United States General Accounting Office

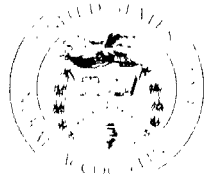
GAO

Report to the Chairman, Committee on Science, Space, and Technology, House of Representatives

July 1990

SPACE TRANSPORTATION

NASA Has No Firm Need for Increasingly Costly Orbital Maneuvering Vehicle



GAO/NSIAD-90-192

GAO
United States
General Accounting Office
Washington, D.C. 20548

National Security and
International Affairs Division

B-239570

July 31, 1990

The Honorable Robert A. Roe
Chairman, Committee on Science,
Space, and Technology
House of Representatives

Dear Mr. Chairman:

As you requested, we have reviewed the National Aeronautics and Space Administration's (NASA) Orbital Maneuvering Vehicle (OMV) program. Specifically, we evaluated the need to continue the OMV program in light of reductions in its capabilities and the reasons for changes in OMV program costs and schedules.

We are sending copies of this report to the Administrator of NASA and appropriate congressional committees. Copies will be made available to other interested parties upon request.

This report was prepared under the direction of Mr. Mark E. Gebicke, Director, NASA Issues, who may be reached on (202) 275-5140 if you or your staff have any questions concerning the report. Major contributors to the report are listed in appendix I.

Sincerely yours,

Frank C. Conahan
Assistant Comptroller General

Executive Summary

Purpose

The Orbital Maneuvering Vehicle (OMV) was conceived in 1986 as a $405 million multipurpose space tug. However, the estimated cost of the program has grown to $736.5 million. In late 1989, the National Aeronautics and Space Administration (NASA) reduced or eliminated some of the OMV's planned capabilities to contain growing program costs.

The Chairman, House Committee on Science, Space, and Technology, asked GAO to determine (1) whether NASA had established a firm need for the OMV and (2) why the program costs have grown so much.

Background

The OMV program was initiated as a way of extending the practical reach of the space shuttle. It was to transport satellites from the shuttle to other orbits, reboost them when their orbits decayed, retrieve and return them to the shuttle when they malfunctioned, and control their reentry into the atmosphere when their useful lives expired. Subsequent OMV enhancements would enable it to refuel satellites in orbit, perform in-orbit satellite repairs, and rescue out-of-control satellites. The OMV was to operate initially from the shuttle's cargo bay but would ultimately operate from the Space Station Freedom.

OMV was designed to be a free-flying, remotely controlled propulsion stage about 15 feet in diameter and 6 feet thick that would be carried into orbit inside the shuttle's cargo bay. Once separated from the shuttle, the OMV would be remotely controlled by astronauts working at consoles on earth.

The OMV's detailed design and development phase began in fiscal year 1986. The cost-plus-award-fee contract provides for the design, development, test, verification, and delivery of one OMV flight vehicle and associated support equipment.

Results in Brief

A firm requirement for the OMV does not exist. NASA can accomplish the OMV's scheduled missions of reboosting the Hubble Space Telescope and deploying and reboosting the Advanced X-ray Astrophysics Facility in other ways that cost less. Other potential missions may or may not materialize, but the OMV would have to be significantly enhanced before NASA could use it on most of these other missions.

Since the OMV's design and development phase began in 1986, estimated OMV program costs have increased by 82 percent, even though the

vehicle's capabilities have significantly decreased. The increase is attributable to (1) schedule stretchouts caused by internal NASA budget reductions, (2) program changes, and (3) contract cost growth. Further cost increases appear likely, especially if NASA is to make maximum use of the OMV.

Principal Findings

OMV Is Not Needed for Scheduled Missions

In late 1989, NASA reduced or eliminated a number of planned OMV performance capabilities. The OMV is now being designed principally to reboost the Hubble Space Telescope and deploy and reboost the Advanced X-ray Astrophysics Facility. Several NASA studies show, however, that the shuttle can perform these missions without the OMV.

A recent performance assessment shows that the OMV will not be needed to deploy the Advanced X-ray Astrophysics Facility if advanced solid rocket motors are available on the shuttle. According to the assessment, the shuttle with these motors will be able to deliver this observatory to its desired orbital altitude without the OMV. The first shuttle flight using the advanced motors is scheduled for late 1995—well before the observatory's April 1997 deployment schedule.

Other NASA studies show that the shuttle can maintain the Hubble and the X-ray observatories at acceptable altitudes by reboosting them during regularly scheduled maintenance flights. One or two additional shuttle flights dedicated to reboosting the observatories could be required early in the next century if the OMV is not developed.

The cost of the two additional shuttle flights to reboost the observatories would be about $277 million. The cost of continued development and operation of the OMV for the two missions would be about $716 million—more than two and one-half times the cost of the shuttle flights.

Future Mission for the OMV Uncertain

Program officials have identified other, longer-term missions that they believe the OMV could enhance. For example, an OMV-type vehicle may be needed to help maneuver materials in space if NASA undertakes staffed missions to the moon or to Mars. However, these missions have not yet been approved, and NASA has not decided what equipment would be needed to perform them. If these missions are approved and the OMV is

used, capabilities that were removed from the design in 1989 would have to be restored. These capabilities include the addition of advanced solar arrays to allow for basing at Space Station Freedom.

Estimated Costs Continue to Increase

Since the design and development phase began in fiscal year 1986, estimated OMV program costs have incurred a net increase of $331.5 million—from $405.0 million to $736.5 million. Schedule stretchouts caused $256.1 million of the increase. Program changes such as shifting responsibility for OMV operations from Marshall Space Flight Center to the Johnson Space Center added another $105.9 million. The remaining $123.1 million of the increase was attributed to contract cost growth. NASA reduced the program estimate by $153.6 million by eliminating some of the OMV's capabilities and reducing cost reserves. NASA requested $85.4 million in its fiscal year 1991 budget.

The same factors that caused earlier cost increases could cause future increases. According to the Associate Administrator for Space Flight, the OMV program is not immune to future budget cuts, which could cause additional schedule delays and cost increases. Also, program changes are to be expected as a result of the critical design review scheduled for April 1991 and subsequent hardware fabrication and testing. NASA is also concerned about additional contract cost growth. A number of the subcontracts have not yet been awarded, and firm prices have not been negotiated for other subcontracts. The current estimate includes a cost reserve to cover future changes, but the reserve is about half the amount NASA normally includes in cost estimates of programs at this stage of development.

OMV acquisition costs could increase to a cumulative total of $1.3 billion if NASA decided to use the vehicle for other missions, which would involve (1) restoring capabilities eliminated in the 1989 restructuring, (2) purchasing a second vehicle, (3) making the two OMVs compatible with expendable launch vehicles, and (4) purchasing an initial contingent of spare parts. However, NASA considered it unlikely that it would do all of these things.

Recommendation and Agency Action

Continued development of the OMV is not the most cost-effective approach to accomplishing currently scheduled missions and future mission requirements are uncertain. In its draft report GAO therefore recommended that the NASA Administrator terminate the OMV program. NASA terminated the OMV program 6 days after receiving GAO's draft report,

citing budget pressures and the absence of a firm, near-term requirement for the vehicle.

Matter for Congressional Consideration

The Congress should deny the $85.4 million requested for OMV development in fiscal year 1991, less any amount needed for termination expenses. According to a preliminary NASA estimate, about $33.2 million of fiscal year 1991 funding will be needed for termination.

Agency Comments

GAO incorporated NASA's comments into this report where appropriate.

Contents

Figures

Abbreviations

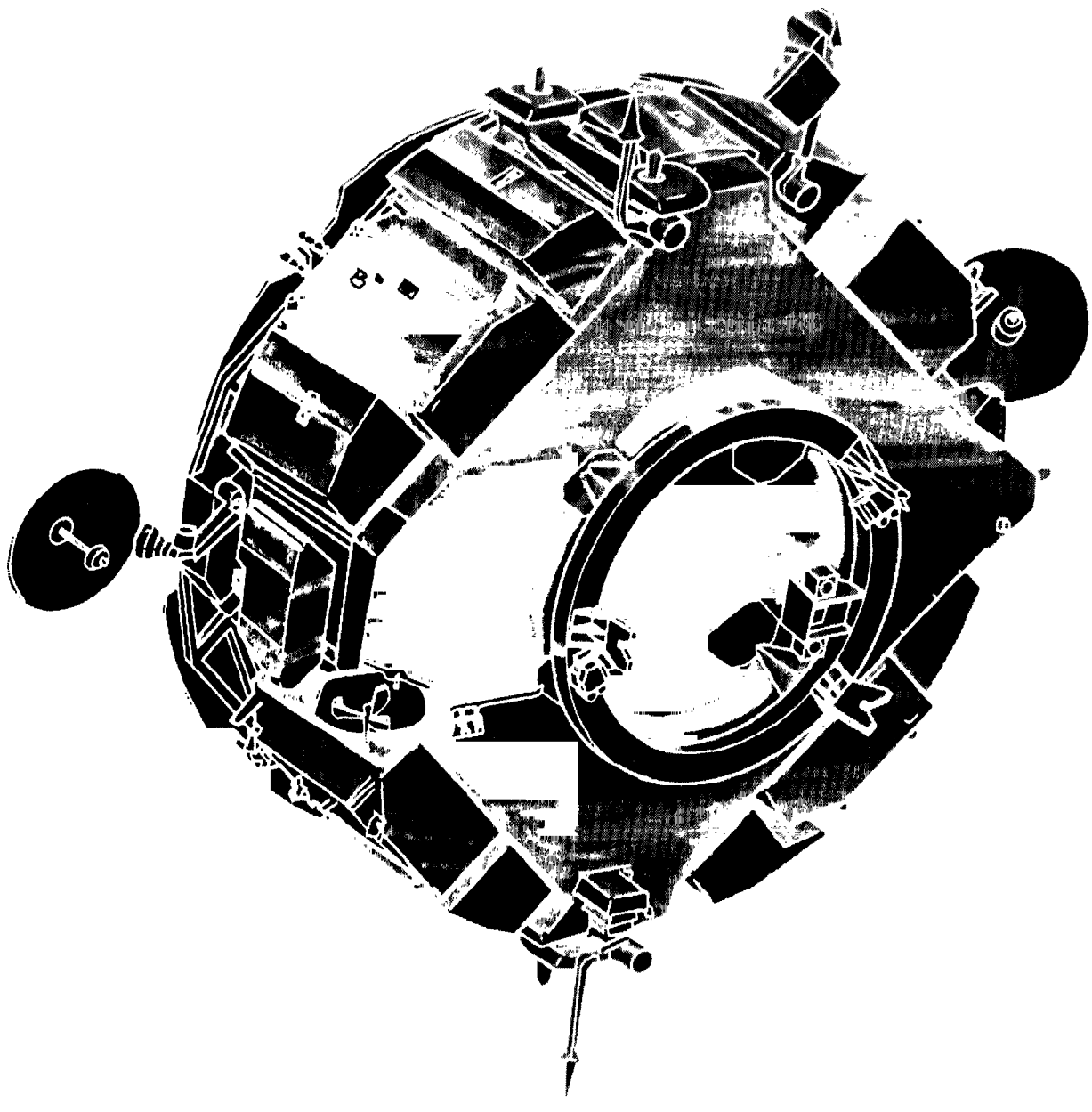
AXAF	Advanced X-ray Astrophysics Facility
GAO	General Accounting Office
HST	Hubble Space Telescope
NASA	National Aeronautics and Space Administration
OMV	Orbital Maneuvering Vehicle

Introduction

The National Aeronautics and Space Administration (NASA) is developing the Orbital Maneuvering Vehicle (OMV) to supplement the space shuttle's capability to deliver, retrieve, and service satellites. The OMV is to provide the capability to transport satellites to and from the shuttle's cargo bay and other orbital altitudes and inclinations[1] and to reboost the satellites when their altitudes decay. Other capabilities are to include viewing satellites to help diagnose their condition and controlling the reentry of satellites into the earth's atmosphere when their useful lives expire.

[1]Orbital altitude is a satellite's height above the earth. Inclination is the angle of the satellite's orbit relative to the earth's equator.

Figure 1.1: Orbital Maneuvering Vehicle



The OMV is to be a remotely controlled, free-flying vehicle. It will be about 15 feet in diameter and 6 feet thick and will weigh 19,200 pounds with a full load of fuel.

The OMV is to have three propulsion systems: a main propulsion system to provide the vehicle's primary thrust, a reaction control system to provide the control needed to maneuver and guide the vehicle, and a cold gas system to propel the vehicle when it is operating close to satellites that are very sensitive to contamination. The OMV will have its own thermal, electrical, guidance, navigation, control, data management, and communications subsystems. The OMV is designed to be carried to orbit inside the shuttle's cargo bay. Once separated from the shuttle, it will be remotely controlled by astronauts working at consoles on earth.

In a typical satellite reboost mission, the OMV will first be removed from the cargo bay by the shuttle's remote manipulator arm. After the shuttle moves a safe distance from the OMV, the ground-based OMV operators will remotely ignite the vehicle's propulsion system and provide the commands needed to guide it to the general area of its target satellite. Upon arrival at the approximate rendezvous area—about 3 miles behind and 1 mile below the target—the OMV's on-board radar will seek the precise satellite location. When the OMV is about 1,000 feet from its target, a television camera and floodlights aboard the vehicle will be switched on, and the earth-based operators will begin a slow docking maneuver. Just before docking, the relative speed between the vehicle and its target satellite will be extremely slow—perhaps only an inch or less per second. Once docking is accomplished, the operators can guide the OMV and the satellite to its destination and then return the OMV to the shuttle.

After each mission, the shuttle will return the OMV to earth, where it will be refurbished and stored for use on future flights. With refurbishment, the OMV is expected to last 10 years.

Program History

The OMV's conceptual design has evolved over a number of years. NASA planned to use its predecessor, the Teleoperator Retrieval System, to reboost Skylab to a safe orbit, but it terminated the program in 1978 when Skylab reentered the earth's atmosphere earlier than expected. NASA then redefined the concept to make the vehicle more versatile. From 1983 through 1985, NASA and three contractors conducted studies and analyses to define a preliminary design for the OMV.

The detailed design and development phase began in November 1986 when NASA selected TRW, Incorporated, as the OMV prime development contractor. The cost-plus-award-fee contract with TRW provides for the design, development, test, verification, and delivery of one OMV flight

vehicle and associated support equipment. It also includes mission support for the OMV's development test flight and refurbishment of the vehicle following that flight. The contract contains options for production of a second OMV flight vehicle and mission support for up to nine additional OMV flights.

In mid-1989, TRW notified NASA that it anticipated overrunning negotiated contract costs. Following the disclosure, NASA decided to restructure the program. Both TRW and NASA strengthened program management and reduced the scope of the development contract to lessen cost and technical risks. The scope reductions simplified the vehicle's design but also reduced its planned capabilities. In addition, NASA and TRW agreed in principle to change the contract fee structure. The contract originally provided for a base fee and a variable award fee determined by NASA's periodic evaluations of TRW's contract performance. The parties had agreed to eliminate the base fee and make all future fee payments contingent on NASA's periodic award fee evaluations. The conversion of the contract to an all award-fee contract was never officially finalized.

NASA also decided to revise the program schedule, stretching the development program out by 18 months because of fiscal year 1990 and 1991 funding limits. The OMV's first launch, originally planned for April 1990, was scheduled for April 1995.

Program Costs

NASA estimated that OMV development would cost $736.5 million. Through fiscal year 1990, the Congress has appropriated $245.6 million. NASA requested another $85.4 million for OMV in its fiscal year 1991 budget.

Program Management

The OMV is being developed under NASA's Office of Space Flight. The Marshall Space Flight Center, NASA's lead center, is responsible for total OMV program management. Marshall is also responsible for the design, development, test, and evaluation of the OMV flight vehicle and its ground support equipment, airborne support equipment, payload accommodations equipment, and ground control console. The Johnson Space Center is responsible for activities associated with integrating the OMV and its payloads into the space shuttle and for OMV flight operations. The Kennedy Space Center is responsible for launch and landing activities.

Objectives, Scope, and Methodology

We reviewed the OMV program at the request of the Chairman, House Committee on Science, Space, and Technology. Our objectives were to determine (1) whether NASA had established a firm need for the OMV and (2) why the program's costs had increased.

To determine if NASA had established a firm need for the OMV, we reviewed NASA studies, reports, and briefings that addressed uses for and alternatives to the OMV. We discussed potential uses and benefits of the vehicle with OMV program officials at NASA Headquarters, Marshall Space Flight Center, Johnson Space Center, and TRW. We also interviewed managers of NASA and Department of Defense programs identified as potential OMV users to determine their requirements for the vehicle and other alternatives for accomplishing the missions. These included officials of the Hubble Space Telescope, Advanced X-ray Astrophysics Facility, Gamma Ray Observatory, Satellite Servicing System, Space Station Freedom, Earth Observing System, Waves in Space Plasma, Mars/Lunar Initiative, Shuttle-C, and Survivable Power Subsystem programs.

To determine the reasons for program cost growth, we reviewed internal NASA program, contract, and budget documents and contractor cost reports. We also discussed the reasons for cost growth with NASA and TRW program officials.

We reviewed the OMV program from August 1989 through April 1990 in accordance with generally accepted government auditing standards.

NASA Has Not Established a Firm Need for the OMV

NASA does not need the OMV to accomplish the primary missions for which it was designed. In late 1989, NASA reduced or eliminated a number of the vehicle's planned capabilities to contain growing costs. The designated missions of the OMV were to reboost the Hubble Space Telescope (HST) and deploy and reboost the Advanced X-ray Astrophysics Facility (AXAF). NASA can accomplish these missions with the shuttle at less cost than the continued development and operation of the OMV. Furthermore, requirements for other potential missions using the OMV are uncertain, and most of these missions cannot be completed with the currently configured OMV.

Program Restructuring Reduced OMV's Capabilities

As originally conceived, the OMV was to be used as a multipurpose space tug for a number of satellites. It was to transport payloads or satellites to and from the shuttle or space station and other orbits, reboost them when their orbits decayed, retrieve and return them when they malfunctioned, examine payloads to help determine whether and why they malfunctioned, and control their reentry into the atmosphere when their useful lives expired. In 1989 NASA restructured the program to contain escalating costs. Many of the OMV's planned capabilities were reduced or eliminated in the restructuring. NASA was designing the OMV in such a way that these capabilities could be restored later, if needed. Table 2.1 shows the major OMV performance characteristics and the effects of the restructuring.

Table 2.1: Status of Major OMV Performance Requirements

Performance requirement	Eliminated	Reduced	Unchanged
Missions			
Deliver payloads		X	
Retrieve payloads		X	
Reboost payloads		X	
Deboost payloads[a]		X	
View payloads[b]		X	
OMV Basing and Control			
Shuttle based			X
Space station based	X		
Space based[c]	X		
Ground controlled			X
Station controlled	X		
Automatic navigation to payloads	X		
Manned control during final docking			X
OMV Operations			
Cold gas propulsion[d]			X
Low "G" trajectory[e]			X
Contingency return of payloads	X		
Accommodation of various enhancements		X	
Payload Accommodations			
Provide limited resources to payloads	X		
3-point docking system			X
1-point docking system	X		
OMV Maintenance			
On-orbit maintenance	X		
10-year refurbishment			X

[a]Deboost - controlling the angle and location at which a satellite reenters the Earth's atmosphere.

[b]Viewing - flying around satellites to examine them for possible malfunctions.

[c]OMV was to have been capable of parking in orbit for up to 9 months between missions.

[d]Cold gas propulsion is needed to avoid contaminating some payloads, such as the Hubble Space Telescope.

[e]Low "G" trajectory means very low acceleration.

Scaling down the OMV's capabilities limited the missions it would be able to accomplish. Because of changes in its propulsion, electrical power, and guidance systems, the OMV would not be able to deliver, retrieve, or reboost payloads as far as originally planned. It would not be able to deboost as large a payload as originally planned.

The reductions were most dramatic in the delivery and deboost missions. For example, the distance the OMV could transport a 3,500-pound satellite in an initial delivery mission was reduced by 60 percent.[1]

The shuttle alone can deliver large payloads into space more efficiently, according to a recent assessment by the Johnson Space Center. This study showed that the shuttle can deliver payloads weighing more than 9,000 pounds to higher orbits than the shuttle-OMV combination could deliver them. With the combined weight of a payload and the 19,200-pound OMV, the shuttle's initial orbiting altitude will be lower, and the reduced-capability OMV would not be able to make up for the lower shuttle altitude.

Also, the reduced-capability OMV would not be able to control the reentry of large payloads, whose fall to earth may present a safety hazard. The full-capability OMV was expected to be able to deboost payloads weighing up to 75,000 pounds; the reduced-capability OMV would not be able to deboost payloads weighing more than 15,000 pounds. NASA currently has no requirement to deboost payloads weighing less than 15,000 pounds, since objects of this size and smaller normally burn up during reentry into the Earth's atmosphere, according to the NASA headquarters OMV Program Manager.

NASA would not be able to base the reduced-capability OMV at Space Station Freedom and control it from that location or to leave the vehicle in space between missions. Therefore, the OMV would have to be transported to and from each mission on the shuttle.

The reduced-capability OMV would not be able to automatically navigate to its payload as was originally planned. Ground controllers would have to guide it during the entire flight sequence. As a result, the time needed to track a target payload increased from 5 minutes to about 3 hours. Two additional ground-based flight controllers would be needed to generate data for the tracking.

The reduced-capability vehicle would not be able to provide resources such as communications or power to its payloads except for rare instances when payloads would be hard-wired to the OMV. Also, one of two planned docking mechanisms was eliminated from the vehicle

[1]The reduction was from 340 nautical miles to 135 nautical miles, assuming a 1-degree change in the satellite's orbital inclination.

design during the restructuring. As a result, the OMV would not be compatible with some payloads that might be carried on the shuttle.

Originally, the OMV was to have been repaired while in orbit by astronauts who would have worked from Space Station Freedom to remove and replace groups of components called "orbital replacement units." The reduced-capability OMV would not have orbital replacement units. If it malfunctioned while in space, it would have to be returned to earth for repairs.

According to NASA officials, the OMV was designed so that capabilities eliminated in the restructuring could be restored to the vehicle if they were needed. Space would be reserved in the vehicle to restore the capabilities, and any needed couplings would be built.

OMV Not Needed for Scheduled Missions

The reduced-capability OMV is being designed primarily to deploy the AXAF and reboost the AXAF and HST as their orbits decay. Recent NASA studies show, however, that the vehicle is not needed to perform these missions. The cost of using only the shuttle for these missions is lower than the cost of continued development and operation of the OMV.

Shuttle Can Deliver AXAF Without OMV

Under NASA's current schedule, the shuttle will be able to deploy the AXAF observatory without OMV's assistance. Advanced solid rocket motors needed for the shuttle to deliver the AXAF to its required altitude are scheduled to be available more than a year before the planned 1997 launching of the observatory.

To avoid having to reboost the AXAF for at least 5 years, NASA would like to deliver it to an initial orbital altitude of 320 nautical miles. Altitudes of large satellites in low earth orbit decay over time due to drag, which is influenced by activity on the sun. The observatories' abilities to collect scientific data could be adversely affected if their orbits are allowed to get too low, especially during periods of high solar activity. As a result, NASA expects that the observatories may have to be reboosted to higher orbits from time to time. However, at an initial altitude of 320 nautical miles, NASA estimates that it should not be necessary to reboost the AXAF during its first 5 years on orbit.

NASA officials once believed that the OMV was needed to get the AXAF to an altitude of 320 nautical miles. With its current solid rocket motors, the shuttle will not be able to deliver the 32,800-pound AXAF to an

orbital altitude higher than about 270 nautical miles. A February 1990 performance assessment by the Johnson Space Center showed, however, that the shuttle cannot carry both the AXAF and OMV into orbit on the same flight. The assessment also showed that with the advanced solid rocket motors, expected to be available in December 1995, the shuttle can carry AXAF to an initial orbit of 320 nautical miles without the OMV. The OMV will not be needed for AXAF deployment if the shuttle's advanced solid rocket motors are available as scheduled.

If NASA cannot maintain the schedule for the advanced solid rocket motors and they are not available when AXAF must be launched, NASA could launch the observatory on a shuttle with currently designed motors and boost it to a higher orbit later. Either the shuttle or the OMV could provide the boost. Without the OMV, two shuttle flights would be needed to boost AXAF to its desired altitude of 320 nautical miles; with the OMV, only one flight would be needed. If the OMV were used, it could be carried into space prior to the AXAF being launched, or the OMV could be launched after the AXAF deployment to boost the observatory to its desired orbit. However, the OMV's current design would have to be modified to allow it to remain in space for several months.

Shuttle Can Reboost Observatories at Lower Cost

Recent NASA studies show that the shuttle can reboost the HST and AXAF observatories without the OMV. By reboosting the observatories a little during each scheduled maintenance visit, only one or two shuttle flights dedicated to reboosting the observatories should be required to keep them at sufficiently high altitudes even under worst-case conditions, according to the studies. The two dedicated shuttle flights would be less costly than continued OMV development and operation.

NASA plans for the shuttle to revisit HST and AXAF periodically to maintain them and to replace their scientific instruments. Current plans are to revisit the HST every 3 years for maintenance and every 5 years for instrument replacement. One new scientific instrument is already under development and should be available for incorporation into the HST in 1995. AXAF is to be revisited every 5 years for servicing and refurbishment.

Two space studies show that the shuttle will be able to keep the observatories at acceptable altitudes even without the OMV. According to a September 1989 Johnson Space Center study, the shuttle can reboost the HST a little on each scheduled maintenance mission and keep it at a sufficiently high altitude through the turn of the century. If solar activity is

especially high near the turn of the century, one additional flight might be needed to reboost HST to a sufficiently high altitude. However, according to the study, the telescope will not have to be reboosted if solar activity is at an average level.

In a similar study completed in March 1990, NASA's Office of Space Flight concluded that one or two additional shuttle flights might be required early in the next century to reboost the observatories without the OMV. One flight dedicated to reboosting AXAF would be needed in 2000 and one flight dedicated to reboosting HST would be needed in 2001. All other reboost requirements could be accomplished during planned maintenance and refurbishment missions.

These two shuttle flights are a less costly way of reboosting the observatories than continued development and operation of the OMV. The marginal costs of two shuttle flights in fiscal years 2000 and 2001 together with the cost of terminating the OMV program would be about $277 million. The cost of completing the OMV development, conducting the development test flight, storing the vehicle at Kennedy, and operating it for the two flights would cost over two and one-half times that amount—an estimated $716 million. The two estimates are shown in table 2.2.

Table 2.2: Costs of Options for Reboosting HST and AXAF Observatories

Dollars in millions

Cost category	Shuttle only	Shuttle with OMV
Complete OMV development	[a]	$529.50[b]
OMV termination cost	$79.40	
Shuttle flight for OMV development test (1995)[c]	[a]	77.50
OMV storage (1996-99)	[a]	17.60
Shuttle flight to reboost AXAF (2000)[c]	96.60	[a]
OMV flight to reboost AXAF	[a]	44.88
Shuttle flight to reboost HST (2001)	100.95	[a]
OMV flight to reboost HST	[a]	46.90
Total	**$276.95**	**$716.38**

[a]Not applicable.

[b]The current cost estimate to complete OMV development is $736.5 million less costs expected to be incurred through June 30, 1990, ($207 million).

[c]The shuttle flight costs are the marginal cost of a 1995 flight, the last year for which NASA has projected shuttle flight costs. Marginal costs are the incremental costs for adding one additional shuttle flight in each of the years. These costs do not include fixed costs associated with shuttle flights, which NASA will incur whether or not additional flights are undertaken.

Future Mission Requirements Are Uncertain

According to NASA's Office of Space Flight, the OMV is needed not only for delivery and reboost of HST and AXAF but also as a part of the nation's overall space transportation infrastructure. However, NASA has not yet decided to undertake any of the missions it has identified as potential applications for the OMV. Furthermore, the currently configured OMV would not be able to perform the missions even if they were approved. The potential missions include (1) carrying supplies and materials from expendable launch vehicles to Space Station Freedom, (2) serving as the propulsion module for the station's assured crew return vehicle, (3) transporting equipment and supplies from expendable launch vehicles to the station's Polar Orbiting Platform, (4) transporting automated satellite servicing equipment, and (5) providing a contingency capability in the event of another shuttle accident.

Using expendable launch vehicles with the OMV to resupply Space Station Freedom would reduce requirements for the space shuttle, according to officials of NASA's Unmanned Launch Vehicles and Upper Stages Branch of the Office of Space Flight. The OMV could be used to transfer the supplies from the expendable launch vehicles, which would be parked 20 nautical miles away, to the station. Similarly, the OMV could be used to transfer to and from the station materials needed for any manned missions to the moon and Mars. According to NASA, the OMV would have to be modified so that it could be based either at the station or in space, and the amount of propellant it could carry would have to be increased to accomplish these missions. Neither of the missions has been approved. NASA currently plans to use the manned shuttle to resupply all of the station's needs. No decision has been made on ways to accomplish any manned missions to the moon and Mars. Also, NASA may have alternatives to using the OMV for these missions. At least one firm is interested in providing commercial launch services for station resupply. This firm maintains that it could deliver the supplies and materials to the station.

The OMV development contractor has proposed using the OMV to return a crew from Space Station Freedom to Earth in an emergency. However, the OMV's design would have to be modified to permit the vehicle to be based at Freedom and to increase its propulsion capabilities. NASA is currently studying various ways of returning crews from Freedom but does not plan to select a crew return vehicle design until 1994.

According to OMV program officials, the OMV could be used with expendable launch vehicles to resupply the polar orbiting platform, which is planned as part of NASA's Earth Observing System. However, according

to a program official, it would not be cost-effective to design the polar orbiting platform so that it could be resupplied. Even if NASA later decided to include the capability to resupply the polar orbiting platform in its design, the currently configured OMV could not be used in the resupply operation. The OMV would have to be modified to make it compatible with expendable launch vehicles and enable it to be based in space or at the platform. Also, another OMV would have to be purchased for this mission, since the space shuttle cannot go to polar orbit, and the OMV could therefore not be retrieved from the platform.

The OMV might also be used to transport automated satellite servicing equipment if development of that equipment is approved. NASA is currently studying designs that would enable it to maintain satellites in orbit by robotically replacing component modules and refueling the satellites. If developed, the satellite servicing system could be attached to the OMV. However this system is not expected to be available before 2000, potential servicing missions have not been defined, and robotically serviceable satellites do not currently exist. Also, the OMV's design would have to be modified to enable it to be used with the satellite servicing system.

OMV program officials also have stated that the vehicle could be used if the shuttle were to become incapacitated. For example, the OMV and expendable launch vehicles could resupply the station if the shuttle were not available for a long period. However, the OMV would have to be modified so that it could be launched on an expendable launch vehicle.

Estimated OMV Costs Have Continued to Increase

OMV's estimated costs have substantially increased due to schedule stretch-outs, program content changes, and contract cost growth. Further increases are likely because the OMV is in an early stage of development, reserves to cover future program changes are less than NASA normally includes in its estimates, and system enhancements are needed for OMV to perform some of its potential missions. Program acquisition costs could also increase to about $1.3 billion if NASA restores the capabilities eliminated from the OMV's design, purchases a second vehicle, makes the two vehicles compatible with expendable launch vehicles, and purchases an initial contingent of spare parts. NASA has not yet prepared a complete estimate of operational phase costs but has estimated the costs of certain specific missions.

Program Costs Have Grown Substantially

Since OMV development was approved in 1986, estimated program costs have increased about 82 percent, from $405.0 million to $736.5 million. At the same time, the vehicle's capabilities have been significantly reduced. The program estimate would have been about $890.0 million if NASA had not reduced the estimate by about $154.0 million by eliminating some of the OMV's capabilities and paring cost reserves. Table 3.1 shows the cost changes.

Table 3.1: Changes in OMV Cost Estimates

Dollars in Millions

Cost changes	Amount
Increases	
Schedule stretch-outs	$256.1
Program changes	105.9
Contract cost growth	123.1
Subtotal of increases	**$485.1**
Decreases	
Reduced technical capabilities	−$81.5
Reduced cost reserves	- 72.1
Subtotal of reductions	**- 153.6**
Net change	**$331.5**

According to NASA, schedule stretch-outs resulting from internally imposed budget cuts are the primary cause of the cost increases to date. NASA has reduced the OMV budget in each of the last 4 years to fund higher priority programs. The budget reductions meant that work had to be postponed and the development program delayed. The stretch-outs

have added 5 years to the OMV's development program. The schedule for the vehicle's first flight slipped from April 1990 to April 1995. Schedule stretch-outs increased OMV costs over $256 million.

According to NASA and TRW officials, the primary lesson to be learned from the OMV program is that a project started without a firm, near-term requirement is likely to "become the bank" for programs with more immediate funding needs. Because no other program is dependent on the availability of OMV, NASA reduced its budget and stretched out development to provide more funds for other, more urgently needed programs.

Program changes added about $106 million to estimated costs. A primary change was associated with moving responsibility for OMV operations from the Marshall Space Flight Center to the Johnson Space Center. When the program was initially approved, the Marshall Space Flight Center was assigned responsibility for both development and operations. Soon after the contract was signed, however, NASA decided to shift responsibility for OMV operations to the Johnson Space Center. Officials at Johnson concluded that developing the hardware and software for OMV operations and operator training would cost about $69 million more than previously estimated. Various other program changes added another $37 million to the estimate. These included, for example, changes resulting from the vehicle's preliminary design review.

Contract cost growth accounts for an increase of over $123 million, of which $75 million was for the prime contractor's work and $48 million was for estimated subcontract costs. According to the previous OMV Program Manager, TRW's original contract price of $212 million underestimated OMV development costs. TRW agreed that its original contract price was too low because it had made optimistic assumptions. For example, TRW had assumed that it would not have to develop unique components for the OMV but instead could use some off-the-shelf hardware. TRW also believed that the frequency of OMV schedule changes contributed to its inability to estimate prices.

The program cost estimate would have been even higher if it had not been offset in part by contract scope reductions in 1989 and reductions in cost reserves. The reductions in scope included simplifying the OMV's design and decreasing its planned capabilities. Spare parts and some tests and documentation were also deleted. In addition, NASA also reduced the amount of reserves contained in the estimate to absorb

future cost increases. The estimate just prior to the program restructuring contained reserves equal to about 34 percent of the future development costs. Reserves in the current estimate are equal to about 15 percent of the remaining development costs.

Further Cost Increases Are Likely

OMV costs will likely continue to rise, especially if NASA is to make maximum use of the vehicle. The program is still in an early design phase, and reserves to cover future cost increases are significantly less than NASA normally includes in its program cost estimates. Further, to complete some potential missions, NASA would have to modify the OMV by restoring some capabilities previously deleted and adding a new capability—delivery of the OMV by expendable launch vehicles. NASA may also have to purchase an additional vehicle and the spare parts needed for maintenance.

Adequacy of Cost Reserves

The OMV development program is less than half complete, and those same factors that caused cost increases in the past could also cause future cost increases. The $736.5 million estimate includes a $72.6 million reserve to absorb future cost increases, but that amount is only about half the amount NASA normally budgets for programs at this stage in development, according to the Chief of the Cost and Economic Analysis Branch, NASA Comptroller.

The OMV program could experience more of the same type of budget cuts that have already caused schedule stretch-outs and added $256.1 million to the program's cost. NASA's Associate Administrator for Space Flight told the Subcommittee on Space Science and Applications, House Committee on Science, Space, and Technology, in February 1990 that if NASA has to make budget cuts in fiscal year 1991, the "OMV would not be immune to its fair share of the cuts." In this regard, NASA's fiscal year 1991 budget request of $15.1 billion represents a 23-percent increase over fiscal year 1990, and the agency projects that its budget requirements will increase by another 17 percent in fiscal year 1992 and an additional 10 percent in fiscal year 1993. With projected increases of this magnitude, cuts in NASA's budget requests are a distinct possibility as Congress attempts to address the deficit and other pressing fiscal issues over the next several years.

More design changes are also to be expected. The program's critical design review is not scheduled until April 1991. Following the design review, the contractor will begin hardware fabrication and testing.

Design changes are to be expected as a result of the design review and fabrication and testing activities. According to the Chief of NASA's Cost and Economic Analysis Branch, most cost increases occur during a program's hardware fabrication and testing phases. According to this official, it is not unusual for development programs to take longer than planned because of problems identified during testing of complex components such as electronic assemblies.[1] Extending a program increases its cost.

Other contract cost increases are also possible, particularly in subcontracts. Subcontract costs in the $736.5 million estimate, are for the most part not based on negotiated prices or firm proposals from the subcontractors. Through February 1990, firm prices had been negotiated for only about 65 percent of the subcontracts. Also, TRW did not have proposals from subcontractors detailing the cost impact of the most recent program stretch-out. According to Marshall's Deputy OMV Project Manager, NASA believes that the current estimate for subcontracts is adequate, but it cannot be certain of that until firm proposals are received and negotiated.

The $72.6 million cost reserve included in the estimate is less than half the amount NASA normally includes in program estimates prior to critical design review. The reserve, or allowance for program adjustment, is intended to absorb cost increases that may occur in the future. According to the Chief of NASA's Cost and Economic Analysis Branch, NASA would normally include in the estimate a cost reserve equal to about 30 percent of future costs for such a complex program prior to its critical design review. The OMV reserve is only about 15 percent of future costs.

According to the Deputy OMV Project Manager, when NASA restructured the development program in 1989, it reduced the OMV's cost and technical risk. The Deputy Project Manager concluded that, in total, the cost reserves would be adequate, but amounts available in fiscal years 1990 and 1991 would be marginal. If costs were to increase significantly in these years, work would have to be deferred and the schedule might have to be delayed again.

[1]There is a 4-month cushion built into the OMV program to accommodate schedule changes during the fabrication and testing phase.

Future Program Enhancements

NASA is considering purchasing an additional vehicle, restoring capabilities, and modifying the OMVs to make them compatible with expendable launch vehicles. According to preliminary NASA estimates, these actions, together with an initial contingent of spare parts for the two vehicles and a spare propulsion module could add another $540.6 million to the OMV's acquisition cost, raising the total for two OMVs to about $1.3 billion. NASA considered that the additional costs, if required, would be a part of the vehicle's operational, rather than the developmental program. Table 3.2 shows the potential additional acquisition costs.

Table 3.2: Potential Additional OMV Acquisition Costs

Dollars in millions

Cost Category	Cost
Restored capabilities	$112.7
Second OMV	303.8
Expendable launch vehicle compatibility	25.2
Spare parts	69.3
Spare propulsion module	29.6
Total	**$540.6**

Modifying the OMV would cost about $112.7 million, according to a preliminary NASA estimate. This estimate assumes that the OMV would be modified to restore its full capabilities after NASA purchased a second OMV with full capabilities. Another $25.0 million would be needed to design, develop, and qualify the modifications if NASA did not purchase a second vehicle.

NASA estimated that a second, full capability OMV could be purchased for about $303.8 million if production of the vehicle were authorized for fiscal year 1993. The vehicle would be delivered in May 1998.

Modifying the two OMVs to make them compatible with expendable launch vehicles such as the Titan IV would cost an estimated $25.2 million. Purchasing the initial contingent of spare parts and components needed to maintain the vehicles would cost another $69.3 million between fiscal years 1993 and 1996. A spare propulsion module, which might be needed if the OMV were based at Space Station Freedom, would cost an estimated $29.6 million.

NASA considers it unlikely that it would do all of these things. The agency described them as "an accumulation of various possible options

that represent a worst case scenario that probably would never materialize."

OMV Operational Costs

Because of uncertainty about when and for what purposes the OMV would be used, NASA has not prepared a comprehensive estimate of OMV operations costs. Instead, the agency estimated operation costs for two alternative mission scenarios.

Both scenarios involve reboosting the HST in mid-1996 and boosting the AXAF to its desired altitude when it is deployed in 1997. In the first scenario, the OMV would be carried into space and left there to await AXAF deployment. In the second scenario, the AXAF would be launched first and the OMV brought up later to boost the observatory to its final altitude. NASA estimated that the first scenario would cost about $90.1 million, while the second would cost about $81.7 million. Both estimates include costs to (1) store the OMV following its 1995 test flight; (2) remove the OMV from storage, prepare it for launch, and reboost the HST with it in June 1996; (3) refurbish the OMV following the HST reboost; (4) launch and operate the OMV to boost AXAF to its final destination in 1997; and (5) refurbish the OMV and place it in storage to await some future mission. The primary difference between the two estimates is that the first scenario includes the cost of adding gallium arsenide solar arrays to equip the OMV for space basing.

NASA also estimated the annual recurring cost of storing the OMV between missions and the operation cost for a typical reboost mission. Both of these estimates are in constant fiscal year 1990 dollars, since it is not known when the reboost mission would occur or how long the vehicle would have to be stored between missions. NASA estimated that $3.2 million a year would be needed to store the OMV and that an additional $28.9 million would be needed for a typical reboost mission.[2]

[2]OMV storage and operations shown in table 2.2 on page 21 are based on these estimates, but the amounts in the table include an allowance for future inflation of 4.5 percent a year for each year after 1990.

Conclusions, Recommendation, Matter for Congressional Consideration, and Agency Comments

Conclusions

NASA has not adequately justified or established a need for the OMV. The vehicle's two scheduled missions can be accomplished by other means that cost less. Furthermore, although NASA has identified other potential missions for the vehicle, these missions have not been approved and no requirements have yet been firmly established for them. Even if these missions were approved, the OMV would have to be modified, at additional cost, before it could be used for them.

Because NASA has not had a firm need for the OMV, it has been a target for budget cuts that have proved to be costly to the OMV program. Faced with more pressing needs and not enough funds, NASA officials have reduced the program's funding in each of the last 4 years to fund higher priority programs that had firmer requirements. Most of the OMV's cost increase can be attributed to schedule delays.

Further cost increases are likely, especially if NASA is to make maximum use of the vehicle. Schedule delays, program changes, and cost growth have already caused development costs to nearly double. These same factors could cause further increases, since it is still early in the OMV's development stage, and reserves to cover future cost increases are only about half the amount NASA normally budgets in cost estimates of similar programs. Also, OMV program acquisition costs could increase to $1.3 billion if NASA decides to (1) restore all of the vehicle's originally planned capabilities, (2) purchase an additional vehicle, (3) make the two vehicles compatible with expendable launch vehicles, and (4) purchase an initial contingent of spare parts.

A primary lesson learned from the OMV program is that a development program should not be started before a firm requirement is established. Once started, the program should be funded so that it can be conducted expeditiously and efficiently.

Recommendation and Agency Action

In our draft report we recommended that the Administrator terminate the OMV program. NASA estimated that it had already spent $199.4 million on the program through June 6, 1990, and that an additional $79.4 million[1] would be required for termination. However, the remaining $450.1 million cost to complete the development and any additional

[1]The $79.4 million required for termination includes $46.2 million in fiscal year 1990 funds and $33.2 million in fiscal year 1991 funds.

costs for restoring capabilities eliminated in the 1989 restructuring, procuring a second vehicle, and operating the vehicles would be avoided if the program were terminated.

NASA terminated the OMV program and instructed TRW to cease all work under the contract 6 days after receiving our draft report. The agency cited budgetary pressures and the lack of a firm, near-term requirement for the vehicle as reasons for the termination.

Matter for Congressional Consideration

The Congress should deny the $85.4 million requested for OMV development in fiscal year 1991, less any amount needed for termination expenses. According to a preliminary NASA estimate, about $33.2 million of fiscal year 1991 funding will be needed for termination.

Agency Comments

We incorporated NASA's comments into this report where appropriate.

Major Contributors to This Report

National Security and International Affairs Division, Washington, D.C.	Charles Rey, Assistant Director James Morrison, Evaluator
Atlanta Regional Office	Lee Edwards, Evaluator-in-Charge Mark Lambert, Site Senior Karen Lindsey, Evaluator

Requests for copies of GAO reports should be sent to:

U.S. General Accounting Office
Post Office Box 6015
Gaithersburg, Maryland 20877

Telephone 202-275-6241

The first five copies of each report are free. Additional copies are $2.00 each.

There is a 25% discount on orders for 100 or more copies mailed to a single address.

Orders must be prepaid by cash or by check or money order made out to the Superintendent of Documents.

United States
General Accounting Office
Washington, D.C. 20548

Official Business
Penalty for Private Use $300

First-Class Mail
Postage & Fees Paid
GAO
Permit No. G100