxy floor covering an area of 4000 ft². These two major facilities at MSFC will be utilized in an integrated manner over the next two years to prepare a sound design requirements/design criteria data base to help guide the OMV development program.

CONCLUDING REMARKS

The OMV offers a wide range of new satellite services capabilities to complement the STS program and to support a future Space Station. A sound data base exists to support an aggressive program leading to development of an operational OMV capability by early 1990.
OMV IN THE SPACE STATION ERA

CO-ORBATING PERMANENT FACILITIES PLATFORM
PLACEMENT/RETRIEVAL
RETRIEVE DATA
EXPERIMENT
EXCHANGE
REBOOST

STATION
• INSPECTION
• LOGISTICS
• SUPPORT AND MAINTENANCE

SPACE STATION

SATellite
PLACEMENT/RETRIEVAL

ASSY SUPPORT
AND
LOGISTICS

RETRIEVABLE SATELLITES
FOR SERVICING AT SHUTTLE OR STATION

RETRIEVE OTV'S

FIGURE 3

STATION-BASED

SHUTTLE-BASED
OMV BASING CONCEPTS

SPACE STATION

OMV STAYS ON ORBIT

ORBIT STORED

OMV RETURNS ON SAME SHUTTLE

GROUND BASED

SPACE STATION BASED

FIGURE 4
RETRIEVAL, SERVICING AND REDPLOYMENT WITH OMV

FIGURE 5

OMV

RETRIEVE

RMS TO

REDOFF

RECOVERY ORBITER

REDEPLOY

REFUEL

REDOFF
OMV OPERATIONAL MODES

INITIAL OMV OPERATIONAL MODES

• PROGRAMMED MODE
• PILOTED MODE (GROUND BASED)
• PRIMARY INERTIAL HOLD
• AUTOMATIC (MIN. PWR.) MODE
• CONTINGENCY ON-ORBIT HOLD MODE (9 MONTHS MIN.)

EXTENDED CAPABILITY MODES (INCORPORATE OR BE SCARRED TO INCORPORATE)

• SPACE STATION MODES
  A. CONTROL VIA OMV CONTROL CENTER ON SS
  B. LONG-TERM QUIESCENT STORAGE WHILE ATTACHED TO SS

• SPACE BASED MODE
  A. EQUIPMENT ADD-ON'S TO PERMIT LONG DURATION ORBITAL MISSIONS

FIGURE 6
FLIGHT SHARING POTENTIAL
SPACELAB AND OMV

FIGURE 10
LEO PERFORMANCE ENVELOPE OF ORBITAL MANEUVERING VEHICLE
OMV LEO PERFORMANCE

\[ W_{\text{PROP}} = 6566 \text{ LB} \]
\[ I_{\text{SP}} = 285 \text{ SEC.} \]
NO PLANE CHANGE

FIGURE 12
PERFORMANCE OF UPPER STAGE + OMV PROPULSION MODULE

GEOSYNCHRONOUS ORBIT

\[ W_{\text{PROP}} = 6566 \text{ LB.} \]
\[ W_{\text{S}} = 2521 \text{ LB.} \]
\[ I_{\text{SP}} = 285 \text{ SEC.} \]

FIGURE 13
ORBITAL MANEUVERING VEHICLE
PAST ACTIVITIES


MSFC TELEOPERATOR SYSTEM

PHASE A/B STUDY

$27M

MMC

CDR

(GENERICOMV
DEFIN.

COMMERCIAL
DEVEL.

OPTIONS

I TERMINATE MARTIN

TRS

PHASE C/D

MSFC

L PLANE

MODULE

ORBITAL MANEUVERING VEHICLE

MSFC INHOUSE

RFP

PHASE A/B

MODULAR DESIGN

SUPPORTING DEVELOPMENT

INHOUSE RFP

A

$870K

VOUGHT

STUDY

$300K

MARTIN

STUDY

$193K

I RFP

SUPPORTING DEVELOPMENT

$2.5M + 70 MAN YRS

OMY-TRAD $75M

100 MAN YRS

MSFC STUDIES

RFP

PHASE A/B

STUDIES

$870K

COMMERCIAL DEVELOPMENT OPTIONS

MSFC TELEOPERATOR SYSTEM

RETIRIEVAL

MAC

OMV-IRAD

S7.5M

FIGURE 15

Past Activities

OMV CONCEPTS

- LENGTH 37".
- PROP 3,700 lb H₂/OMH
- INERT 3,911 lb.  
MSFC DESIGN REF. CONCEPT

- LENGTH 40".
- PROP 3,880 lb H₂/O₂/OMH
- INERT WT. 1,000 lb.  
GEN. DYNAMICS (OMM) SPACECRAFT MANEUVER MODULE

- LENGTH 17 IN.
- PROP 1,000 lb H₂/OMH
- INERT WT. 2,444 lb.  
VOUGHT (61 PROP) (OMS COMPATIBLE)

- LENGTH 7 FT.
- PROP 1,000 lb H₂/OMH
- INERT 2,866 lb.  
MARTIN MARK II/OMV (MINIMUM MODS)

- LENGTH 41 IN.
- PROP 1,000 lb H₂/OMH
- INERT 2,876 lb.  
MARTIN MARK II/OMV (OPTIMIZED)

FIGURE 16
KEY DESIGN GUIDELINES AND CONSIDERATIONS

- Payload placement and/or retrieval capability
- Shuttle based with LEO mission capability
- Capable of long duration orbital storage
- Minimum practical length and weight
- Minimize orbiter interfaces
- Control from ground station (compatible with control from space)
- Must have growth potential for future extended capability including unique mission activities and operation at GEO
- Must be able to be space station based
- Modular design approach
- Use proven/developed hardware to extent practical
- Design for 10 year life with refurbishment

FIGURE 17
MSFC
REFERENCE DESIGN
OMV

DIMENSIONS:
37 X 178 INCHES

WEIGHT:
10,496 POUNDS (LOADED)

PROPELLANT:
6,700 POUNDS NTO/MMH

FIGURE 20
PROPULSION MODULE

DIMENSIONS:
37" X 138 INCHES

WEIGHT:
2189 LBS

METHOX/NTO/MMH:
200 LBS
6700 LBS
2189 LBS

MASS FRACTION:
.722
## OMV Weight Summary (LBS.)

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*Contingencies: 15% on first three subsystems and 5% on all other subsystems*
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<tr>
<td>Valve Control Electronics</td>
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</tr>
<tr>
<td>Electrical Power</td>
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<tr>
<td>Primary Batteries</td>
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<tr>
<td>Cabling and Distribution</td>
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</tr>
<tr>
<td>Electrical Power</td>
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<tr>
<td>Cameras/Video</td>
<td></td>
</tr>
<tr>
<td>Computer</td>
<td></td>
</tr>
<tr>
<td>Transponders/Amplifier</td>
<td></td>
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<tr>
<td>Image Processor</td>
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<tr>
<td>Premodulator Processor</td>
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<tr>
<td>Phased Array Antenna</td>
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<tr>
<td>Propellant Tanks</td>
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<tr>
<td>Regulators</td>
<td></td>
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<tr>
<td>Thrusters</td>
<td></td>
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<tr>
<td>Propulsion Propellant Tanks</td>
<td></td>
</tr>
</tbody>
</table>
### Key Milestones

- **Adv System Study (φA)** (Vought)
- Alt. Sys. Analysis (MMC)
- Benefit Analysis (HI)
- Systems Design/Reqsmts. Synthesis
- Definition Study (φB)
- System Development (φC/D)
- First Unit (ETR)

### Mission Kits

### Supporting Development

- A. Rendez. & Docking
- B. Servicing
- C. Debris Ret.
- D. Robotics

---

**Indicates understanding phase (slow start)**

**Figure 24**
# Design & Development Schedule

**OMV**

## Design & Development Schedule

<table>
<thead>
<tr>
<th>Year</th>
<th>Design &amp; Development</th>
<th>Procurements</th>
<th>Tooling</th>
<th>Struct/Propulsion Test Article (S/P TA)</th>
<th>Test Event (STE)</th>
<th>S/P TA Tests</th>
<th>GSE</th>
<th>Flt Unit &amp; ASE</th>
<th>Sys Qual Tests</th>
<th>Sys Qual Tests</th>
<th>System Integration</th>
</tr>
</thead>
<tbody>
<tr>
<td>FY85</td>
<td>RFP</td>
<td>Understanding</td>
<td>TV Proc &amp; Software</td>
<td>Design, Fabricate, Install</td>
<td>FABRI. ASSY, INSTRUMENT C/O</td>
<td>STRUCT TESTS</td>
<td>PROPUL TESTS</td>
<td>DELIV</td>
<td>PATHFINDER</td>
<td>SYSP QUAL</td>
<td>FABRI. ASSY, &amp; C/O</td>
</tr>
</tbody>
</table>
REMOTE SATELLITE SERVICES
CAPABILITY EVOLUTION

S/C DEPLOYMENT & RETRIEVAL
OMV SPACE-BASED OPS OUT OF STS
- OMV REFUELED ON ORBIT
1990

REMOTE REFUELING TANKER
REMOTE SERVICING MECHANISMS
SPACE DEBRIS/TUMBLING S/C RETRIEVAL

MISSION KITS CAPABILITY GROWTH

STS-BASED OPS

SS OPS SUPPORT

SUPPORTING DEVELOPMENTS/STUDIES (FY84$)

REMOTE OPS (DEVEL & TEST)
- DOCKING MECHANISMS
- SENSOR REQMTS (LIGHTING, TV)
- MAN IN-LOOP CONTROLS/DISPLAYS

SUPPORTING DEV/TEST
- GROUND BASED
- ORBITAL DEMO
FY86-87

ADV MISSION KITS
- DEFIN/DEVEL
- TEST
FY88

ADV CAPABILITY CONCEPTS
- REFUELING THE OMV
- REMOTE S/C REFUELING TANKER
- ADV MECHANISMS/SENSORS

FIGURE 28
TELEOPERATOR MOBILITY SIMULATOR WITH OMV MOCK-UP

FIGURE 30