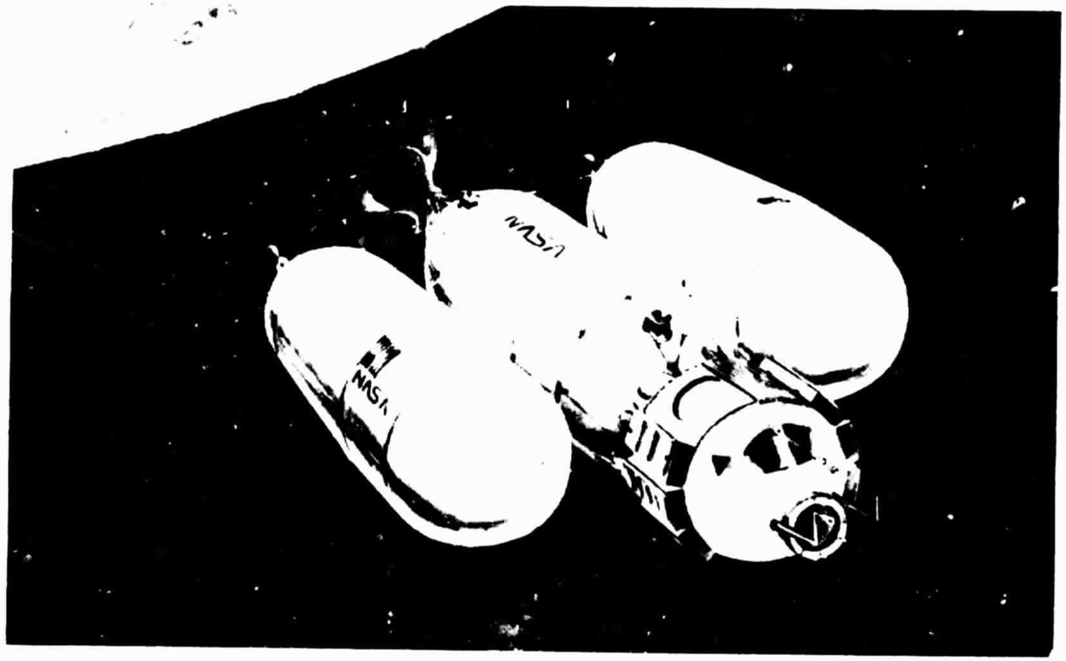
NASA CR 167741

final
briefing

MANNED GEOSYNCHRONOUS MISSION REQUIREMENTS & SYSTEMS ANALYSIS STUDY ADD-ON



GRUMMAN AEROSPACE CORPORATION

MANNED GEOSYNCHRONOUS MISSION REQUIREMENTS & SYSTEMS ANALYSIS STUDY ADD-ON

FINAL BRIEFING
JULY, 1982

GRUMMAN

final
briefing

MANNED GEOSYNCHRONOUS MISSION REQUIREMENTS & SYSTEMS ANALYSIS STUDY ADD-ON

FORWARD

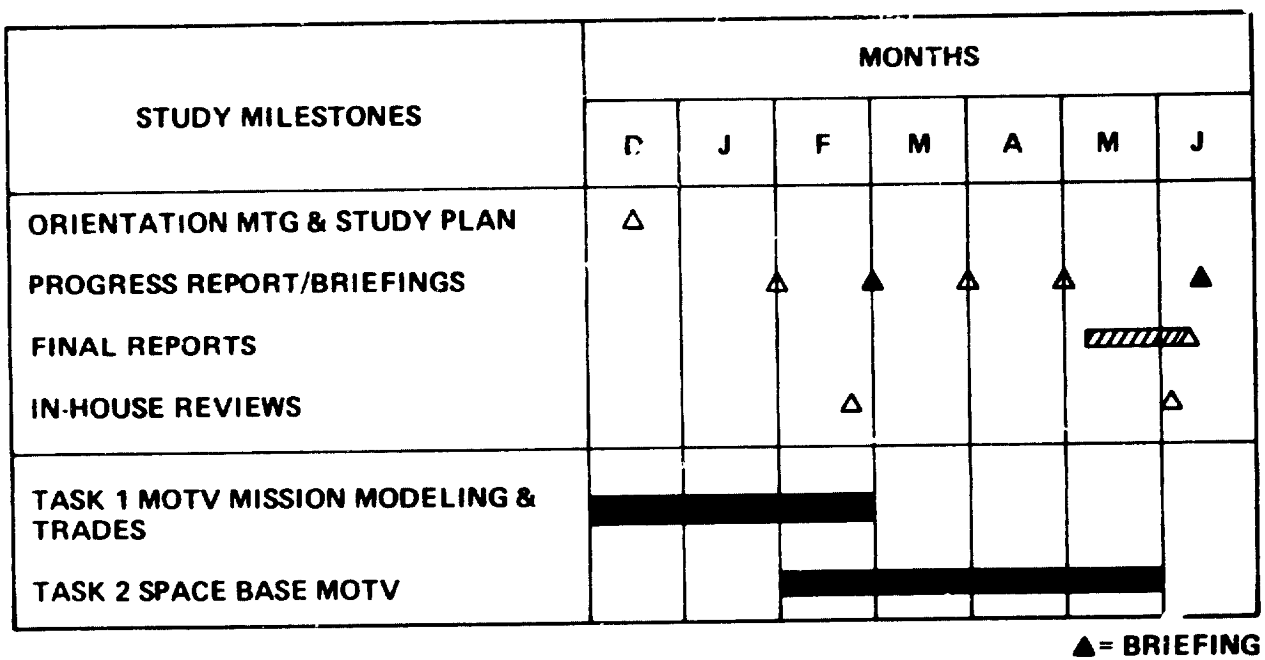
This final report documents the results of a study add-on performed under NASA Contracts NAS 9-15779. The study was conducted under the technical direction of the Contracting Officer's Representative (COR), Herbert G. Patterson, Systems Design, Johnson Space Center. Mr. Lawrence Edwards, NASA Headquarters, Office of Space Transportation Systems, Advance Concepts, was the cognizant representative of that agency.

The Grumman Aerospace Corporation's study manager was Ronald E. Boyland. The major contributors and principal investigators were Stanley W. Sherman, Wesley T. Johnson, and William C. Schoen.

The final report consists of one volume with the following sections:

- Executive Summary
- Turnaround & Configuration Studies
- Performance
- Costing & Sensitivity
- Conclusions & Recommendations

MGMRSAS ADD-ON SCHEDULE



MOTV

TASK 1 – MOTV MISSION MODELING & TRADES

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- OBJECTIVE: CONSTRUCT AN MOTV MISSION MODEL TO ESTABLISH THE BASELINE CONDITION FOR SOC BASING

- APPROACH:
  - EXTEND JSC/SOC MISSION MODEL TO REFLECT SATELLITE SERVICING
  - PROJECT YEARLY TRAFFIC
  - CATEGORIZE DRIVER MISSIONS
  - DETERMINE TRANSITION TO OTV/MOTV
  - PERFORM COST TRADES & SENSITIVITY TO TRAFFIC RATE
  - IDENTIFY SERVICE EQUIPMENT NEEDS.

MOTV

TASK 2 – SPACE BASED MOTV

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- OBJECTIVE: COMPARE 1½ & 2 STAGE, 2 & 3 SHUTTLE LAUNCHED, AND SPACE BASED & GROUND BASED MOTV, IDENTIFY BENEFITS & IMPLICATIONS OF SPACE BASING

- APPROACH:
  - COMPARE 1½ STAGE & 2 STAGE COMMON MOTVs AND THE DIFFERENCES BETWEEN SB & GB VERSIONS
  - DEVELOP SOC BASING CONCEPTS & RELATED SCENARIOS
  - COMPARE MOTVs REQUIRING 2 & 3 SHUTTLE LAUNCHES
  - DETERMINE PROPELLANT SCAVENGING BENEFITS
  - IDENTIFY OPERATIONS COSTS ASSOCIATED WITH SB & GB MOTV
  - SUMMARIZE BENEFITS & IMPLICATIONS OF SPACE BASING
  - RECOMMEND AREAS FOR FURTHER STUDY & TECHNOLOGY DEVELOPMENT.

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MOTV

2 MAN CREW CAPSULE

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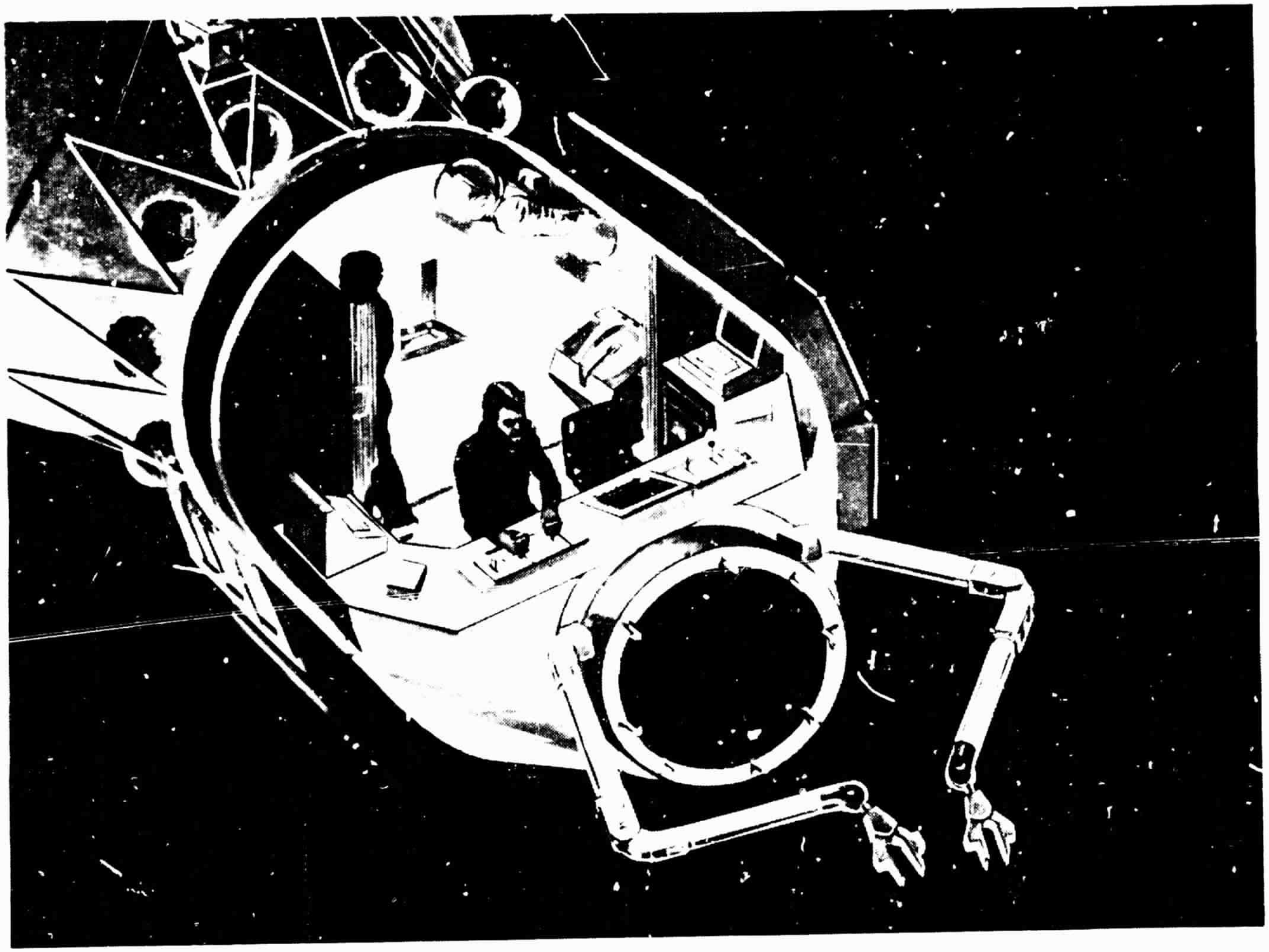

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MOTV

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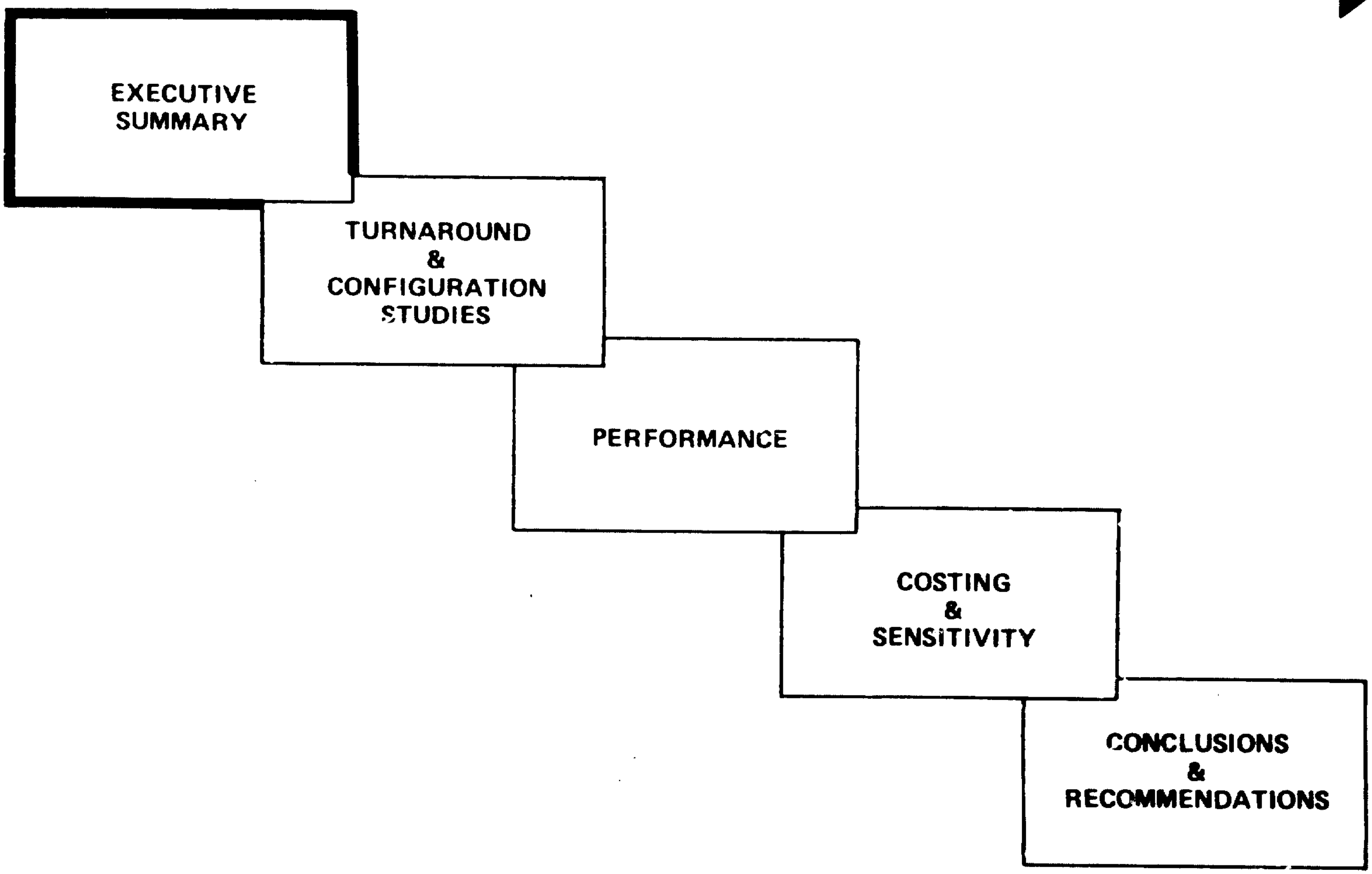
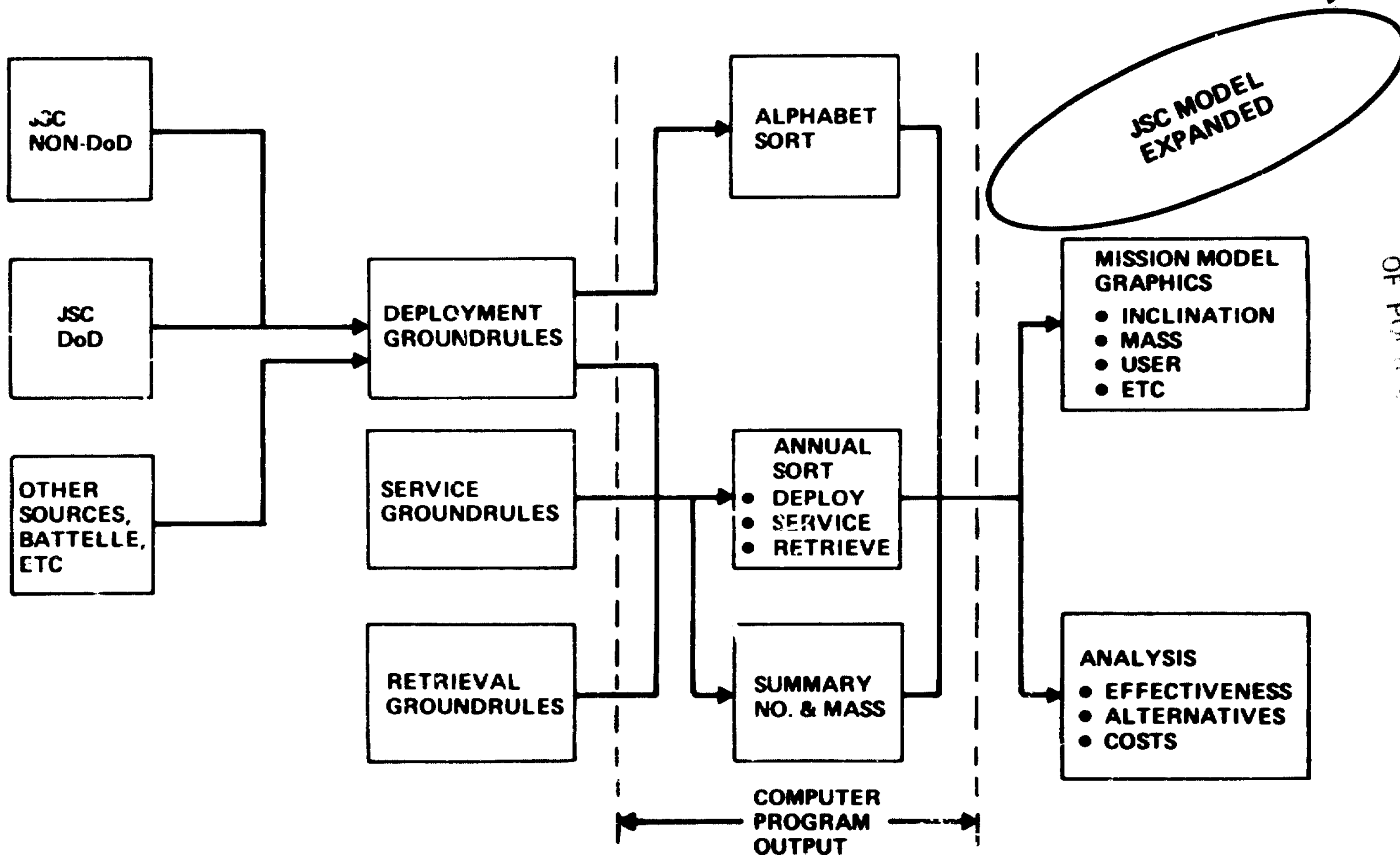


MOTV MISSION MODELING LOGIC

As outlined in the study plan, the mission model for this study is primarily based on data furnished by JSC. The logic chart indicates JSC and other satellite deployment inputs on the left. Deployments are refined and expanded using the deployment groundrules and a deployment library is developed that can be sorted by a computer program. Service and retrieval groundrules are established that, in conjunction with the deployment library and the computer program, allow annual sorts of deployments, servicings, and retrievals plus various payload summaries.

MOTV MISSION MODELING LOGIC (TASK 1)



0477-001D

MISSION SUCCESS OF NEW TELESAT SPACECRAFT

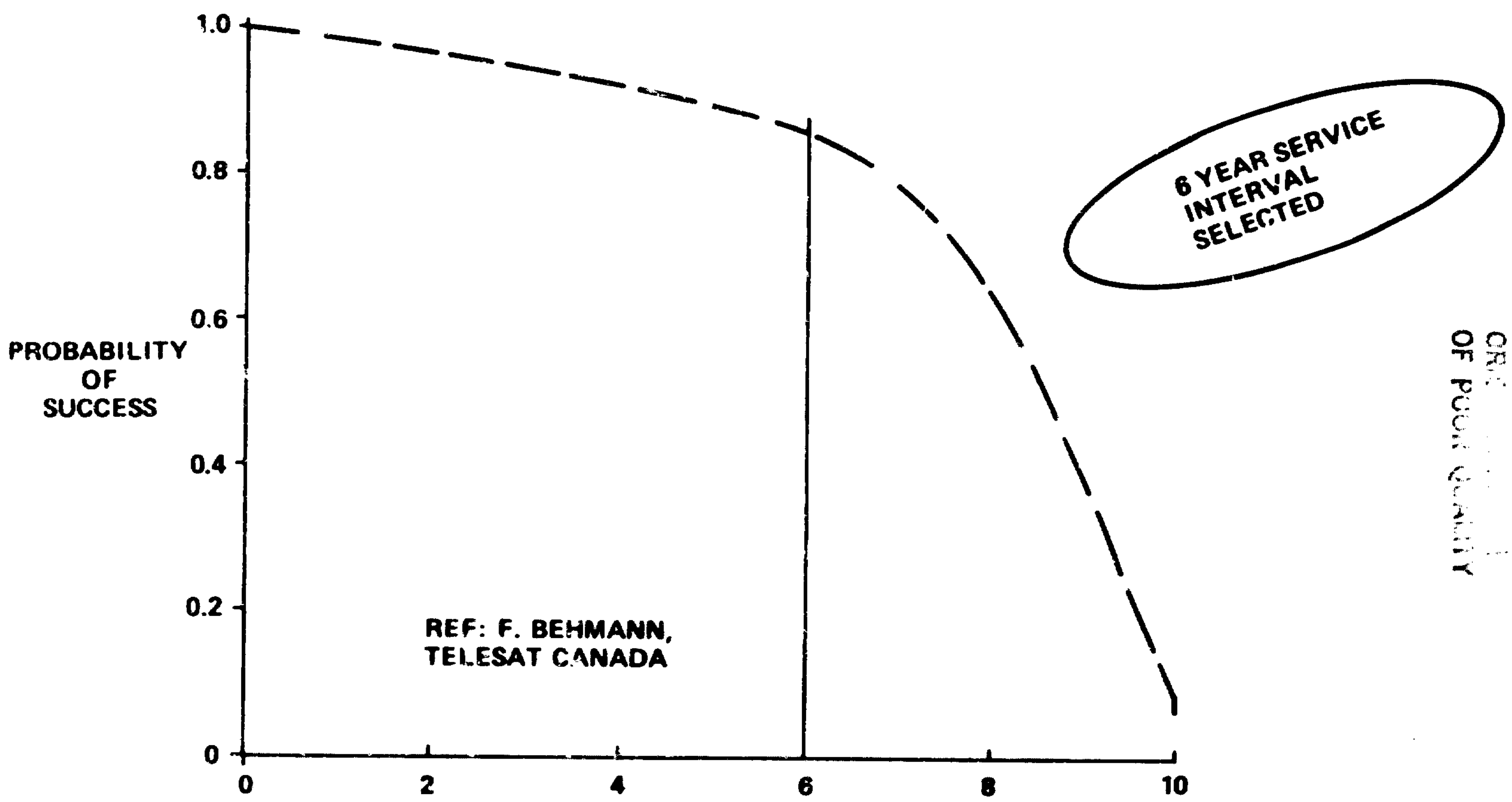
New satellites deployed in the 1990s are expected to have improved reliability. The improved reliability of a new TELESAT spacecraft was estimated by F. Behmann* of Telesat Canada using a reliability wearout model that correlated well with present TELESAT operational data. This new prediction is believed to be typical and indicates rapid degradation after 6 years of service. Servicing on a 6-year interval appears to be a reasonable assumption at this time.

*Improved Reliability for New Satellite Systems, IEEE 1981 Proceedings, Annual and Maintainability Symposium.

MOTV

MISSION SUCCESS OF NEW TELESAT SPACECRAFT

GRUMMAN



0477-079D

OVERCROWDING IN GEO ORBIT

The following two charts were prepared by Walter Morgan, formally of COMSAT and currently with the Communication Center of Clarksburg. They depict current and projected communication satellite deployments through the '80s for C-Band and K-Band. It is readily apparent that communications slots in GEO are becoming increasingly crowded. As satellites die, they become hazards to new satellites placed in the same slot if not removed. According to Mr. Morgan's "Geosynchronous Satellite Log for 1980," they were approximately 80 operational satellites in GEO as of January 1, 1980; and more than 280 active, future, and inactive entries through the '80s. This neglects an unknown number of upper stage objects that also pose a hazard to new placements.

MOTV

OVERCROWDING IN GEO ORBIT: C-BAND SATELLITES

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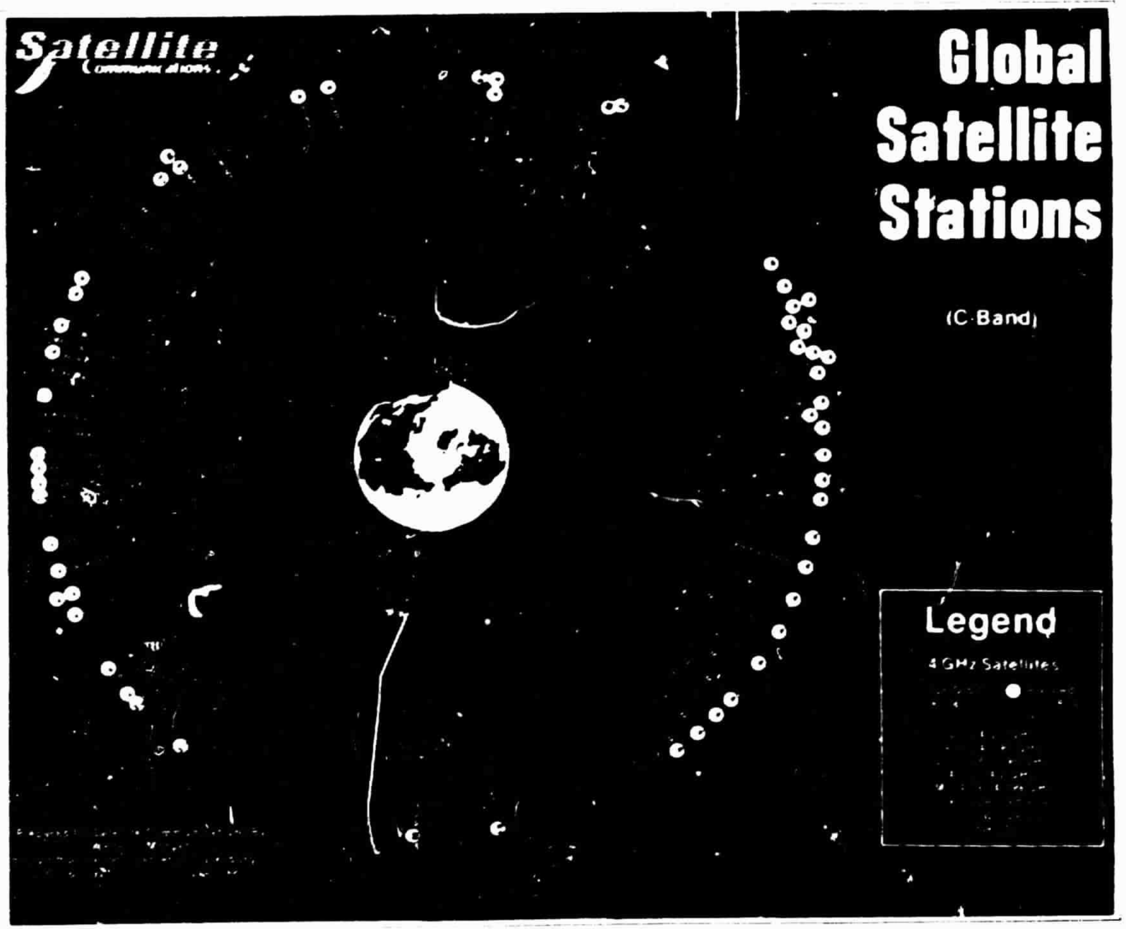

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MOTV

OVERCROWDING IN GEO ORBIT: K-BAND SATELLITES

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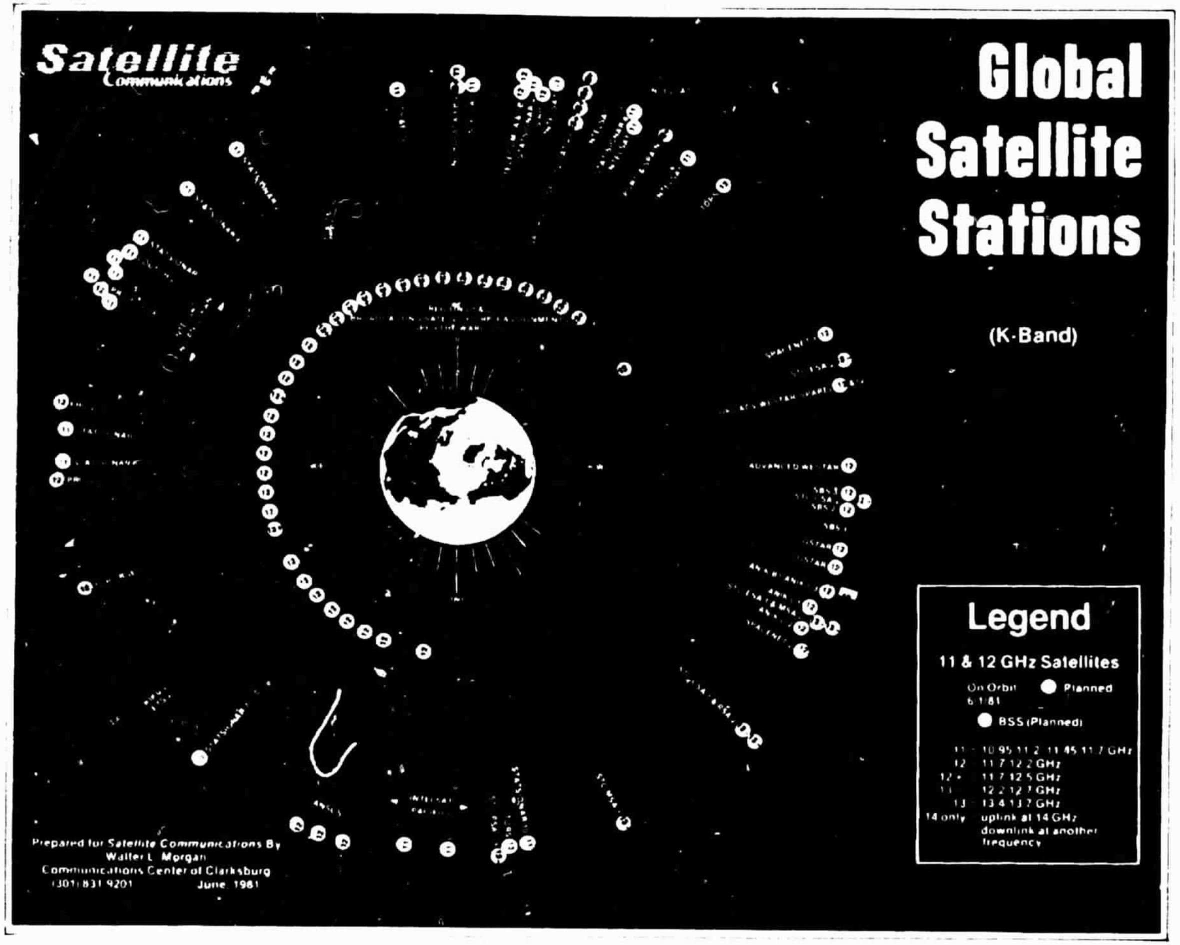

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SATELLITE DISTRIBUTIONS BY INCLINATIONS

The simple breakdown of satellite deployment numbers by final orbit inclination groups is presented on the facing page. The data are separated into two categories, DoD and Other. DoD is obviously the major sponsor of deployments, particularly at the higher orbit inclinations.

MOTV

PAYLOAD DEPLOYMENTS – 1982 THROUGH 2002 DISTRIBUTION BY INCLINATION

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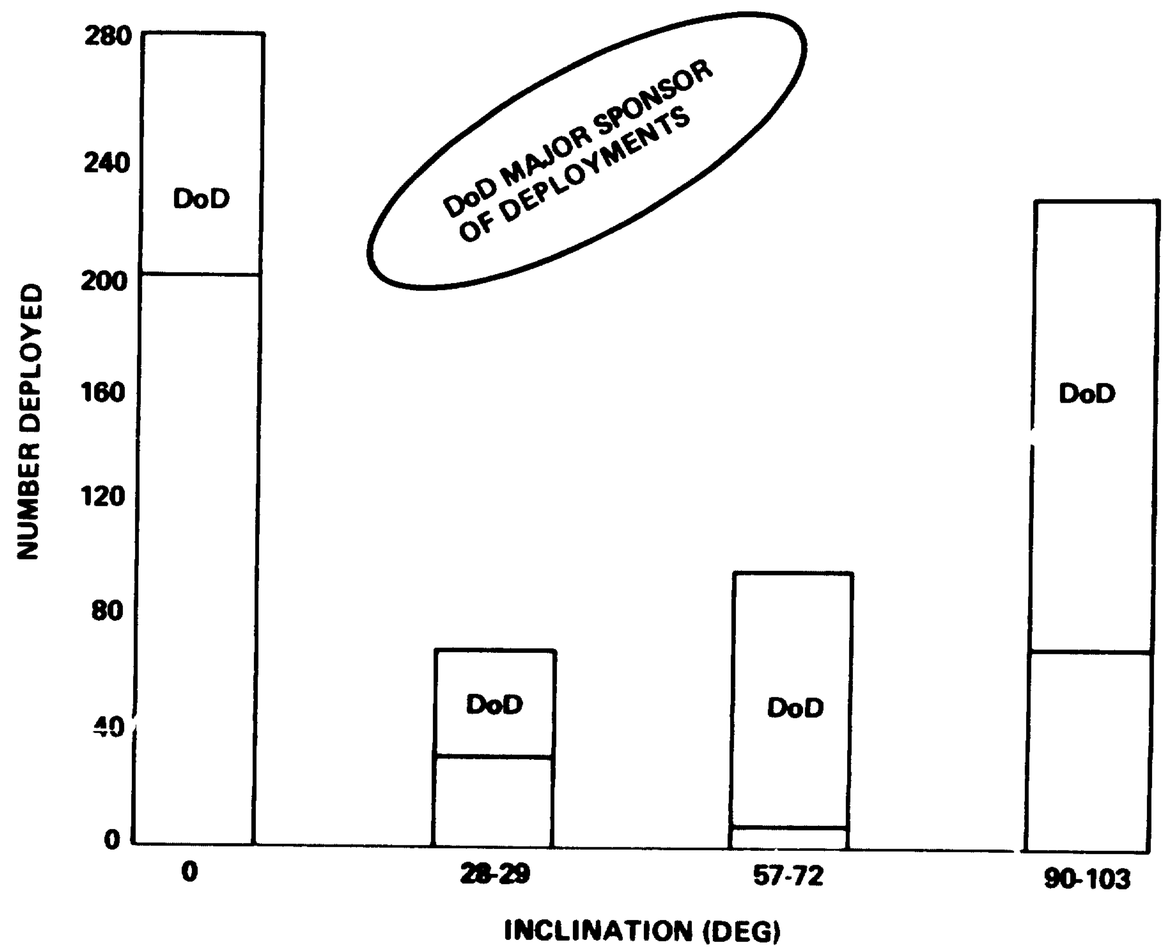

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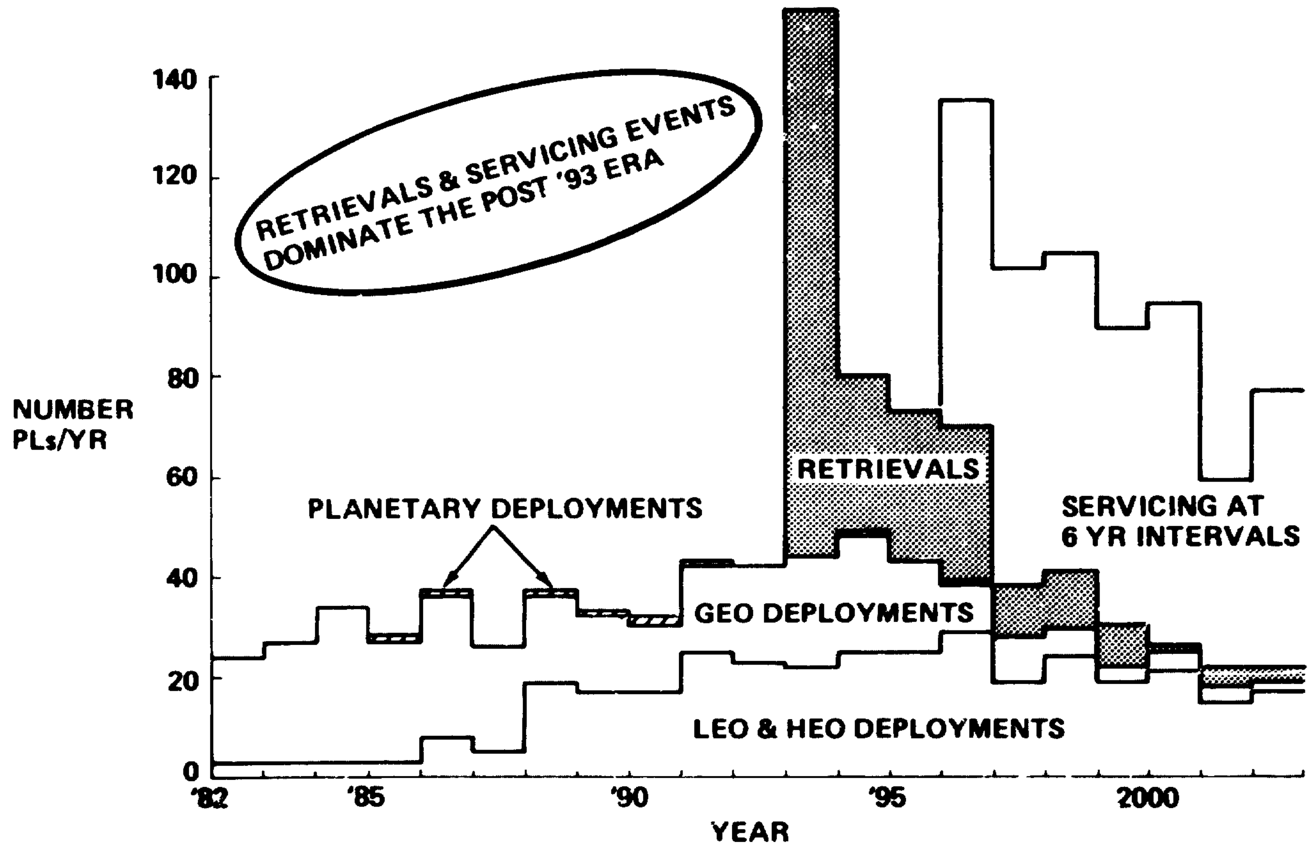
NUMBER OF PAYLOADS BY FUNCTION

The type and frequency of transportation/support activity during the study period are defined in the facing page chart. As shown, GEO deployments account for the major traffic demand through the late 1980s. After that time, LEO and HEO orbits are the larger component of deployment activity.

As discussed, the groundrules that govern retrievals build a large backlog of the activity beginning in 1993. This retrieval requirements shrinks rapidly as the servicing function doubles the life expectancy of many satellites and delays their required retrieval/removal from orbit.

Heavy servicing activity after 1996 dominates the payload support activity.

NUMBER OF PAYLOADS BY FUNCTION, ALL SPONSORS



0477-015D

COMPARATIVE COSTS OF UPPER STAGE OPTIONS

The transport costs of each upper stage option are shown opposite as a function of cumulative delivery mass to orbit. DDT&E costs and the operations cost for each option are included. The cost for developing each stage is shown as the ordinate intercept. The slope of each curve represents operational and hardware costs for each stage taken from the previous chart.

To determine the most cost effective transition program for upper stage options, it was necessary to consider both the IOCs of each option and the payload delivery requirements from our mission model in that time frame. This analysis shows that, in the 1986 to 1988 time frame, the STS Centaur is the least expensive option to handle the delivery requirements to high energy orbits including GEO. After 1988, the least expensive option is the 1 1/2-stage OTV in either the all-propulsive or the aeromaneuvering mode.

MOTV

COMPARATIVE COSTS OF UPPER STAGE OPTIONS

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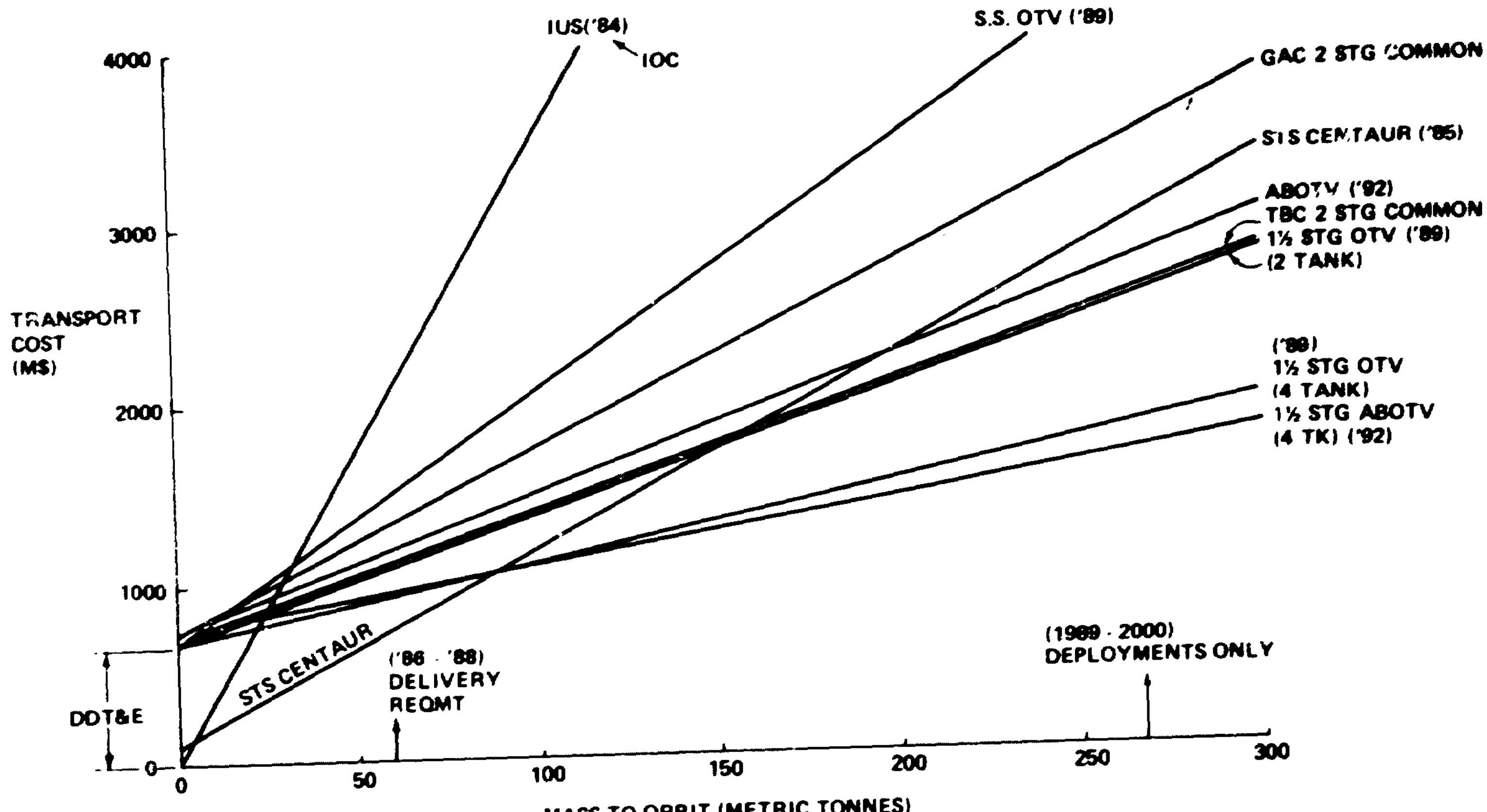

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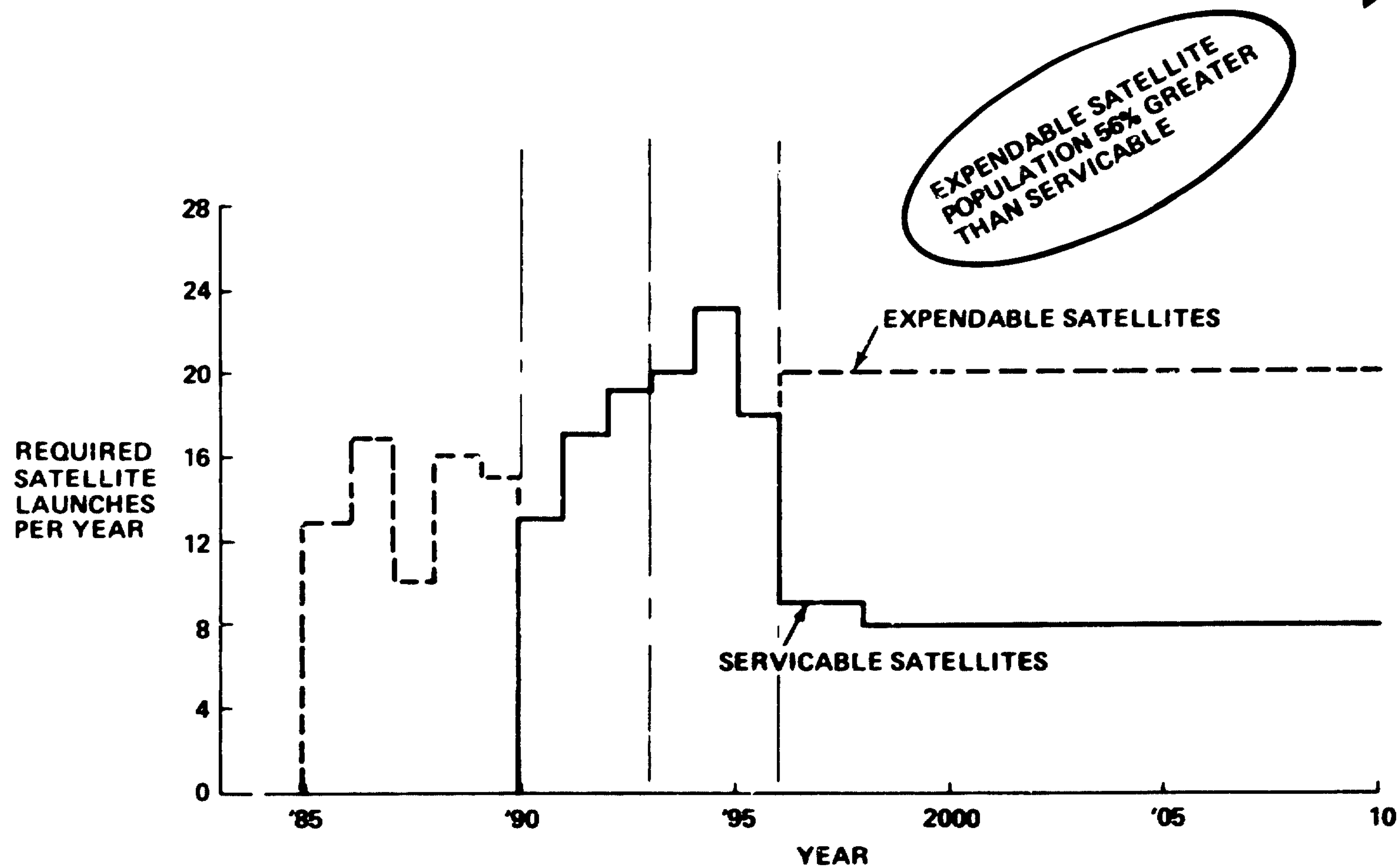
0477-023D

GEO SATELLITE LAUNCHES REQUIRED

The GEO satellite mission model shown previously shows a marked dropoff in GEO deliveries after 1995 when satellite servicing begins. To develop a 20 year program used for comparative costing of expendable vs serviceable systems, it was necessary to project satellite delivery rates to the year 2010. An annual launch rate of 20 expandable satellites per year has been assumed. Replacement of expendable satellites is 12 per year as determined by the mission model analysis.

Prior to 1990, only expendable launch vehicles are available. Serviceable satellites launched in 1990 are assumed to require servicing at 6-year intervals starting in 1996, and their life is extended to 20 years.

GEO SATELLITE LAUNCH REQUIREMENTS



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0477-024D

MOTV GEO SERVICES

This chart summarizes functions performed by the MOTV during the program, after servicing has begun. The number of launches, deliveries, servicings, and removals each year (1966 through 2009) are shown.

The average deliveries, servicings, and removals performed per launch each year are also shown.

The average MOTV mission consists of two deliveries, five servicings, and two removals.

MOTV

MOTV GEO SERVICES (1996 WHEN SERVICING BEGINS THROUGH 2000)

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ACTIVITY/YEAR	'96	'97	'98	'99	2000	'01	'02	'03	'04	'05	'06	'07	'08	'09	TOTAL
TOTAL															
LAUNCHES	4	5	5	5	6	4	4	4	4	4	4	4	4	5	62
DELIVERIES	9	9	8	8	8	8	8	8	8	8	8	8	8	8	114
SERVICINGS	13	17	19	20	23	18	22	26	27	28	31	26	30	34	334
REMOVALS	7	7	11	20	24	4	5	0	1	4	1	4	2	3	93
AVERAGE PER LAUNCH															
DELIVERIES	2.3	1.8	1.6	1.6	1.3	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.6	1.8
SERVICINGS	3.3	3.4	3.8	4.0	3.8	3.0	5.5	6.5	6.8	7.0	7.8	6.5	7.5	6.8	5.4
REMOVALS	1.8	1.4	2.2	4.0	4.0	1.0	1.3	0	0.3	1.0	0.3	1.0	0.5	0.6	1.5

AVERAGE MOTV MISSION: 2 DEL, 5 SERV, & 2 REMOVALS

0477-073D

20-YEAR PROGRAM COMPARATIVE TOTAL COSTS

The chart opposite shows comparative total costs of the expendable and servicable systems for the GEO mission 20-year program.

Relative costs for transportation and satellite replacement, or modification and service modules, debris removals, and crew capsule usage, are highlighted. The predominant cost in the servicable system is transportation and the predominant cost in the expendable system is for replacement satellites.

COMPARATIVE TOTAL COSTS
20 YEAR PROGRAM

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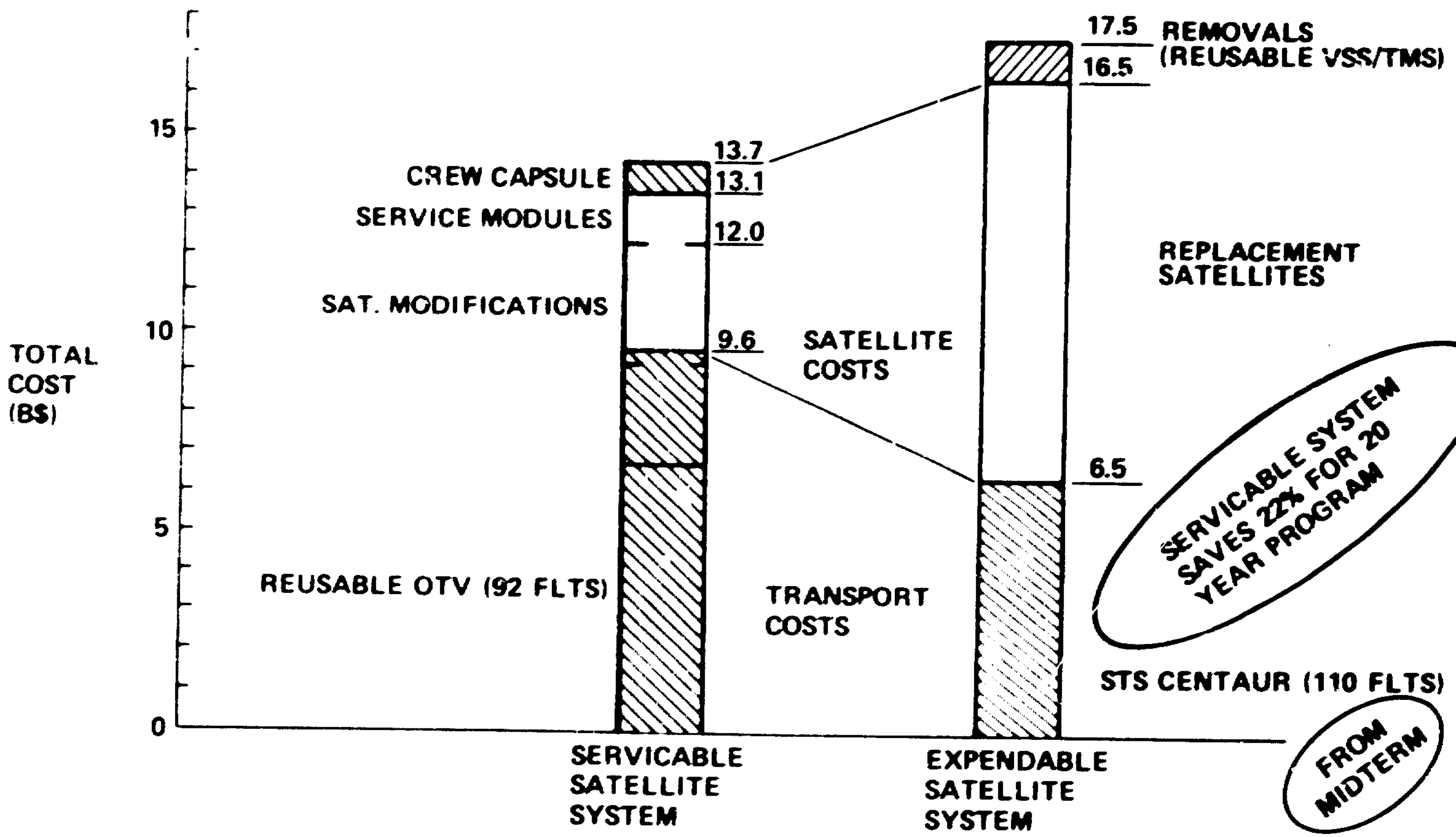
- EXPENDABLE SATELLITES AND LAUNCH VEHICLE (STS CENTAUR)
- SERVICABLE SATELLITES AND REUSABLE OTV/MOTV



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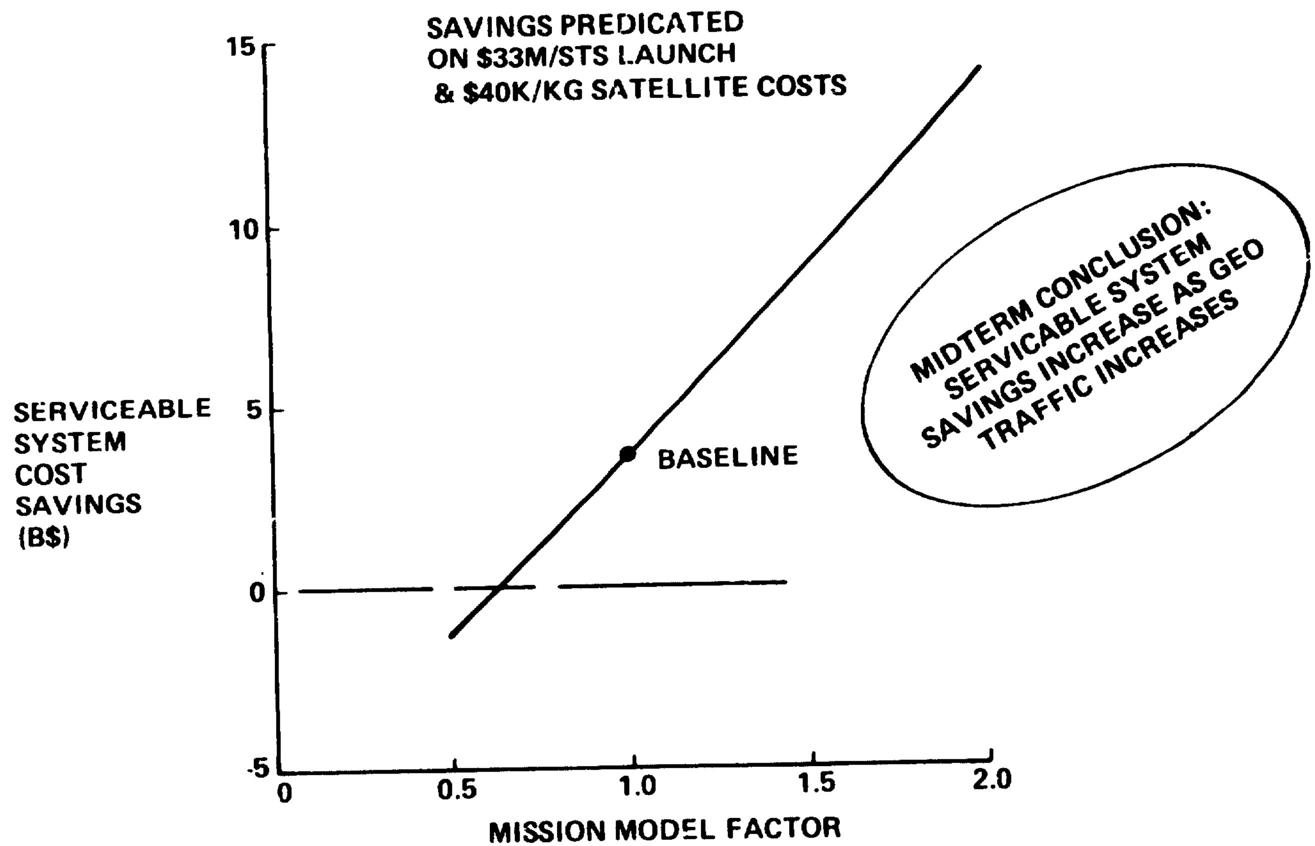
1154-128(T)

COST SENSITIVITY TO TRAFFIC RATE

The chart opposite shows the cost sensitivity to changing the traffic rate in the GEO mission model. The cost deltas previously developed were used to plot the curve shown.

The serviceable system is cheaper for traffic rates that are more than 60% of the baseline mission model.

COST SENSITIVITY TO GEO TRAFFIC RATE



- MISSION MODEL BASED ON 20 EXPENDABLE OR 8 SERVICEABLE SATELLITES LAUNCHED PER YEAR

CORRECTED PROGRAM COST SENSITIVITY TO STS LAUNCH COST

Reexamination of the costing done for the midterm review uncovered an omission that affects the expendable system vs serviceable system delta costs.

Neither system had been charged for satellite delivery to low earth orbit. On the surface, this assumption did no harm since obtaining delta costs was the prime objective. The expendable system, however, requires 166 more satellites during the time period considered. Getting these additional satellites to LEO has been estimated as requiring 21 shuttle flights at 8 satellites per shuttle. While this is well below the shuttle weight capability for each flight (12,000 kg vs 29,500 kg capability), the assumption that eight satellites can be carried in one flight is admittedly optimistic.

This revises the cost sensitivity plot as shown.

MOTV

CORRECTED PROGRAM COST SENSITIVITY TO STS LAUNCH COST

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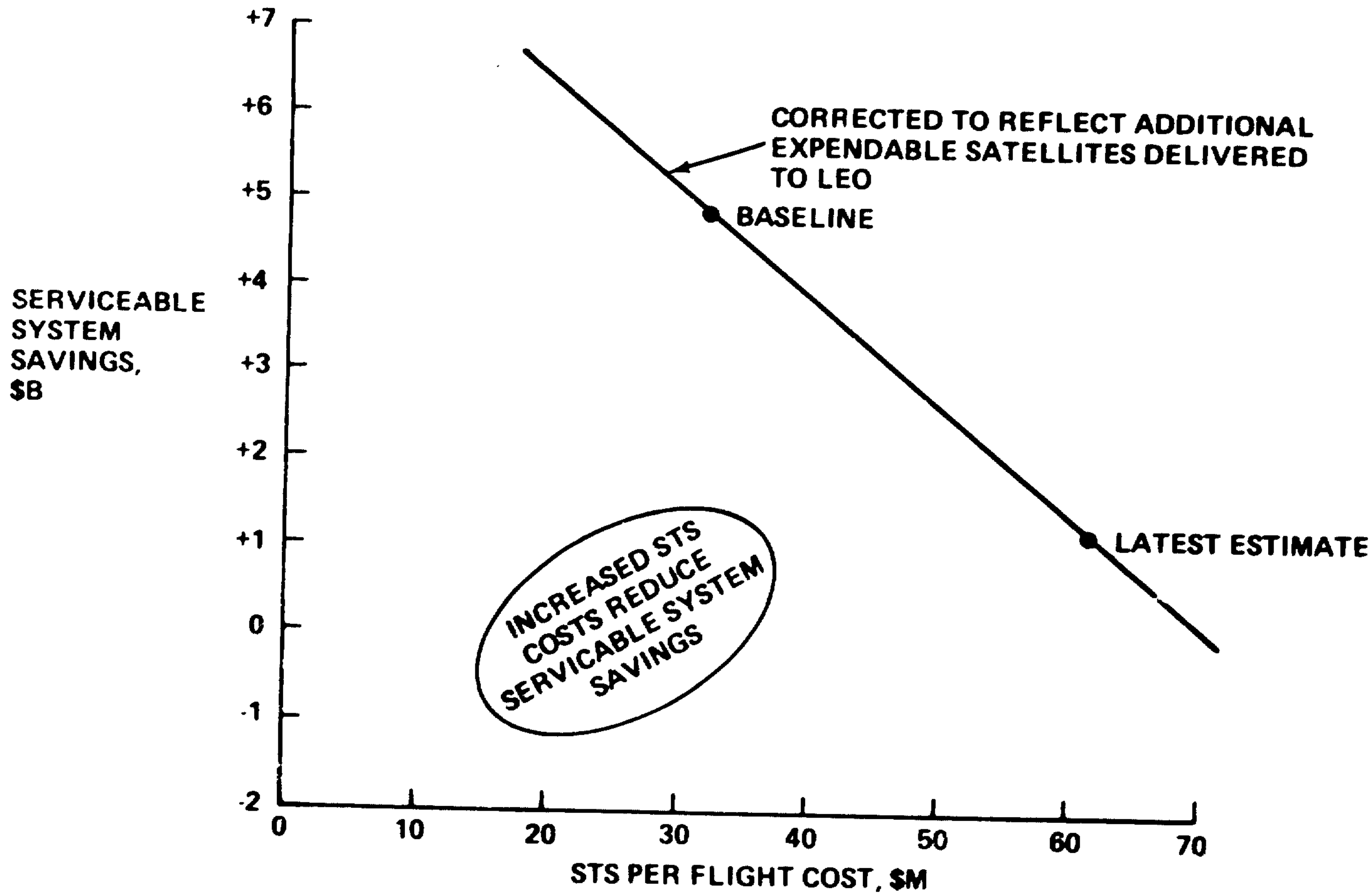


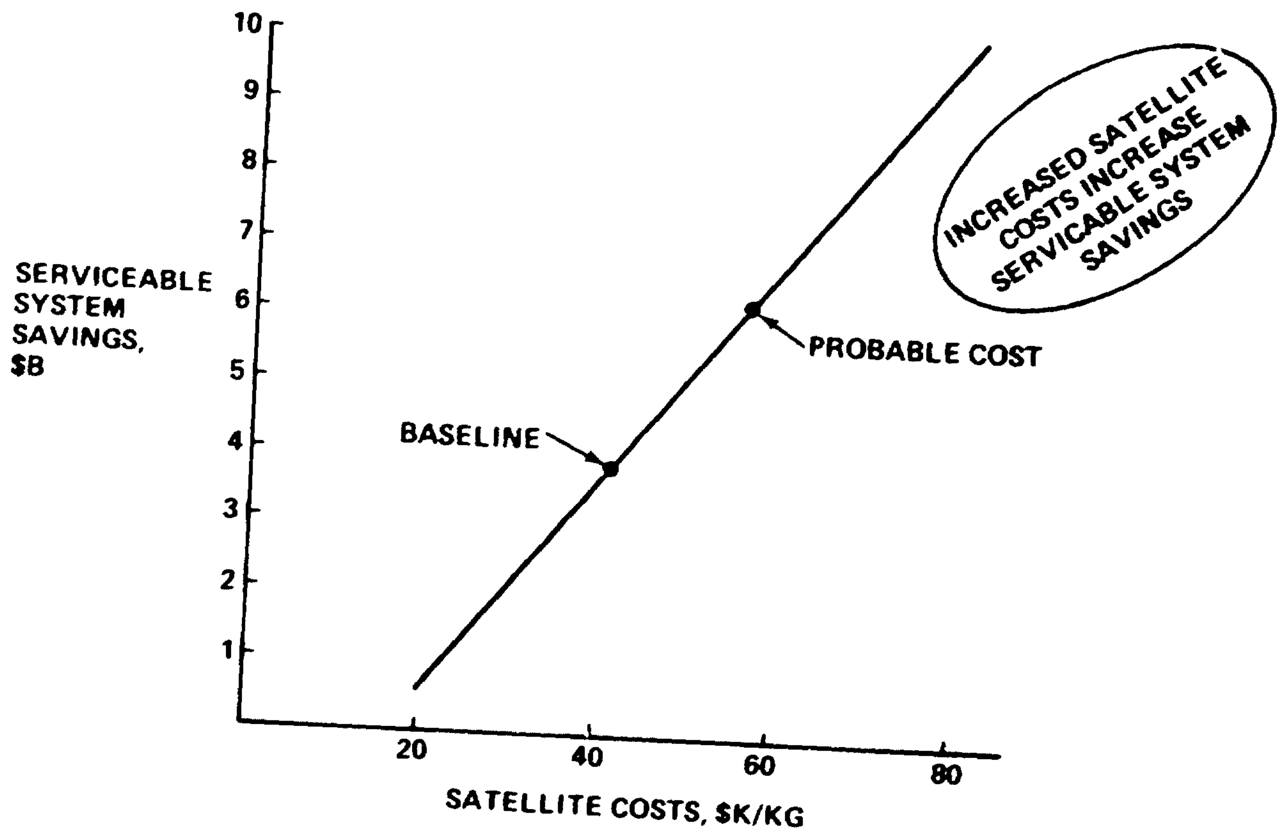
1154-103(T)

PROGRAM COST SENSITIVITY TO SATELLITE COST

In addition to an escalation in shuttle launch costs, evidence suggests that satellite costs are also increasing. In house studies indicate the cost per kilogram for GEO satellites should be $55,000.

This plot shows the increased savings of the serviceable system over the expendable system as satellite costs grow. The above mentioned cost of $55K/kg is indicated as well as the $40K/kg that was assummed at the midterm review.

PROGRAM COST SENSITIVITY TO SATELLITE COST



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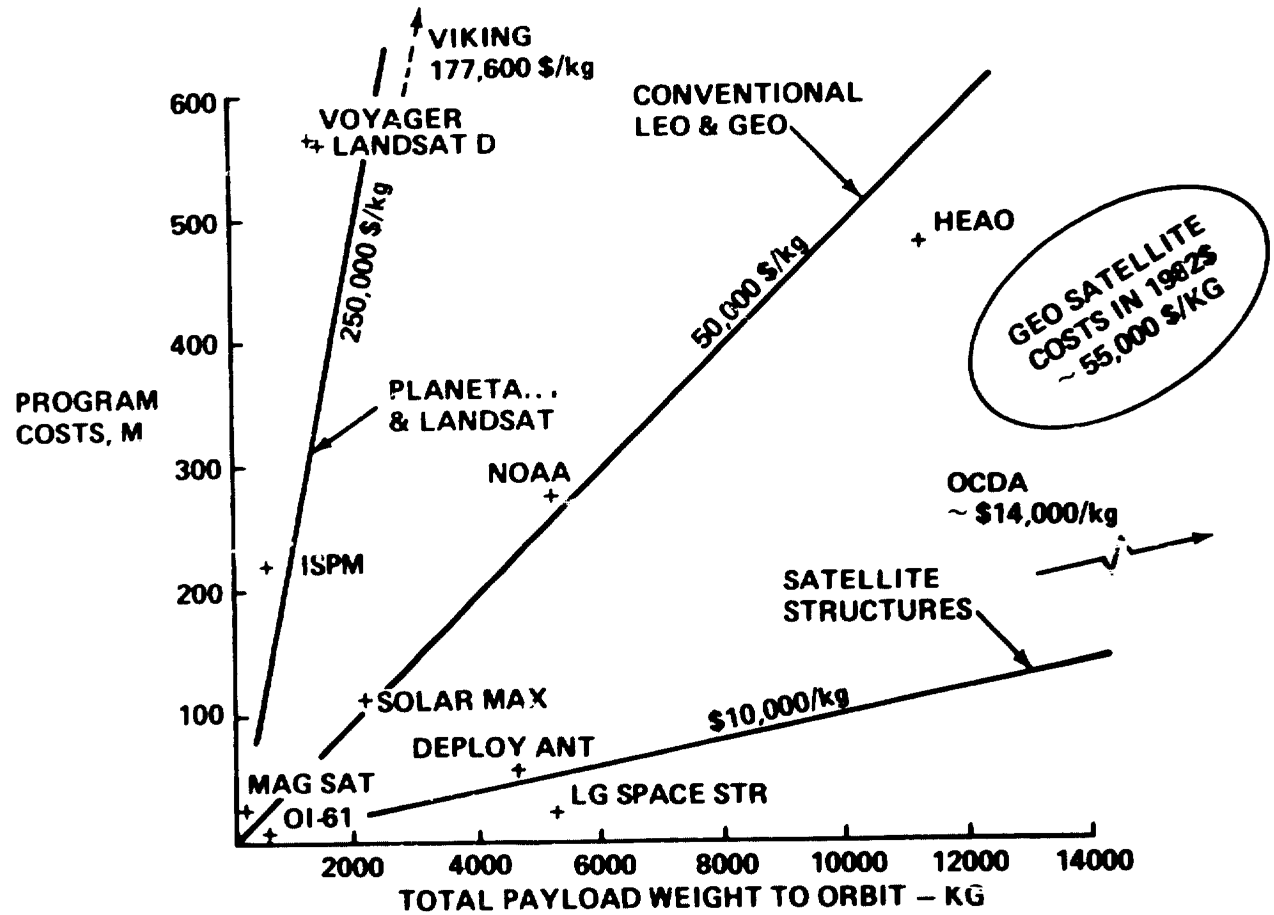
1154-104(T)

TYPICAL SATELLITE COSTS VS MASS

This curve depicts an in house study of satellite costs. Several satellites have been plotted and satellite cost lines for a typical satellite have been drawn. The planetary satellites with their complex navigation devices and avionics cost about $250K/kg. "Dumb" space structures are about $10K/kg. Conventional LEO and GEO satellites are plotted at $50K/kg. All values shown are in 1981 dollars; escalation to 1982 dollars yield approximately $55K/kg for GEO satellites.

TYPICAL SATELLITE COSTS VS MASS PROGRAM COSTS, 1981 $

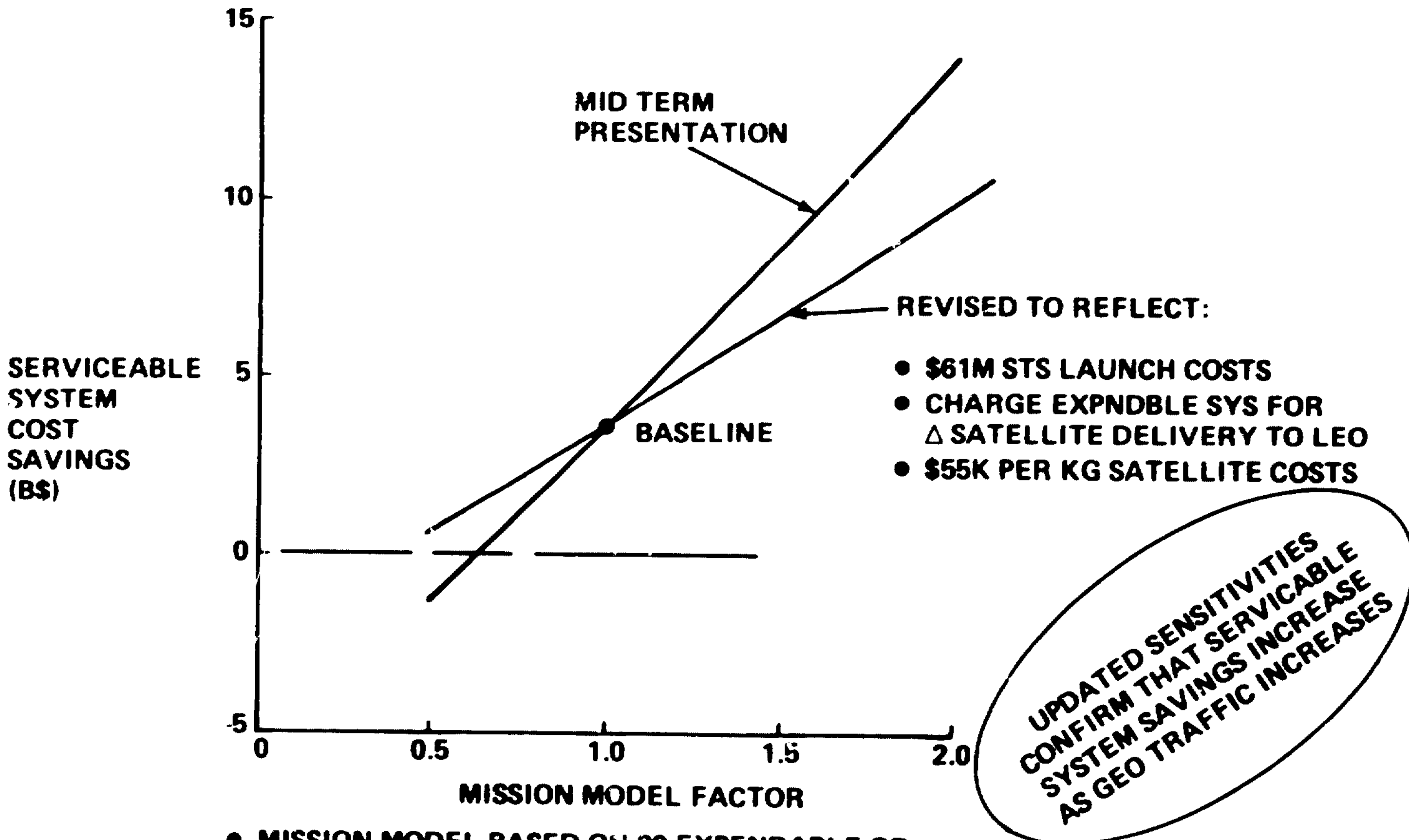


CORRECTED COST SENSITIVITY TO GEO TRAFFIC RATE

This plot again looks at the cost sensitivity to GEO traffic rate. The midterm presentation curve is shown, as well as an updated curve that reflects the anticipated $61M/shuttle launch, the cost to deliver the Delta expendable satellites to Leo, and the reestimated cost/kg of satellites.

The two curves intersect at the baseline mission model. As the mission model is increased the cost savings of the serviceable system is not as pronounced as the midterm presentation. The trend, however, still shows the serviceable system to be cheaper than an expendable system.

CORRECTED COST SENSITIVITY TO GEO TRAFFIC RATE



• MISSION MODEL BASED ON 20 EXPENDABLE OR 8 SERVICEABLE SATELLITES LAUNCHED PER YEAR

1154-106(T)

CORRECTED COST SENSITIVITY TO GEO TRAFFIC RATE: MOTV WITH BALLUTE

This final sensitivity curve shows the effect of adding a ballute to the MOTV. As anticipated the aero manuevering capability of the MOTV is a powerful driver. A ballute was chosen because, in theory, it is easily "kitted" to an existing APOTV. The increased performance, in general, reduces a three tank 1 1/2-stage MOTV to a two tank 1 1/2-stage MOTV. Both the additional weight and the "throwaway" costs for the ballute have been included.

The changes previously reported and the addition of a ballute result in savings (at the mission model) of about $8B over the expendable system.

CORRECTED COST SENSITIVITY TO GEO TRAFFIC RATE ASSUMING MOTV WITH BALLUTE

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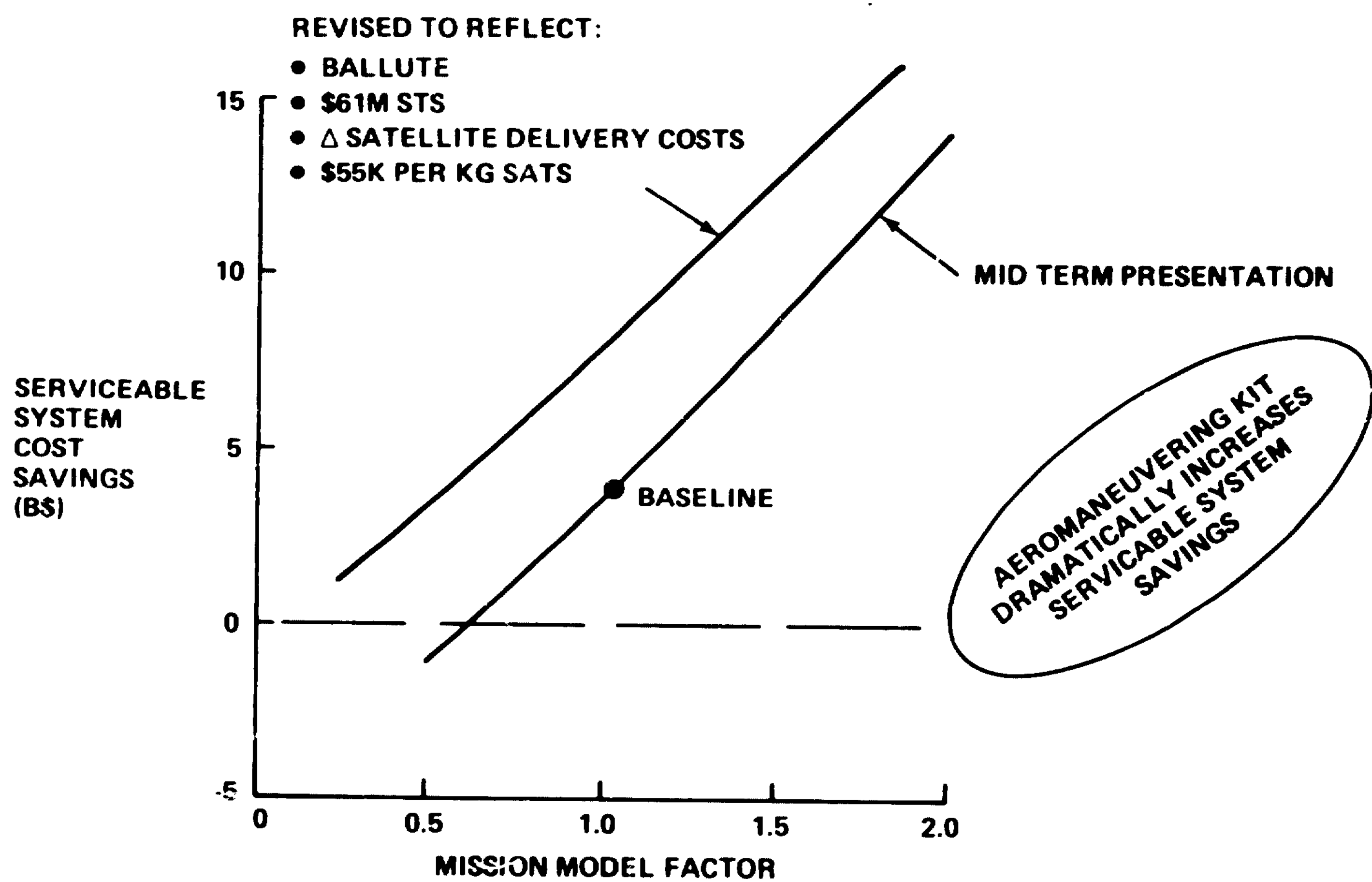

• MISSION MODEL BASED ON 20 EXPENDABLE OR 8 SERVICEABLE SATELLITES LAUNCHED PER YEAR

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1154-107(T)

SOC SYSTEM ADDITIONS FOR 2-STAGE MOTV TURNAROUND

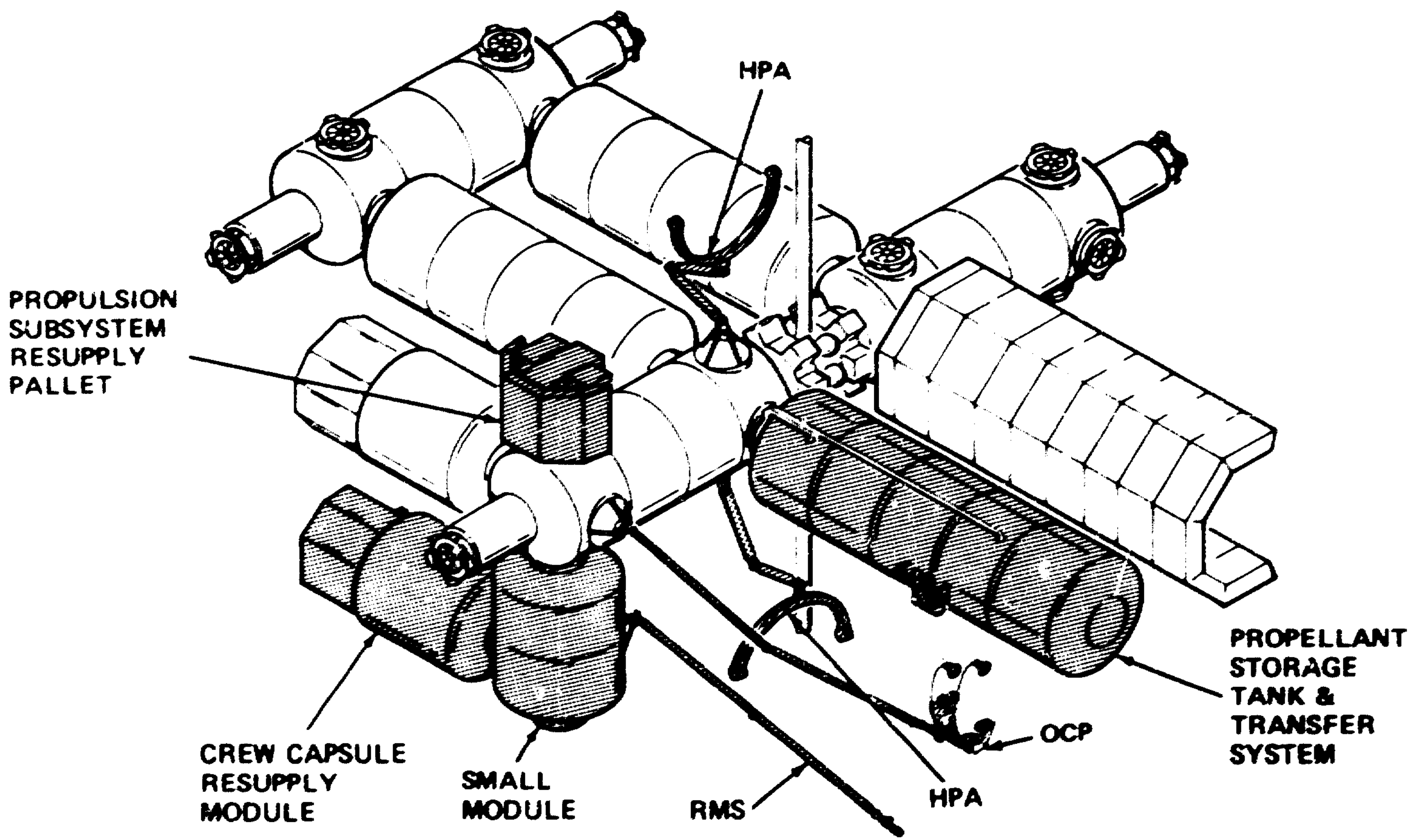
The SOC configuration shown opposite is taken from NASA/JSC's in-house studies. We have added a small module to this basic SOC. The module is made up of basic building block pieces to provide a pressurizes structure on which the MOTV crew capsule will be berthed. The MOTV crew, in shirtsleeves, can transfer directly to the basic SOC. The logistics module carrying servicing resupplies for the MOTV crew capsule is delivered by the orbiter and is berthed to this small module. Part of this module is pressurized and thus, resupplies for the interior of the crew capsule can be transferred directly.

To handle the capture, berthing, handling, and servicing operations, two RMS and two HPAs are mounted as shown. Their control panels are located in the small module. Each has an end effector that can be changed to suit the task being performed. Each HPA has a yoke end effector to mount the MOTV propulsion stage while it is being serviced. The RMS's can mount a snare end effector or an OCP, depending on its particular task.

A propellant storage tank, replenished by the orbiter, is located between the two HPAs. Since each HPA supports a propulsion stage, this is a suitable location for refueling the stages from the tank.

A logistics pallet with propulsion stage service items is delivered by the orbiter and is also berthed as shown.

SOC SYSTEM ADDITIONS FOR 2 STAGE MOTV TURNAROUND



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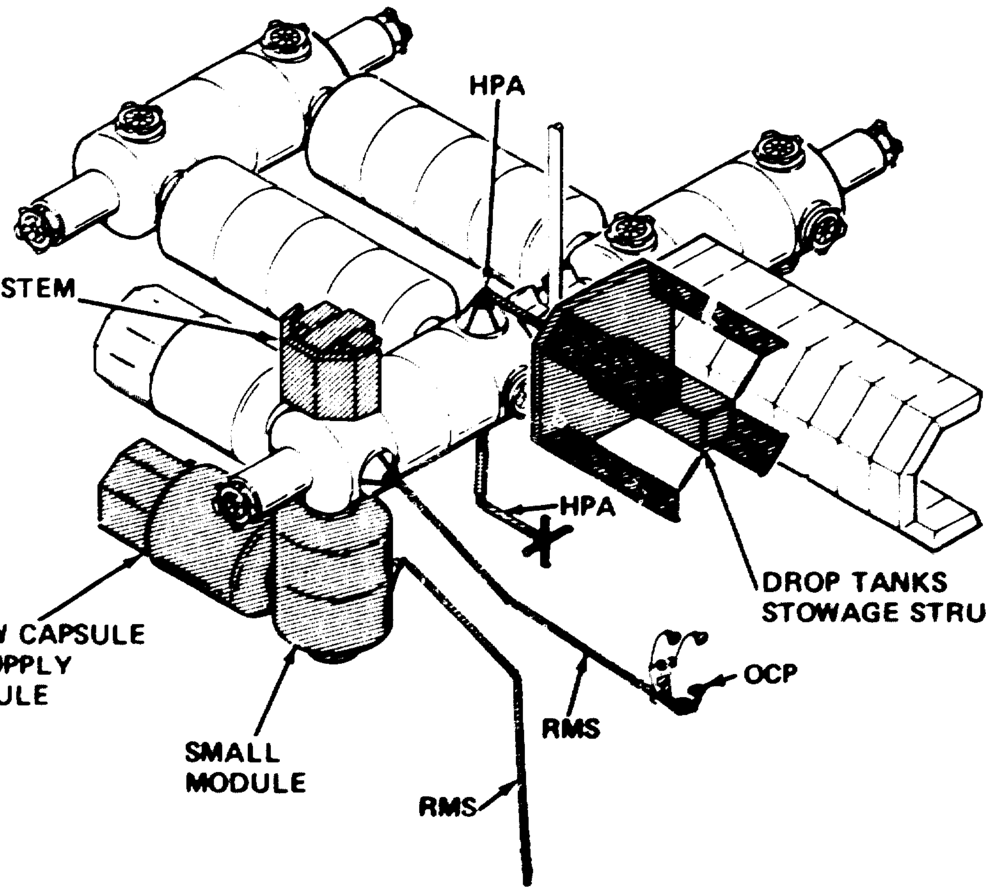
SOC SYSTEM ADDITIONS FOR 1 1/2-STAGE MOTV TURNAROUND

The SOC configuration is taken from NASA/JSC's in-house studies. A small module has been added to the basic SOC. It is made up of basic building block pieces to provide a pressurized structure on which the MOTV crew capsule will be berthed. The MOTV crew can transfer directly, in shirtsleeves, to the basic SOC. The logistics module carrying servicing resupplies for the MOTV crew capsule is delivered by the orbiter and is berthed to this small module. Part of this module is pressurized and, therefore, resupplies for the interior of the crew capsule can be transferred directly.

To handle the capture, berthing, handling, and servicing operations, two RMS and two HPAs are mounted as shown. Their control panels are located in the small module. Each has an end effector that can be changed to suit the task being performed. One HPA has an end effector to mount the MOTV propulsion stage core, while the other HPA end effector is the structure for stowing full drop tanks delivered by the orbiter. The RMS's can mount a snare end effector or an OCP, depending on its particular task.

A logistics pallet with propulsion stage service items is delivered by the Orbiter and is berthed as shown.

SOC SYSTEM ADDITIONS FOR 1½ STAGE MOTV TURNAROUND



5477-091D

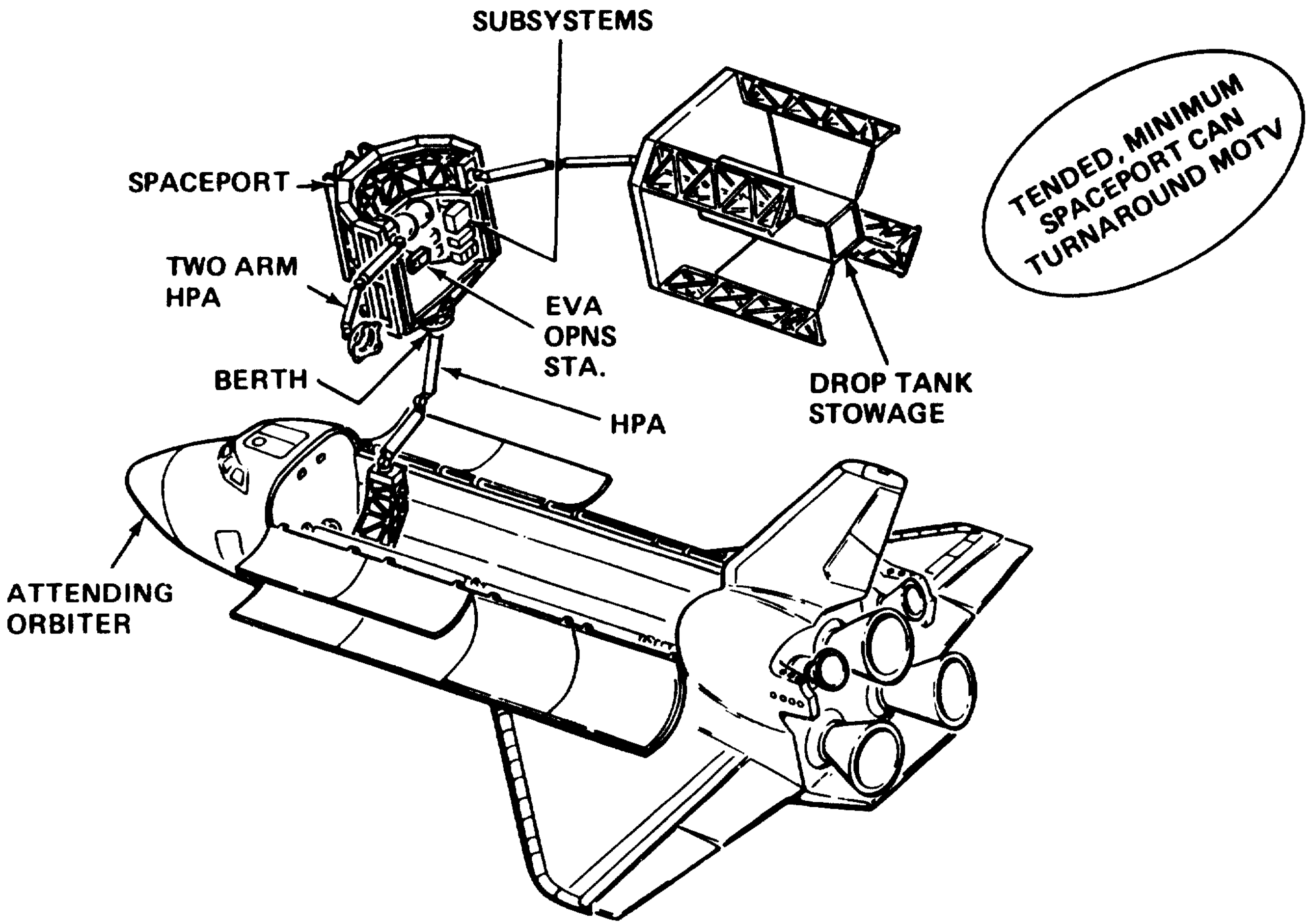
MIN SPACEPORT, ALL EVA TURNAROUND, 1 1/2-STAGE MOTV

As demonstrated on another chart, this facility can be transported to its operational location in LEO by a single shuttle flight. Once there, the orbiter extends its HPA arm, which mounts a berthing fixture at its tip. The orbiter standard RMS is used during construction to fetch and carry the spaceport component parts. The orbiter second RMS mounts the spaceport OCP at its tip to carry an EVA crewman, who monitors operations and assists in assembly.

Build sequence starts with a berthing ring being mated to the orbiter HPA berthing fixture. Assembled onto this ring are support struts that are fanned out to predetermined positions and then locked. A section of the spaceport structural cradle is now attached to the free ends of the appropriate support struts. This is followed by installation of another section of cradle and so on until the cradle is complete. The orbiter HPA articulates to move the cradle until it presents its open side for installation of the spacelab pallet and the spaceport HPA.

When assembly is completed, the OCP, which has been used during the process to support the EVA man, is mounted to a support on the spacelab pallet and left there for spaceport operations.

MIN SPACEPORT, ALL EVA TURN-AROUND — 1½ STAGE MOTV



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MIN SPACEPORT, ALL EVA TURNAROUND, 1 1/2-STAGE MOTV: MOTV SERVICING

Having captured and berthed the MOTV, the RMS end effector is disconnected from the vehicle. It is then indexed to pick up the OCP, which is stowed on the spaceport spacelab pallet. An EVA man boards the OCP that, by RMS actuation, moves him to the MOTV where he services the propulsion stage and the crew capsule with its subsystems. Service replacement items have been brought to LEO in the shuttle and the EVA man obtains the items he needs directly from the orbiter cargo bay. For these servicing operations, it is preferable that both the RMS and OCP be controlled by the EVA man from his control panel on the OCP, rather than have him control the OCP while the operator in the orbiter cabin controls the RMS.

MOTV

MIN SPACEPORT, ALL EVA TURN-AROUND — 1½ STAGE MOTV — MOTV SERVICING

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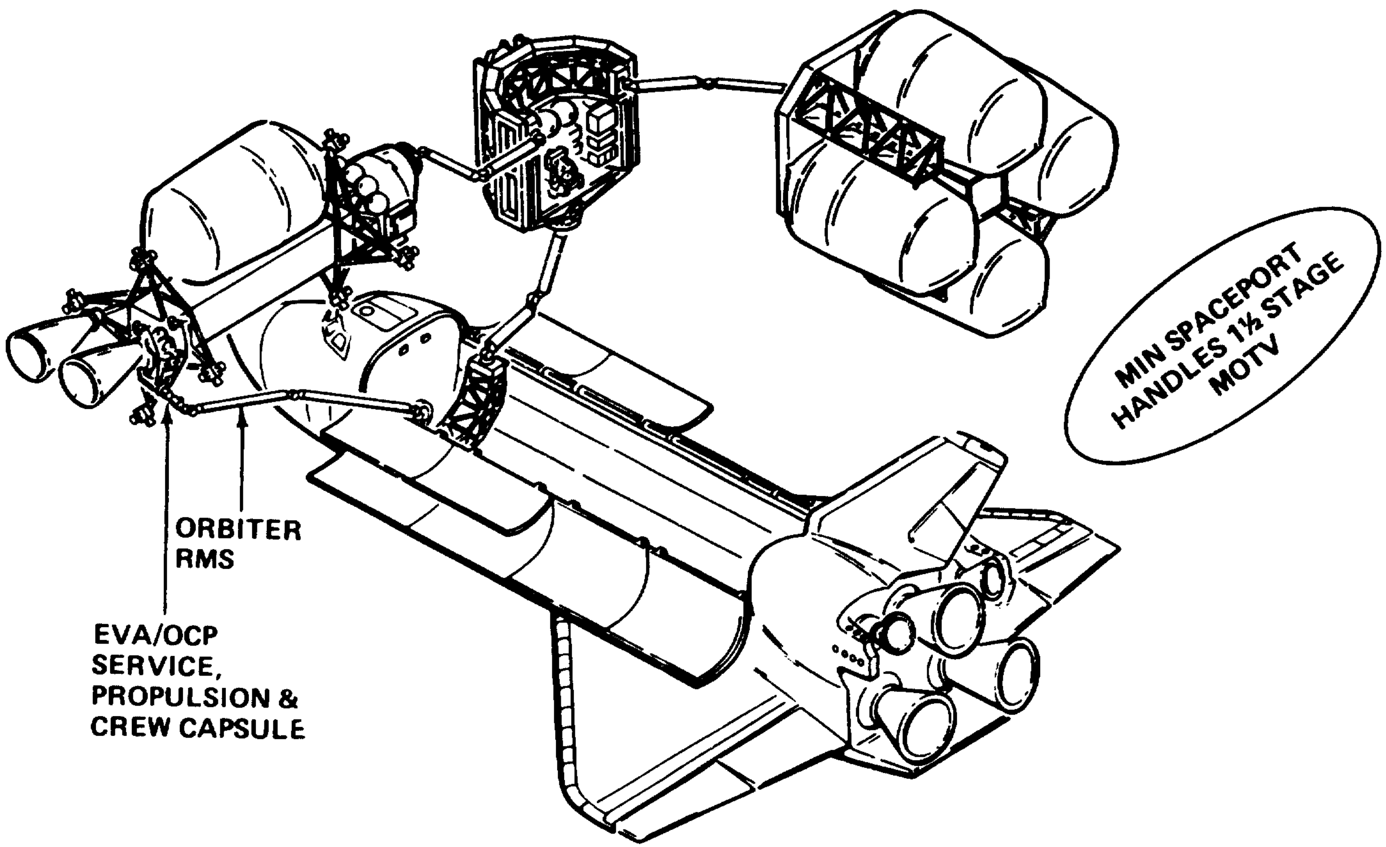


1154-077(T)

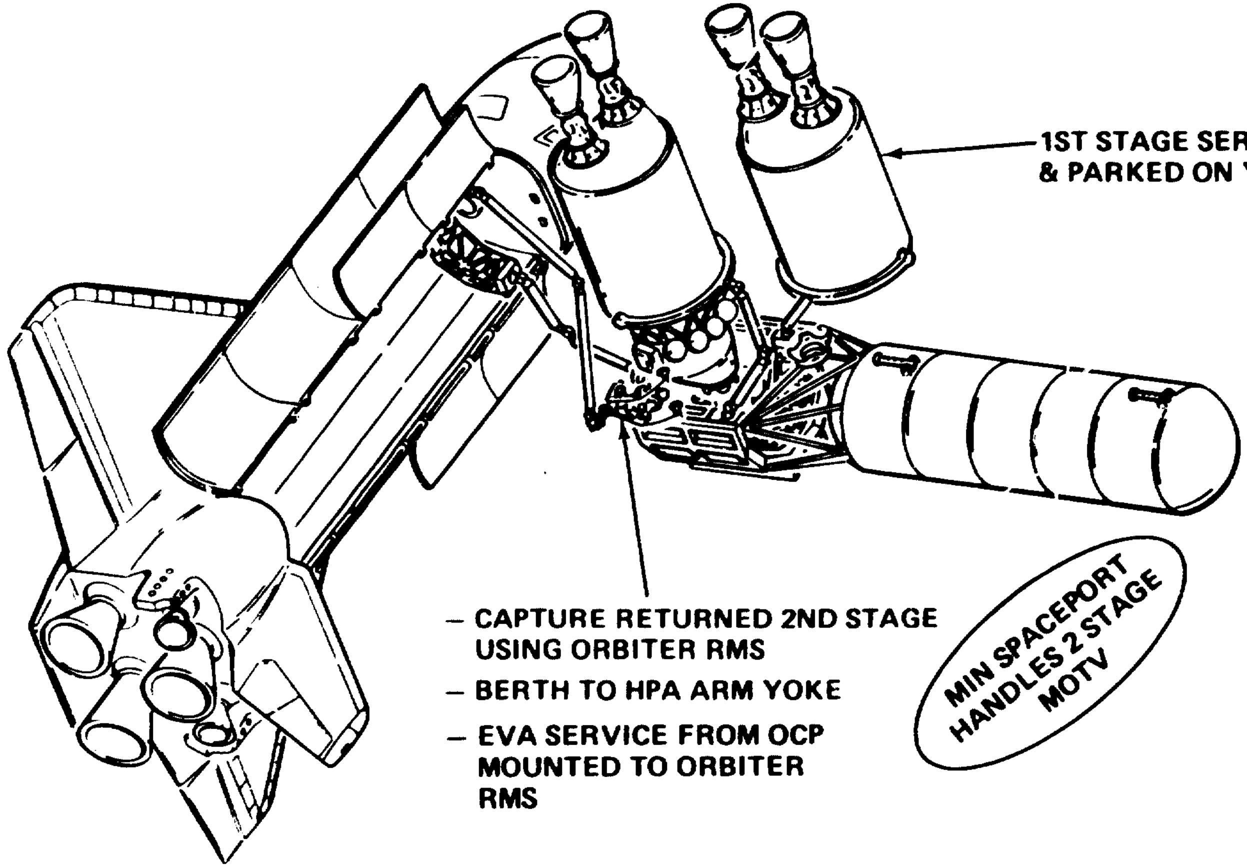
MIN SPACEPORT, ALL EVA TURNAROUND, 2-STAGE MOTV: 2ND-STAGE SERVICE

At completion of its mission, the second stage of a 2-stage MOTV returns to rendezvous with the spaceport for propulsion and crew capsule servicing.

The orbiter on this shuttle tended operation indexes to provide a clear view of the returned stage. Its RMS now captures the stage and berths it to the yoke end effector at the tip of the spaceport HPA arm. If necessary, the orbiter indexes to achieve this berthing. The RMS end effector disengages from the berthed stage, then indexes to pick up the spaceport OCP, which is stowed on the spacelab pallet. An EVA man boards the OCP that, by RMS actuation, moves him to the MOTV where he services the propulsion stage and crew capsule. Service replacement items have been brought to LEO in the shuttle and the EVA man obtains the items he needs directly from the orbiter cargo bay. For these servicing operations, it is preferable that both the RMS and OCP be controlled by the EVA man from his control panel on the OCP.

The orbiter HPA, the spaceport HPA, and the orbiter RMS can all be indexed to put the servicing EVA man at his necessary locations.

MIN SPACEPORT, ALL EVA TURN-AROUND, 2 STAGE MOTV – 2nd STAGE SERVICE



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1154-091(T)

MIN SPACEPORT: EVA/IVA TURNAROUND, 1 1/2-STAGE MOTV: SPACEPORT CONFIGN & MOTV CAPTURE

This spaceport is somewhat similar to the "all EVA" spaceport for 1 1/2-stage MOTV turnaround. It does, however, provide a shirtsleeve environment for the crewman operating the spaceport HPA. This requires a pressurized vessel to house the HPA control station. An MOTV crew capsule is shown here as that vessel. The capsule mounts to the spacelab pallet and has windows added to its domed end for the HPA operator to view the work area. The standard ingress/egress port at the coned end of the capsule mounts a short, flexible tunnel that ends in a berthing ring supported off the spaceport structural cradle. This is where the orbiter berths using its docking module so that a crewman can enter the capsule to operate the spaceport HPA. As with the "all EVA" spaceport, the spacelab pallet mounts subsystems.

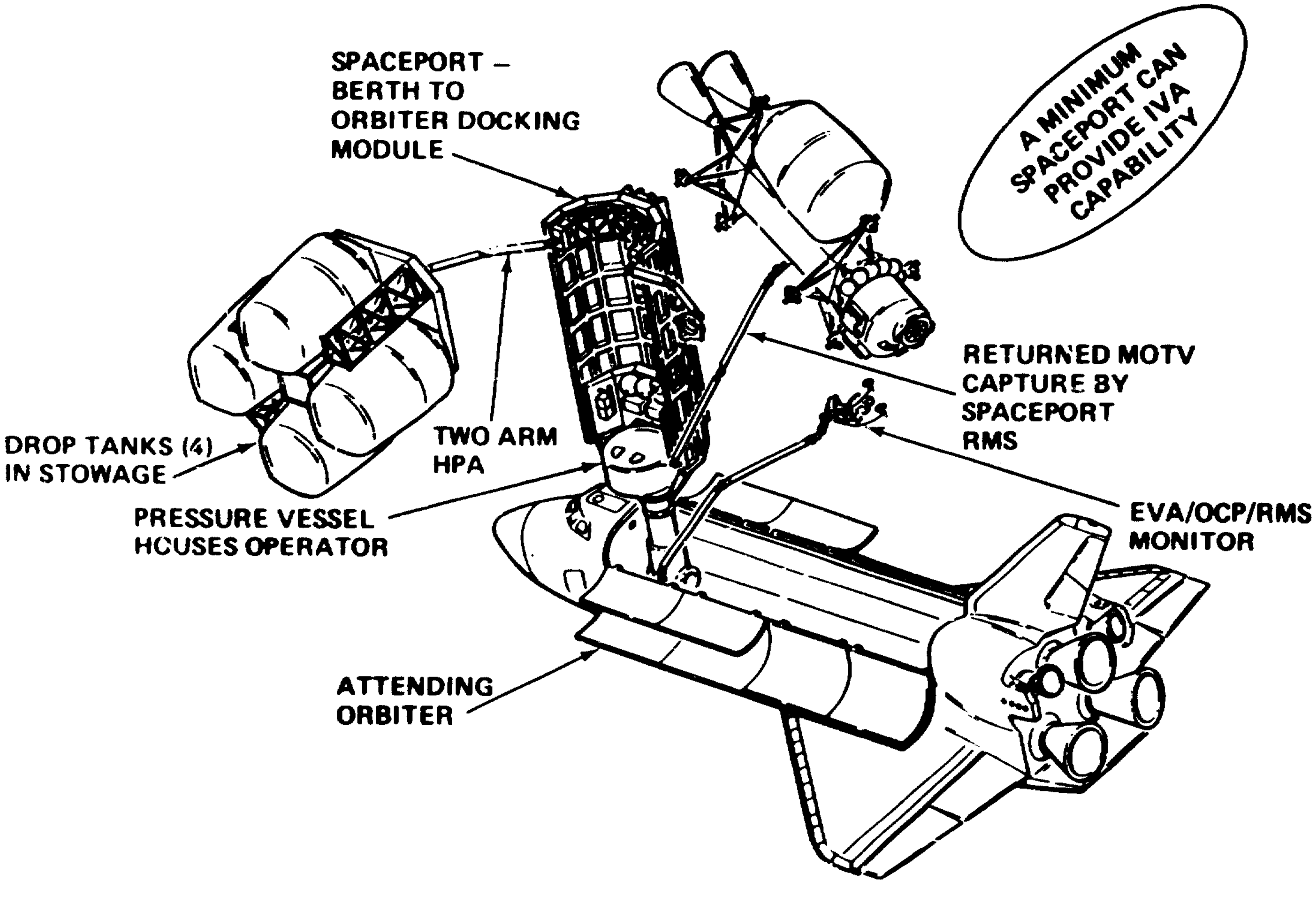
The cradle structure of this spaceport is lengthened so that the HPA can be located far enough from the operator in the capsule to enable him to see the work area through his windows. This HPA provides the same arm tip mounting facilities as does the "all EVA" spaceport HPA.

The HPA is now further from the berthed orbiter than it is with the "all EVA" spaceport. Also, since the orbiter is berthed to the spaceport by a docking module rather than an articulating HPA, the orbiter RMS reach is insufficient for work to be performed on the HPA mounted workpieces within view of the operator's windows. A spaceport mounted RMS is now necessary to handle the workpieces, such as drop tanks and the MOTV. This RMS is operated form the spaceport capsule.

Capture of the returned MOTV for servicing is performed by the spaceport RMS within view of the RMS operator's window. This operation can be monitored directly, as shown, by an EVA man aboard the spaceport OCP mounted on the orbiter RMS for this occasion.

The captured vehicle is berthed to the spaceport HPA arm end effector.

MIN SPACEPORT, EVA/IVA TURN-AROUND, 1½ STAGE MOTV – SPACE-PORT CONFIGN & MOTV CAPTURE



1154-079(T)

APOTV GEO PAYLOAD CAPABILITIES: TWO SHUTTLE LAUNCHES, WITH SCAVENGING

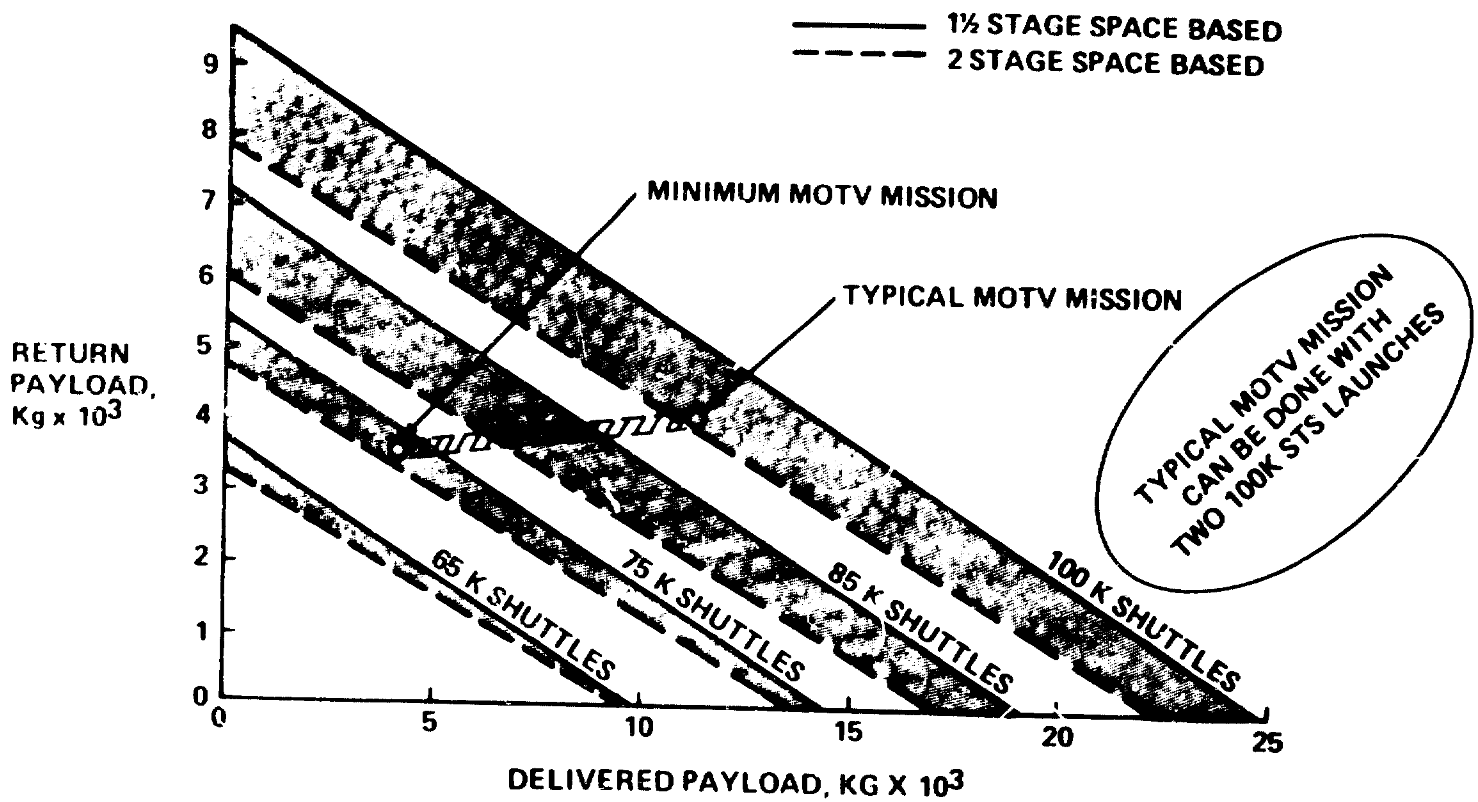
This curve shows the delivery and return payload capability of two shuttle launch APOTVs. A band of APOTV capability is shown for each of the shuttle payload capabilities considered. In each case the 1 1/2-stage space based APOTV is the best performer and the 2 stage common space based APOTV is the worst performer. The other APOTV configurations (1 1/2-stage ground based and 2-stage common ground based) fall within the bands shown.

The minimum and the typical MOTV missions described in the performance ground rules and assumptions have been spotted on the curve. As indicated by this plot the minimum mission requires two 75-K shuttle launches while the typical mission can easily be attained with two 100-K shuttle launches when external tank propellant scavenging is considered

MOTV

APOTV GEO PAYLOAD CAPABILITIES 2 SHUTTLE LAUNCHES – WITH SCAVENGING

GRUMMAN



1154 057(1)

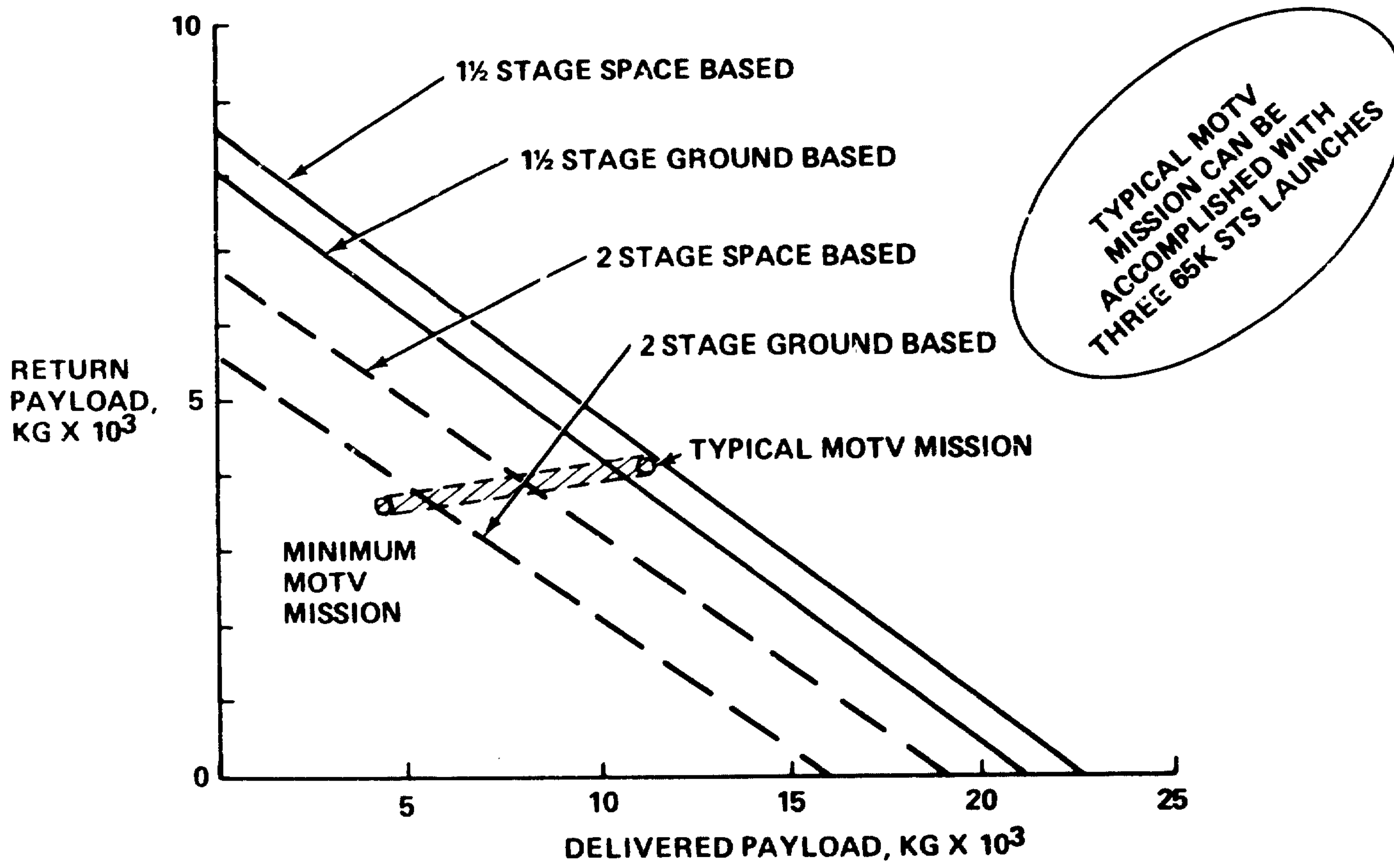
APOTV GEO PAYLOAD CAPABILITIES: THREE 65-K SHUTTLE LAUNCHES, WITH SCAVENGING

This plot shows the GEO payload capabilities of the various APOTV configuration with E.T. propellant scavenging.

Spotted on the curve are the minimum and the typical MOTV missions described in the ground rules and assumptions.

All configurations can perform the minimum MOTV mission. The 1 1/2-stage space based configuration can perform the typical MOTV mission.

APOTV GEO PAYLOAD CAPABILITIES
3 65K SHUTTLE LAUNCHES
WITH SCAVENGING



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1154-045(T)

APOTV GEO PAYLOAD CAPABILITIES: WITH SCAVENGING

This plot shows the return and delivery payload capabilities of the two shuttle launch and three shuttle launch APOTVs. The minimum and the typical MOTV missions described in the performance ground rules and assumptions are also shown as measures of performance.

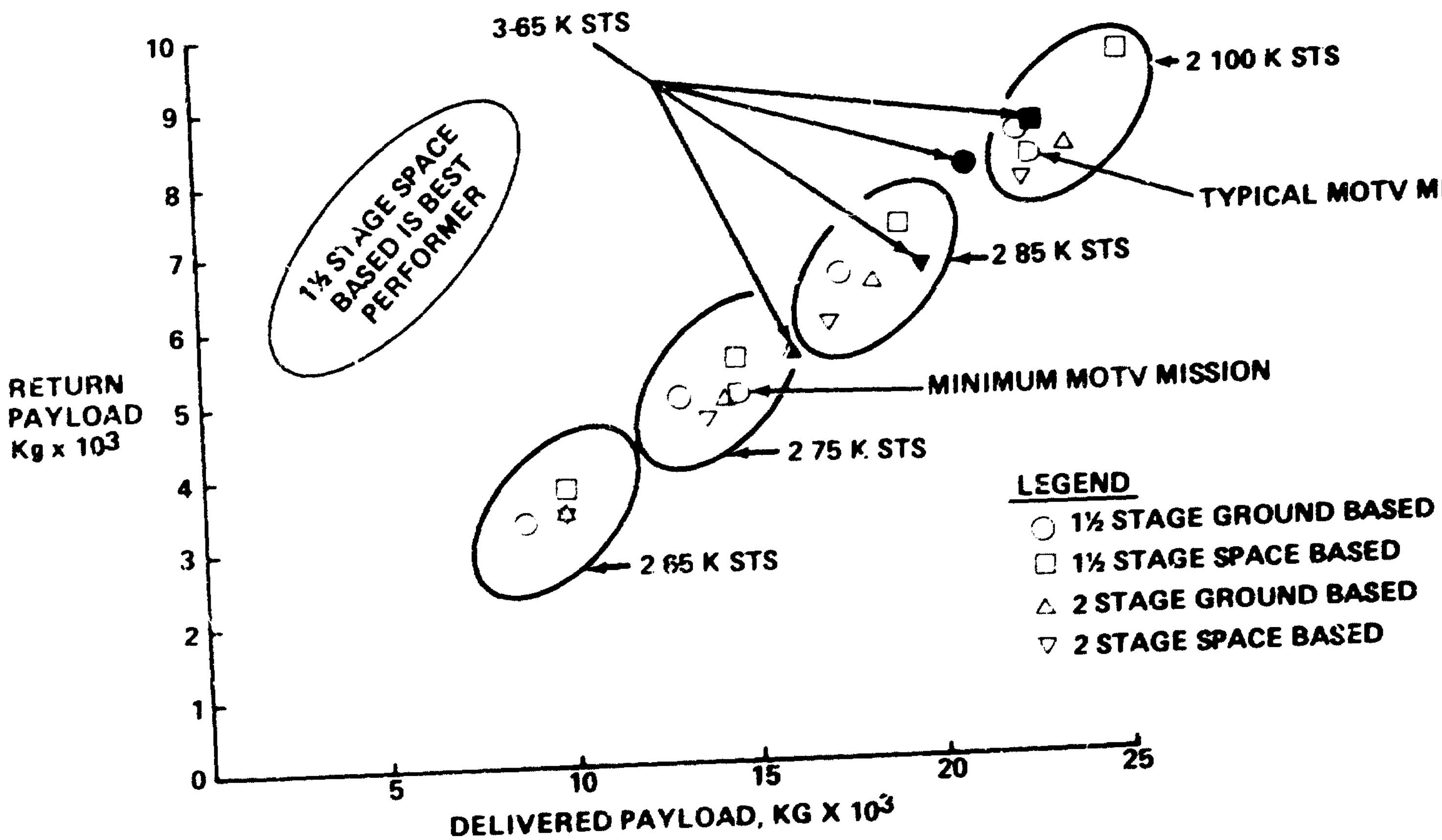
The 1 1/2-stage space based APOTV is consistently the best performer. Its performance with three 65-K shuttle launches and two 100-K shuttle launches are roughly comparable.

The capabilities shown on this plot are with external tank propellant scavenging.

MOTV

APOTV GEO PAYLOAD CAPABILITIES WITH SCAVENGING

GRUMMAN



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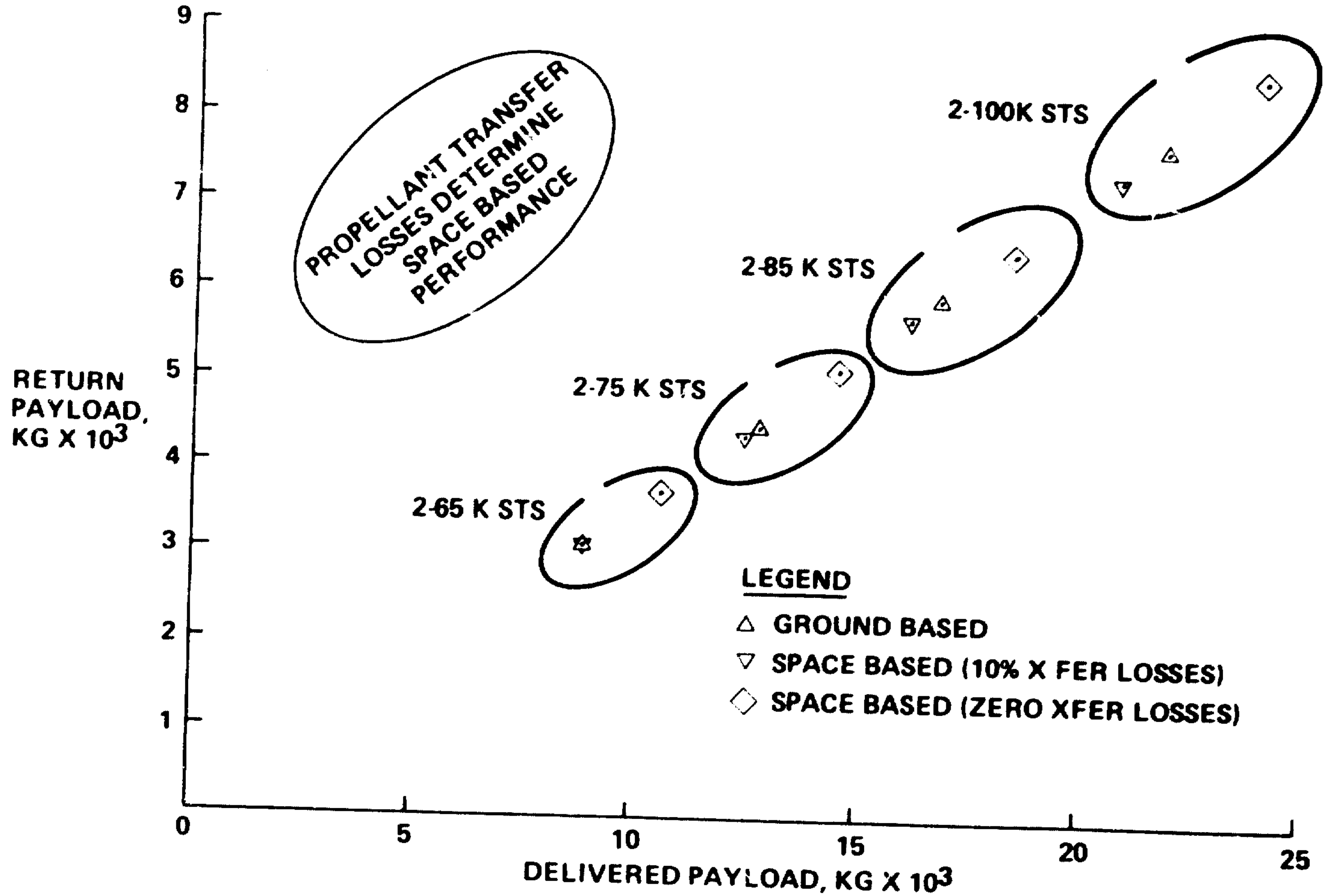
1154-110(T)

2-STAGE COMMON APOTV GEO PAYLAOD CAPABILITY: IMPACT OF PROPELLANT TRANSFER LOSSES

The payload capability of the ground-based and space-based (with 10% propellant transfer losses) 2-stage common APOTV have been plotted. Also plotted is the space-based APOTV payload capability if the propellant transfer losses were zero. The change in performance of the space-based APOTV is appreciable and leads us to question if there is a better way to provide the APOTV propellant.

2 STAGE COMMON APOTV GEO PAYLOAD CAPABILITY – IMPACT OF PROPELLANT TRANSFER LOSSES



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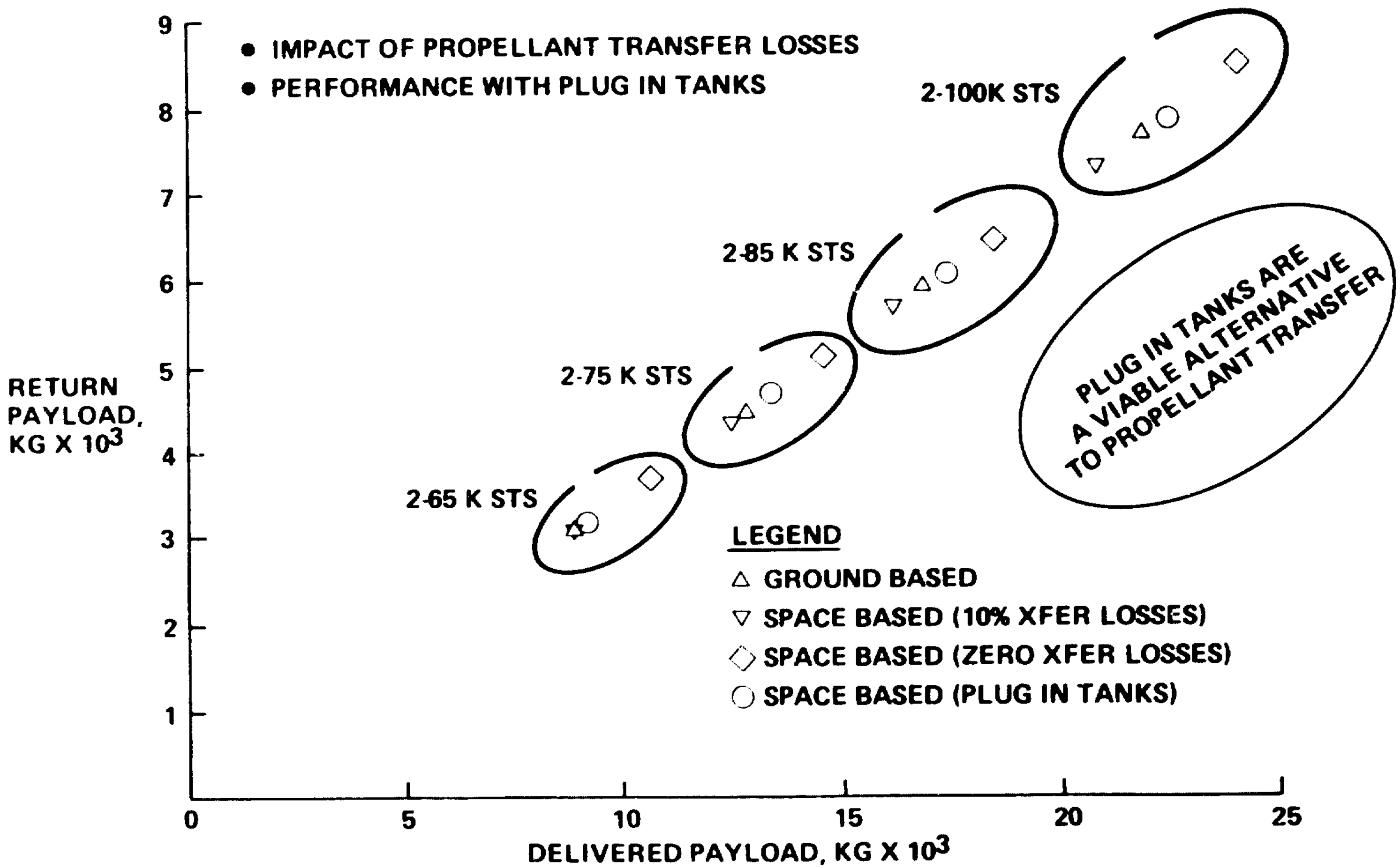
1154-111(T)

2-STAGE COMMON APOTV GEO PAYLOAD CAPABILITY: PERFORMANCE WITH PLUG IN TANKS

This plot shows the performance improvement when plug in tanks are used. As can be seen, this increase in performance is not as dramatic as the zero-transfer-loss case, but the probability of achieving it is far greater. With plug-in tanks, the space based APOTV outperforms the ground based vehicle.

2 STAGE COMMON APOTV GEO PAYLOAD CAPABILITY



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1154-112(T)

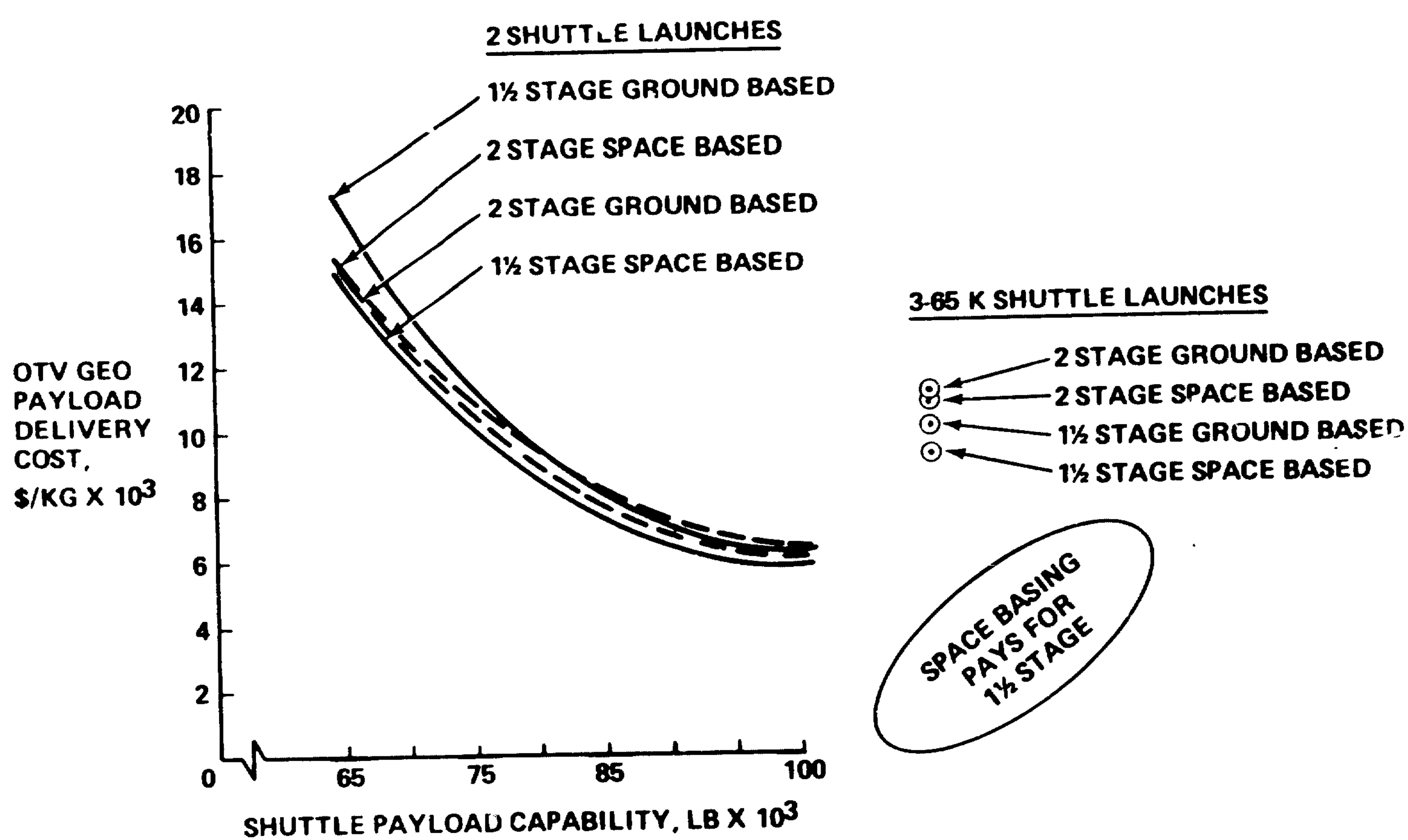
OTV GEO PAYLOAD DELIVERY COST VS SHUTTLE PAYLOAD CAPABILITY AT $61M PER SHUTTLE

This chart shows the OTV payload delivery costs for APOTVs delivering payload only. There is no MOTV crew capsule included.

The curves represent the payload delivery costs for the several APOTVs as the shuttle payload capability is increased. The costs for the same APOTVs using three 65-K shuttle launches are also shown.

These data reflect the APOTV performance and cost without external tank propellant scavenging and shuttle per launch costs of $61M.

OTV GEO PAYLOAD DELIVERY COST VS SHUTTLE PAYLOAD CAPABILITY @ $61M PER SHUTTLE



1154-113(T)

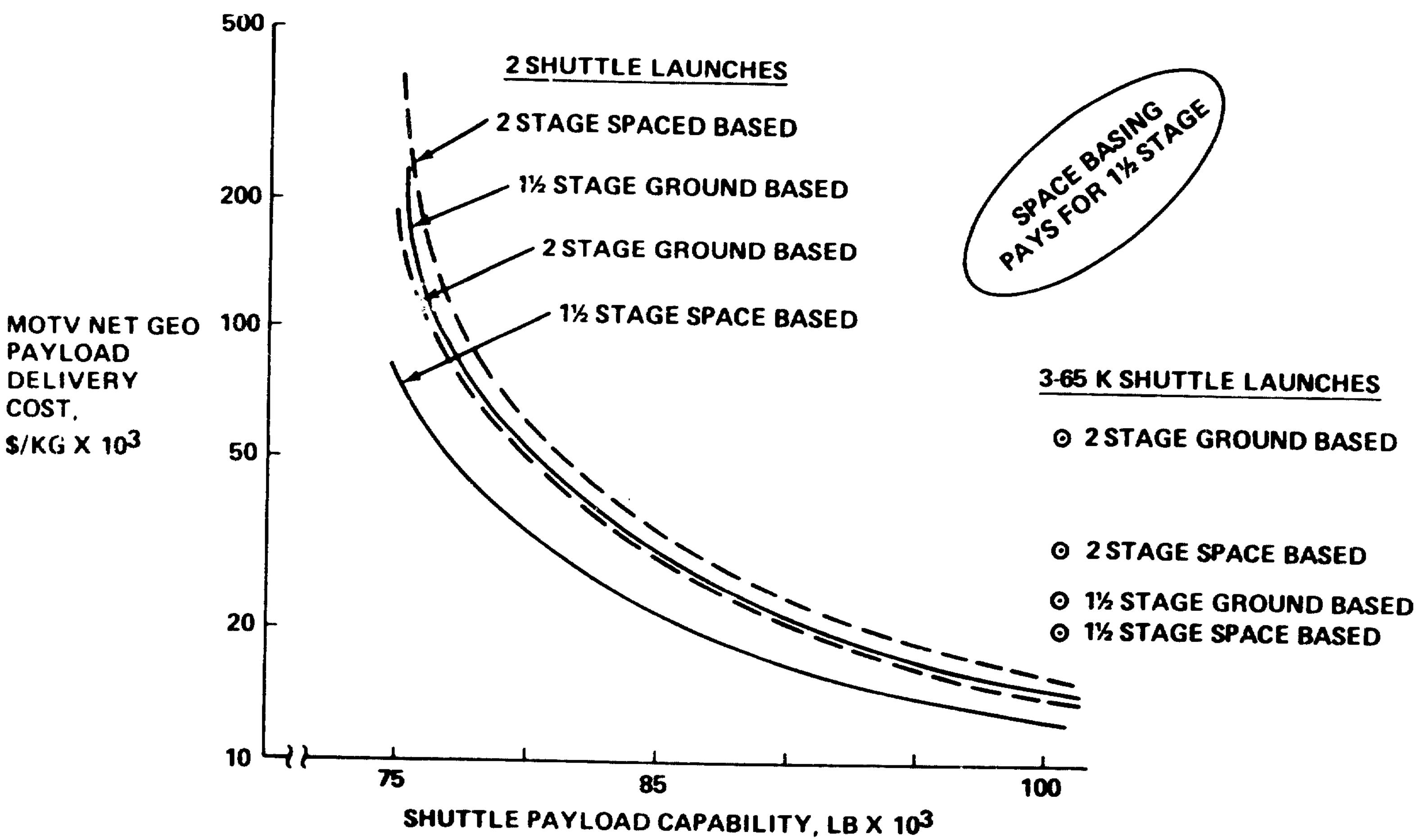
MOTV NET GEO PAYLOAD DELIVERY COST VS SHUTTLE PAYLOAD CAPABILITY: AT $61M PER SHUTTLE

This chart shows the MOTV net payload delivery costs. The cost is for delivering a Kg of payload to GEO over the delivery and return of the crew capsule.

The curves represent the costs for the several MOTVs (limited to two shuttle launches) as the shuttle payload capability is increased. The costs for the same MOTVs using three 65-K shuttle launches are also shown.

These data reflect the MOTV performance and cost without external tank propellant scavenging and shuttle per launch costs of $61M.

MOTV NET GEO PAYLOAD DELIVERY COST VS SHUTTLE PAYLOAD CAPABILITY @ $61M PER SHUTTLE



1154-011(T)

OPTION 1 SPACEPORT (ALL EVA) COSTS: 1982 $M

This chart presents the ROM cost estimate for the all EVA, minimum MOTV turnaround spaceport that is pictured and described in the turnaround & configuration studies portion of this report.

DDT&E and unit production costs have been totaled to arrive at the total cost of the spaceport. All monies are in 1982 dollars.

MOTV

OPTION 1 SPACEPORT (ALL EVA) COSTS, 1982 $M

GRUMMAN

	DDT&E	PROD
STS PAYLOAD BAY SURROGATE STRUCTURE	31.41	2.88
DROP TANK SUPPORT STRUCTURE	66.09	3.66
BERTHING RINGS (2)	9.29	1.98
SPACELAB PALLET	–	3.59
SKYLAB GYROS	–	5.30
AVIONICS	27.09	24.19
FUEL CELLS	35.22	3.78
POWER DISTRIBUTION	1.85	1.15
HPA CONTROLS	–	2.37
2 ARMED HPA	–	2.05
OPEN CHERRY PICKER	–	2.79
END EFFECTOR	–	2.14
SUB TOTALS	170.95	55.88
"WRAPAROUND" (SYSTEM ENG'G, INTEGRATION, ASS'Y & CHECKOUT, INITIAL SPARES, MANAGEMENT, SYSTEM TEST & EVALUATION)	40.18	27.39
TOTALS	211.13	83.27
TOTAL DDT&E & 1 UNIT	294.40	

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1154-016(T)

OPTION 2 SPACEPORT (IVA/EVA) COSTS: 1982 $M

This chart presents the RCM cost estimate for a slightly more ambitious spaceport that utilizes a modified MOTV crew capsule as a command post and permits many tasks to be performed IVA.

The previsouly described option 1 spaceport provides the basis for this cost estimate and additional equipments are added. The total cost reflects the DD&E plus one unit's production cost. All monies are in 1982 dollars.

MOTV

OPTION 2 SPACEPORT (IVA/EVA) COSTS, 1982 $M

GRUMMAN

	DDT&E	PROD
OPTION 1 SPACEPORT (ALL EVA)	211.13	83.27
OPTION 2 SPACE PORT (IVA/EVA) DELTAS		
SURROGATE STRUCTURE DELTA	40.57	2.29
MODIFIED MOTV CREW CAPSULE	62.40	82.93
BERTHING RING TO CREW CAPSULE TUNNEL	8.88	2.22
STS RMS	—	.19
"WRAPAROUND"	26.28	42.94
SUB TOTAL OPTION 2 DELTAS	138.65	130.57
TOTAL OPTION 2	349.78	213.84
TOTAL OPTION 2 DDT&E & 1 UNIT	563.62	

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1154-017(T)

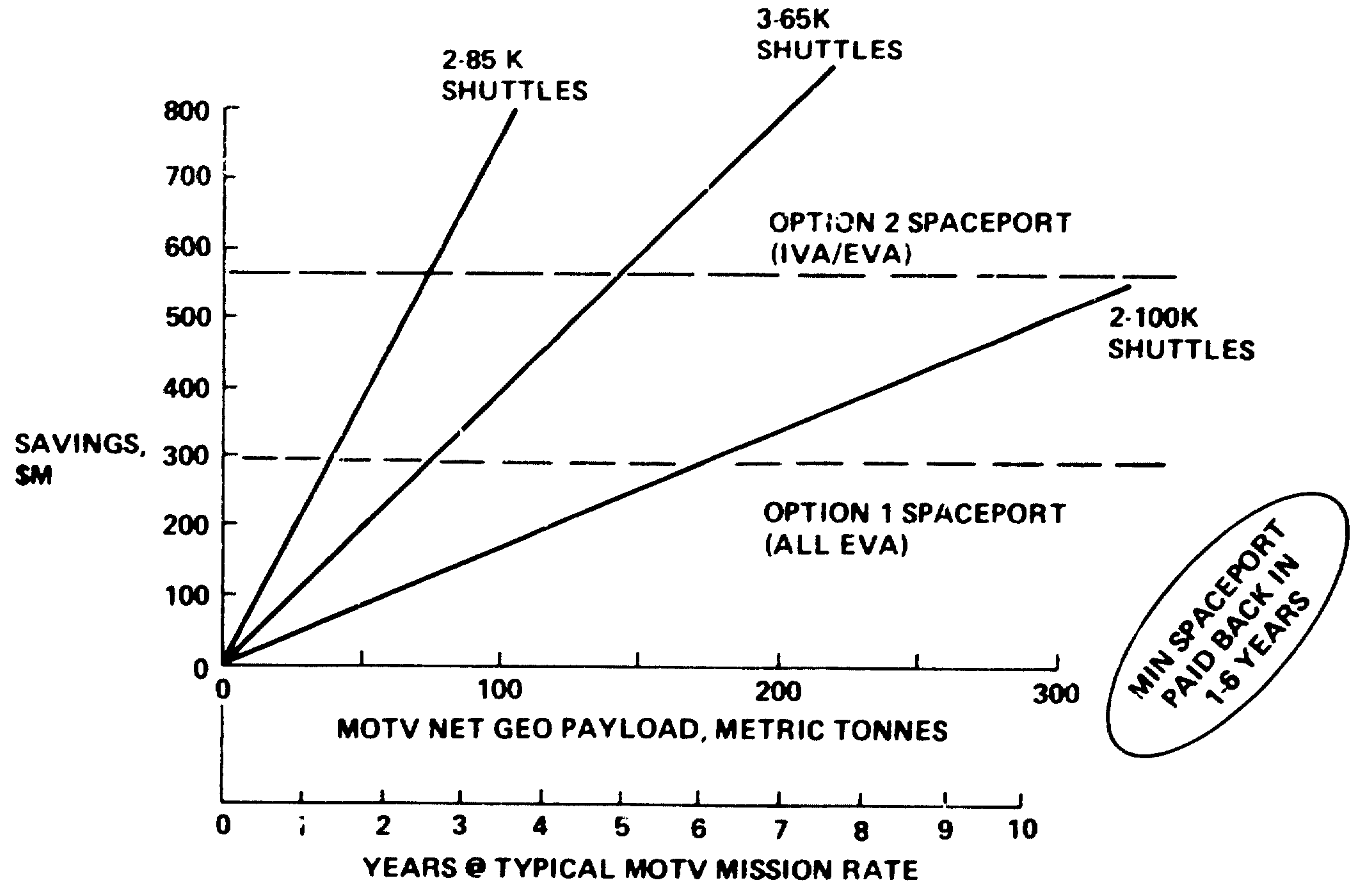
SPACE PORT PAYBACK *61M SHUTTLE

This chart plots the delta program costs between the space based and ground based 1 1/2-stage vs MOTV delivered payload tonnage. A second scale is shown representing the years anticipated to use that tonnage at the typical MOTV mission rate. The resulting cost savings curves for MOTVs using two 85-K shuttles, two 100-K shuttles, and three 65-K shuttles are shown. It should be noted that two 85-K shuttles cannot perform the typical mission.

These data reflect the MOTV performance and cost without external tank propellant scavenging and shuttle costs of $61M per launch.

The time required to pay back the cost of an option 1 (all EVA) spaceport for a three 65-K shuttle MOTV is 2 years.

SPACEPORT PAYBACK — 1½ STAGE SPACE BASED SAVINGS VS MOTV NET GEO PAYLOAD — $61M SHUTTLE



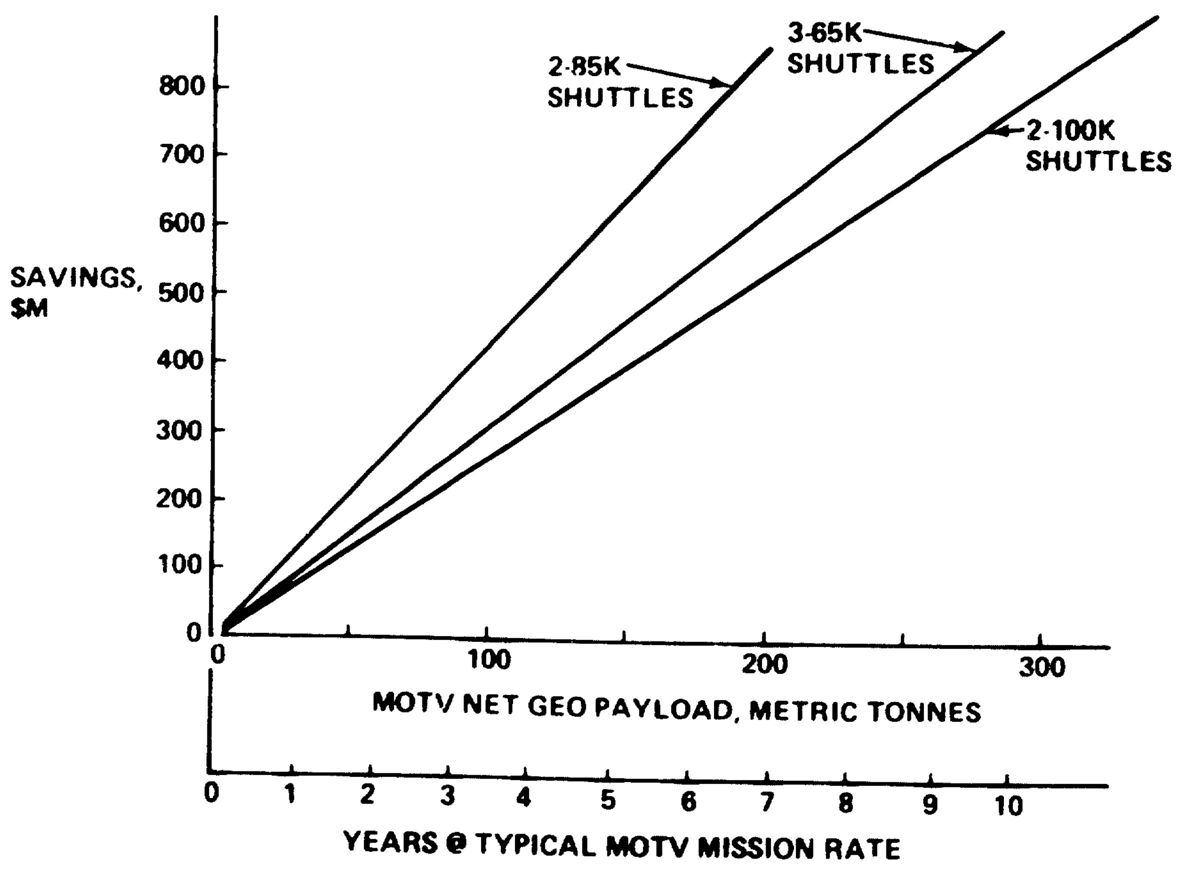
1154-019(T)

EXTERNAL TANK PROPELLANT SCAVENGING COST SAVINGS: $61M SHUTTLE

The cost savings between the 1 1/2-stage space-based MOTVs with scavenging and the same vehicles without scavenging have been plotted vs MOTV payload tonnage to GEO. A second scale is shown representing the years anticipated to use that tonnage at the typical MOTV mission requirement. The resulting cost saving curves for MOTVs utilizing two 85-K shuttles, two 100-K shuttles, and three 65-K shuttles are shown. It should be noted that the two 85-K shuttle MOTV cannot perform the typical mission.

These data reflect shuttle cost of $61M per launch.

E.T. PROPELLANT SCAVENGING SAVINGS – 1½ STAGE SPACE BASED SAVINGS VS MOTV NET GEO PAYLOAD $61M SHUTTLE



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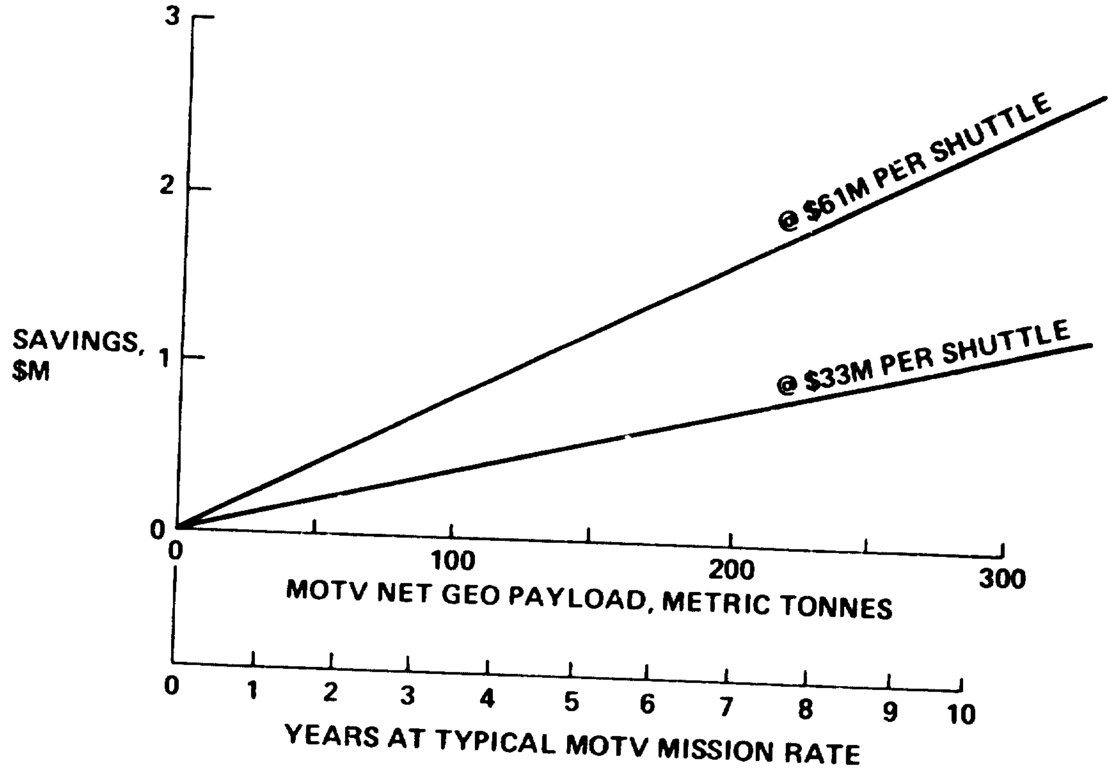
1154-116(T)

100-K SHUTTLE COST SAVINGS

The cost savings between the 1 1/2-stage space based MOTV using three 65-K shuttle launches and the same vehicle using two 100-K shuttle launches have been plotted vs MOTV payload tonnage to GEO. A second scale is shown representing the years anticipated to use that tonnage at the typical MOTV mission requirement. The resulting cost saving curves for MOTVs based on $33M and $61M per shuttle launch are shown.

100K SHUTTLE – 1½ STAGE SPACE BASED SAVINGS VS MOTV NET GEO PAYLOAD



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1154-117(T)

MOTV

CONCLUSIONS

GRUMMAN

- SERVICEABLE SATELLITE SYSTEM MORE COST EFFECTIVE THAN EXPENDABLE SATELLITE SYSTEM
- MINIMUM TENDED SPACEPORT CAN HANDLE OTV/MOTV TURNAROUND AND CAN BE PAID BACK IN 2 TO 5 YEARS
- 2-65K SHUTTLES CANNOT PERFORM MINIMUM MOTV MISSION
- 2-100 K SHUTTLES OR 3-65 K SHUTTLES REQUIRED TO PERFORM TYPICAL MOTV MISSION
- PROPELLANT SCAVENGING IS ATTRACTIVE
- PROPELLANT TRANSFER LOSSES SIGNIFICANTLY REDUCE 2 STAGE SPACE BASED MOTV PAYLOAD CAPABILITY (CONSIDER PLUG IN TANKS)
- SPACE BASED 1½ STAGE IS BEST PERFORMING AND LOWEST COST MOTV

1154-118(T)

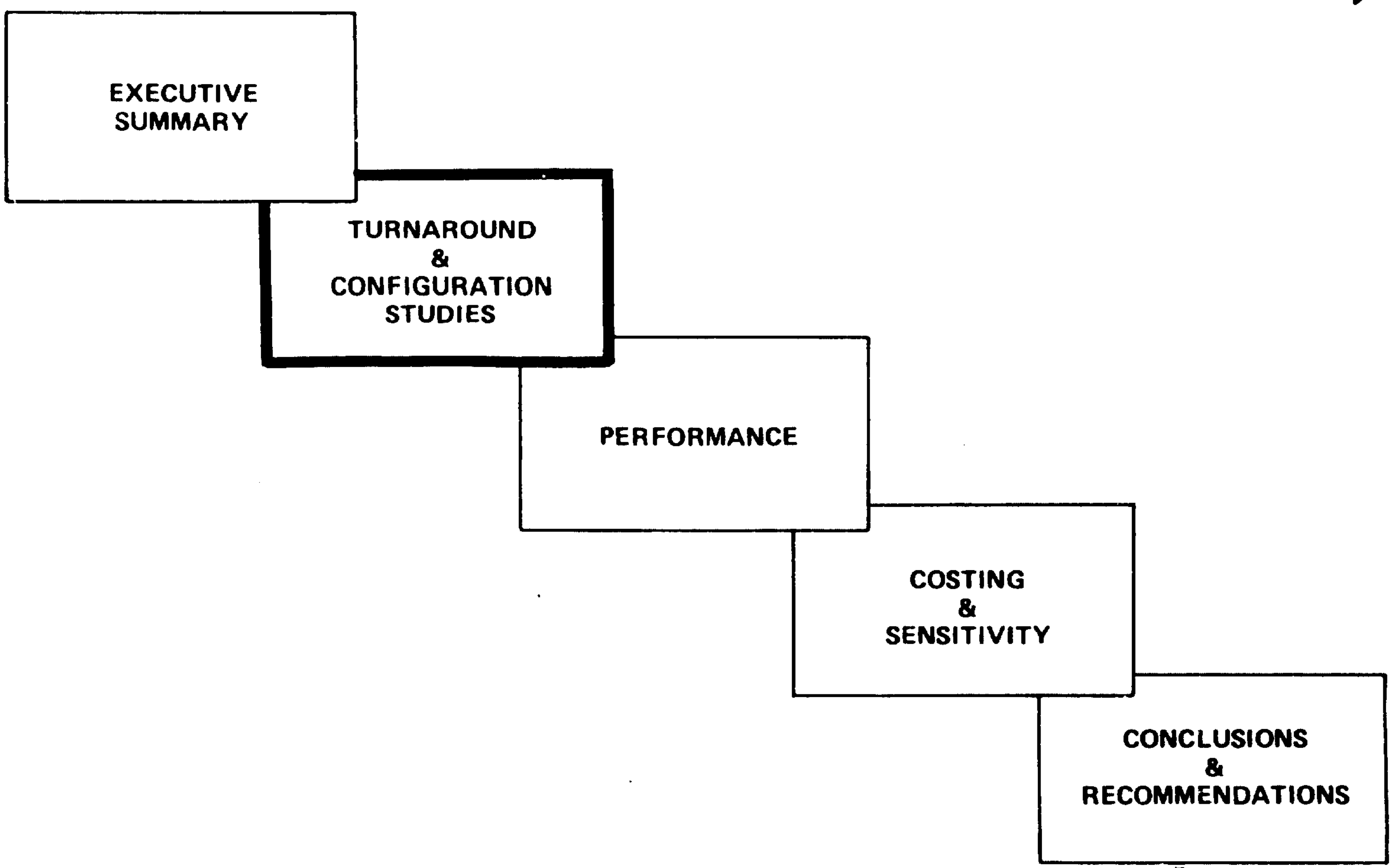
MOTV

RECOMMENDATIONS

GRUMMAN

- PERFORM SIMULATIONS TO QUANTIFY MANNED VS UNMANNED SATELLITE SERVICING CAPABILITY
- PURSUE EXTERNAL TANK PROPELLANT SCAVENGING
- CONTINUE TO DETERMINE, QUANTIFY AND EVALUATE THE DIFFERENCES BETWEEN PLUG-IN TANKS AND PROPELLANT TRANSFER
- DEFINE AND COMPARE CREW CAPSULE SUBSYSTEMS FOR GROUND BASED VS SPACE BASED OPTIONS
- DETERMINE EVOLUTIONARY PROGRAM FOR OTV/MOTV

1154-119(T)


EXECUTIVE SUMMARY
TURNAROUND & CONFIGURATION STUDIES
PERFORMANCE
COSTING & SENSITIVITY
CONCLUSIONS & RECOMMENDATIONS

1154-063(T)

MOTV

MOTV TURNAROUND STUDIES

GRUMMAN

- NOMINAL GEO MISSION SCENARIOS
  - GROUND BASED
  - SPACE BASED
- 1½ STAGE MOTV
  - GROUND BASED
  - SPACE BASED
- 2 STAGE COMMON MOTV
- MIN SPACEPORT OPTIONS FOR SPACE TURNAROUND

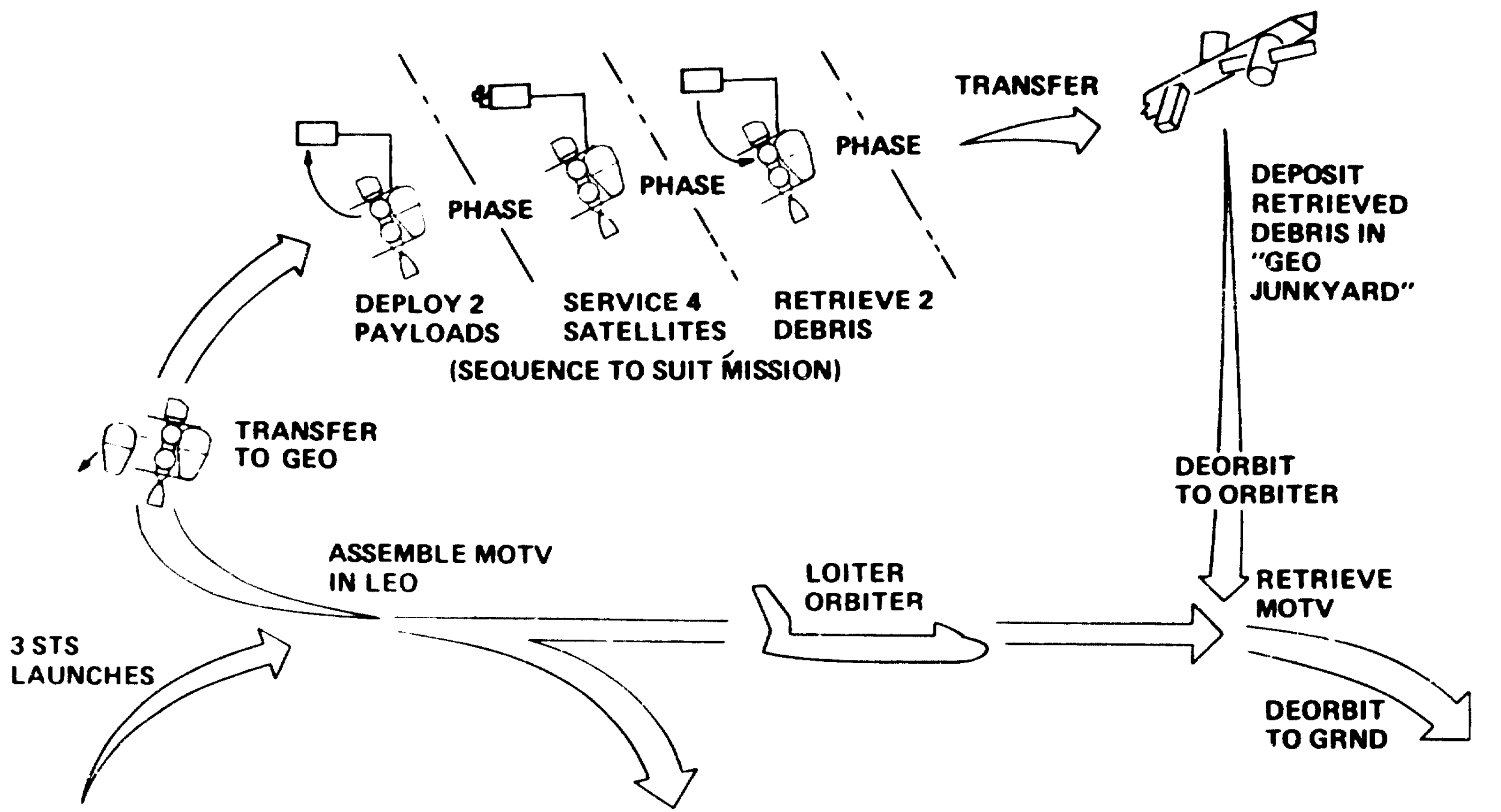
1154-064(T)

NOMINAL MISSION SCENARIO: GROUND BASED MOTV

To illustrate the nominal mission, we have elected to deploy an SPC and a LEASAT; to service four satellites by replacing an MMS module on each; to retrieve an L-SAT and an INTELSAT 5; and to deposit them at a "junkyard" located at GEO + 2000-n-mi orbit. The "junkyard" is assumed to be a long structural beam onto which dead satellites and structures can be mounted.

The scenario portrayed on the opposite page shows that a 1 1/2-stage MOTV has been assembled at LEO from three sequential shuttle launches. The MOTV transfers to GEO to perform the mission. The sequence for deployment/servicing/retrieving depends on the various locations of activities. Upon completion of this sequence, the MOTV transfers to the GEO "junkyard" where it deposits the retrieved debris. It then returns to LEO to be retrieved by the orbiter loitering from the last shuttle launch in the assembly sequence. The orbiter now returns MOTV to the ground for servicing.

NOMINAL MISSION SCENARIO – GROUND BASED MOTV



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1154-065(T)

GROUND BASED 1-1/2-STAGE OTV: CURRENT CONFIGURATION

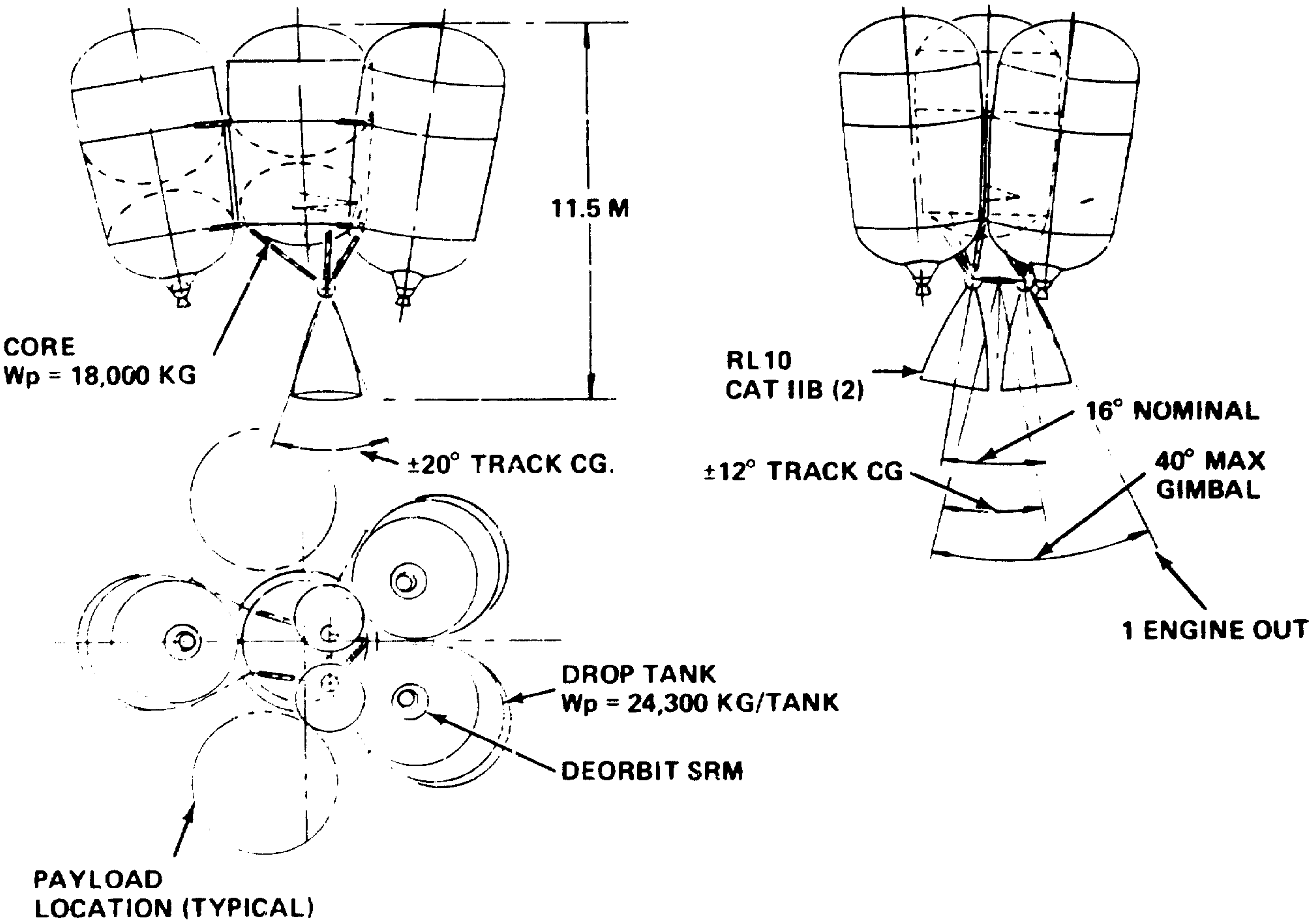
Our earlier MOTV studies used a reference mission that serviced four satellites, 90° apart in GEO. Now our nominal mission is to deploy satellites, to service others, and to remove debris. This has led to a change in the ground based OTV configuration that must provide mounting for satellites to be deployed and for debris to be removed. The current configuration for a ground based OTV is shown here with a capability to mount three drop tanks, although the nominal mission only requires two tanks.

A core comprised of an LO_2 tank and LH_2 tank mounts two RL10 category IIB engines located so their mean thrust line follows the cg as it moves during the mission. The engine maximum gimbal range is $\pm 20^\circ$, which also caters for the change in thrust line for only one engine firing. A maximum of three drop tanks can be mounted to this core in the locations shown. Each drop tank is jettisoned when depleted and then mounts a motor for de-orbit and burns up in the atmosphere. Two locations are provided on the core skirt to mount payloads roughly the size of a drop tank or smaller. Propellant capacities for the core and drop tanks are given.

MOTV

GROUND BASED 1½ STAGE OTV – CURRENT CONFIGURATION

GRUMMAN



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1154-066(T)

GROUND BASED 1-1/2-STAGE MOTV: CONFIGURED FOR NOMINAL MISSION

The preceding chart described the current ground based OTV, which for this mission required only two drop tanks. Since the nominal mission is manned, it needs a crew capsule to house the two crewmen and to provide flight and mission operations stations. The capsule is the "two-man functional minimum" described in an earlier report and has four MMS modules that are mounted to rails on the crew capsule exterior and used for satellite servicing. The capsule also has a folded panel rediator that is deployed during the mission. The nominal mission is performed EVA and requires a pressure suited crewman operating an MMU/WRU. This equipment is mounted to the crew capsule for transport to GEO and back.

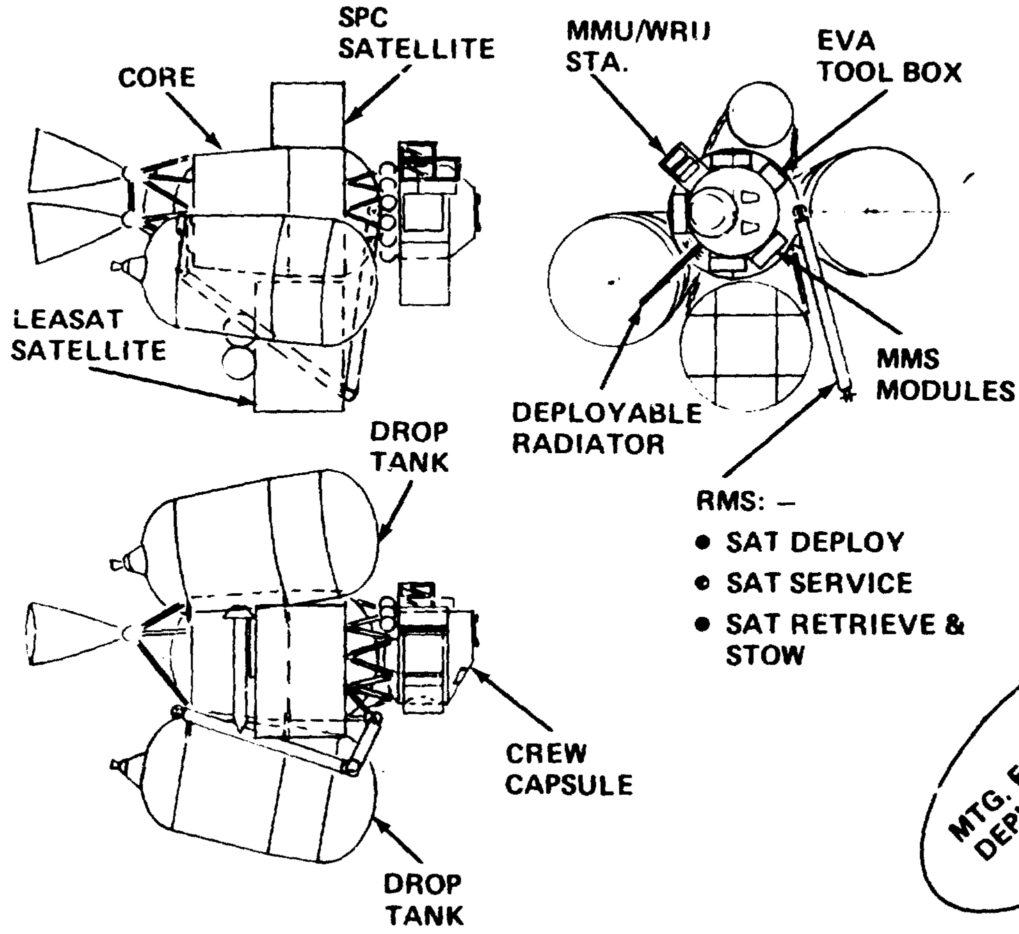
An RMS is mounted to the propulsion core skirt to handle and capture satellites.

Satellites for deployment are the SPC and the LEASAT, which are also mounted to the propulsion core for transfer to their operational locations. There they are deployed by the RMS, which transfers the satellite to a position within view of the capsule windows for activation and check out. Deployment does not necessarily demand EVA activity since the extension of appendages, etc., could be automated.

For servicing, the RMS captures the satellite within view of the crew capsule window. Servicing is performed by an EVA crewman, who, after monitoring the capture, maneuvers the MMU/WRU to pick up the MMS module from its stowage on the crew capsule and then transfers and berths to the satellite. The crewman changes out the MMS module, performs interface checks, and then returns to the MOTV to stow the exchanged module on the crew capsule. After the final checkout, the satellite is released.

Two expended satellites are to be retrieved in GEO, and then transferred to a "junkyard" located at GEO + 2000-n-mi orbit. The RMS captures the dead satellite and mounts it on the propulsion core skirt. Mounting location for the retrieved satellite will be either that vacated by a deployed satellite or a jettisoned drop tank. All drop tanks will have been jettisoned by this stage of the mission.

GROUND BASED 1 1/2 STAGE MOTV —CONFIGURED FOR NOMINAL MISSION



RMS: –
- SAT DEPLOY
- SAT SERVICE
- SAT RETRIEVE & STOW

MTG. FOR 15 FT DIA
DEPLOY/RETRIEVE
PAYLOADS

GROUND BASED 1 1/2-STAGE MOTV WEIGHT SUMMARY

The weight statement for the ground based 1 1/2-stage MOTV as configured for the nominal mission is shown. The weights (in kg) for each of the components is shown in the appropriate column. The columns are then summed for the total weight.

The crew capsule dry weight includes a 25 percent contingency. Contingency for the propulsion stage and drop tanks is 15 percent of the dry weight.

The variation in propellants carried is due to shuttle manifesting. The shuttle that delivered drop tank No. 1 also delivered the GEO payload. As noted, this configuration can deliver and return the crew capsule shown and deliver an additional 4563 kg of payload to GEO orbit.

This weight statement reflects a three-shuttle launch MOTV with no external tank propellant scavenging.

MOTV

GROUND BASED — 1½ STAGE MOTV CONFIGURED FOR NOMINAL MISSION WEIGHT SUMMARY, KG

GRUMMAN

	CREW CAPSULE	PROPLSN STAGE	DROP TANK #1	DROP TANK #2	TOTAL
STRUCTURE	1113	803	637	637	3226
SUBSYSTEMS	1074	501	5	5	1585
PROPULSION		729	298	298	1325
ACPS		500			500
SEPARATION/DEORBIT			152	152	304
TPS	33	170	154	154	511
CONTINGENCY	555	405	187	187	1340
DRY WEIGHT	2775	3108	1433	1433	8791
CREW	163				163
MISSION EQUIPMENT	928				928
CONSUMABLES	234	675			909
RESERVE & RESIDUALS		270	242	242	754
B.O. WEIGHT	4100	4030	1675	1675	11,545
PROPELLANTS		16,470	18,665	24,215	60,880
IGNITION WEIGHT	4100	20,500	20,340	25,890	72,425

THIS CONFIGURATION FULLY UTILIZES THREE 65K SHUTTLE LAUNCHES AND CAN DELIVER 4563 KG TO GEO (OVER & ABOVE DELIVERY & RETURN OF CREW CAPSULE)

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1154-068(T)

GROUND BASED 1 1/2-STAGE MOTV: LEO ASSEMBLY SEQUENCE

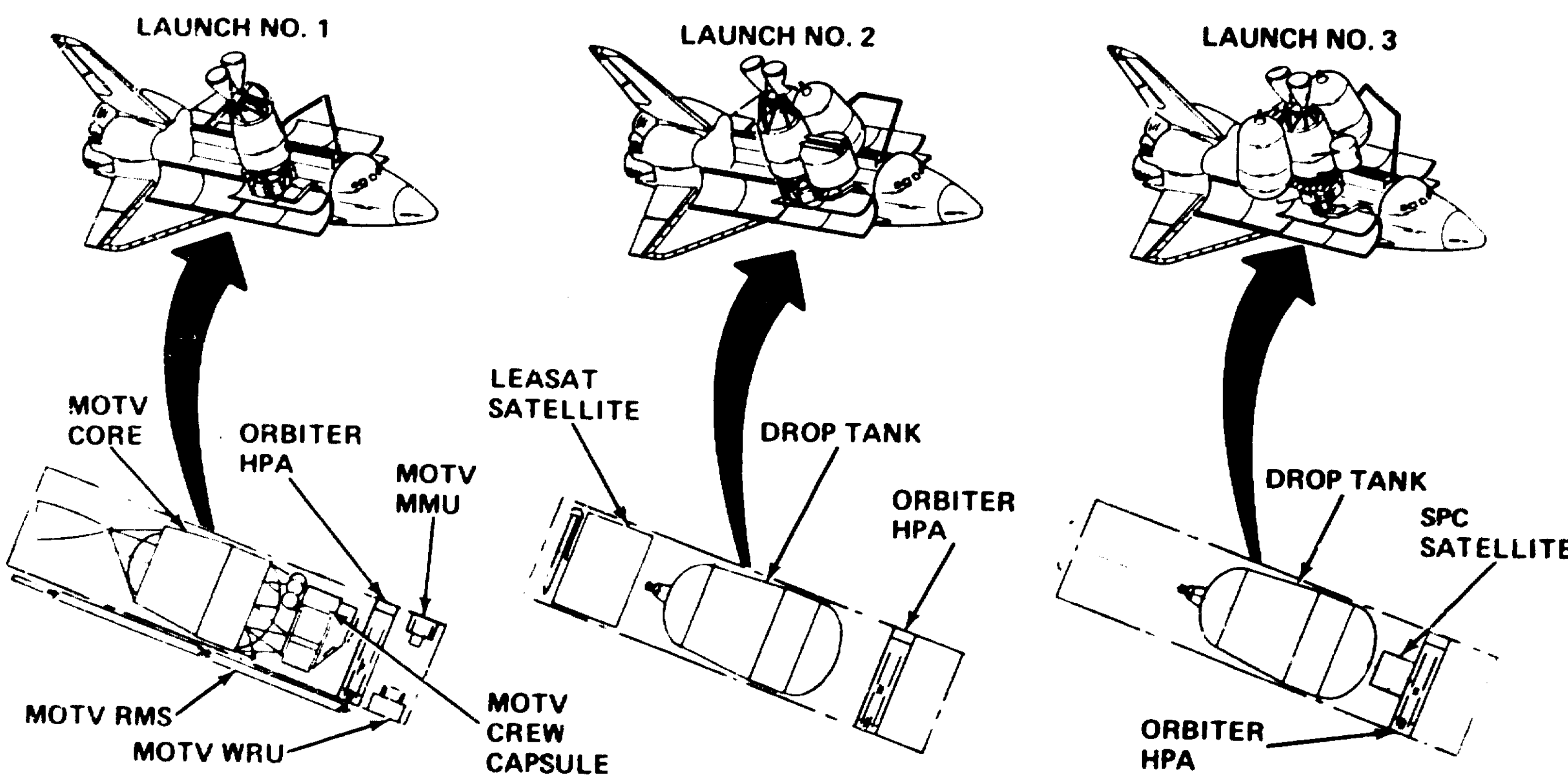
As shown on the mission scenario, three shuttle launches are required to transfer the nominal mission MOTV components from ground to LEO for assembly. The first launch takes the propulsion core and crew capsule, as an assembly, to LEO. The orbiter RMS removes them from the cargo bay and mounts them on the orbiter HPA. There, the MMU and WRU are removed from their stowage in the cargo bay and are mounted to the MOTV crew capsule. Similarly the MOTV RMS, which was transported to LEO in the orbiter starboard RMS location, is installed in its mount on the propulsion core skirt. The vehicle is checked out, then released to stay in a stable, quiescent mode to await the next shuttle launch. The orbiter returns to earth.

A second launch transfers a fueled drop tank and a payload satellite to orbit, where the orbiter captures the orbiting MOTV with its RMS and mounts it to the HPA. The drop tank and satellite are now transferred from the cargo bay and are installed on the MOTV propulsion core. Again, the vehicle is checked out and then released to await the last shuttle launch. The orbiter returns to earth.

The third launch transfers the second drop tank and the other payload satellite to orbit, where the same procedure is followed as on the preceding launch. After check out, the fully configured MOTV transfers to GEO to perform its mission. Meanwhile, the third launched orbiter remains in LEO to retrieve the MOTV core/crew capsule at the end of its mission and to return it to earth for servicing.

If propellant scavenging from the STS external tank is in vogue, then it is assumed that the core tanks and drop tanks will be sized to accept the additional propellants when they are transferred either directly to the tanks from the external tank or via a scavenging tank.

GROUND BASED 1½ STAGE MOTV – LEO ASSY SEQUENCE



1154-069(T)

NOMINAL MISSION SCENARIO: SPACE BASED MOTV

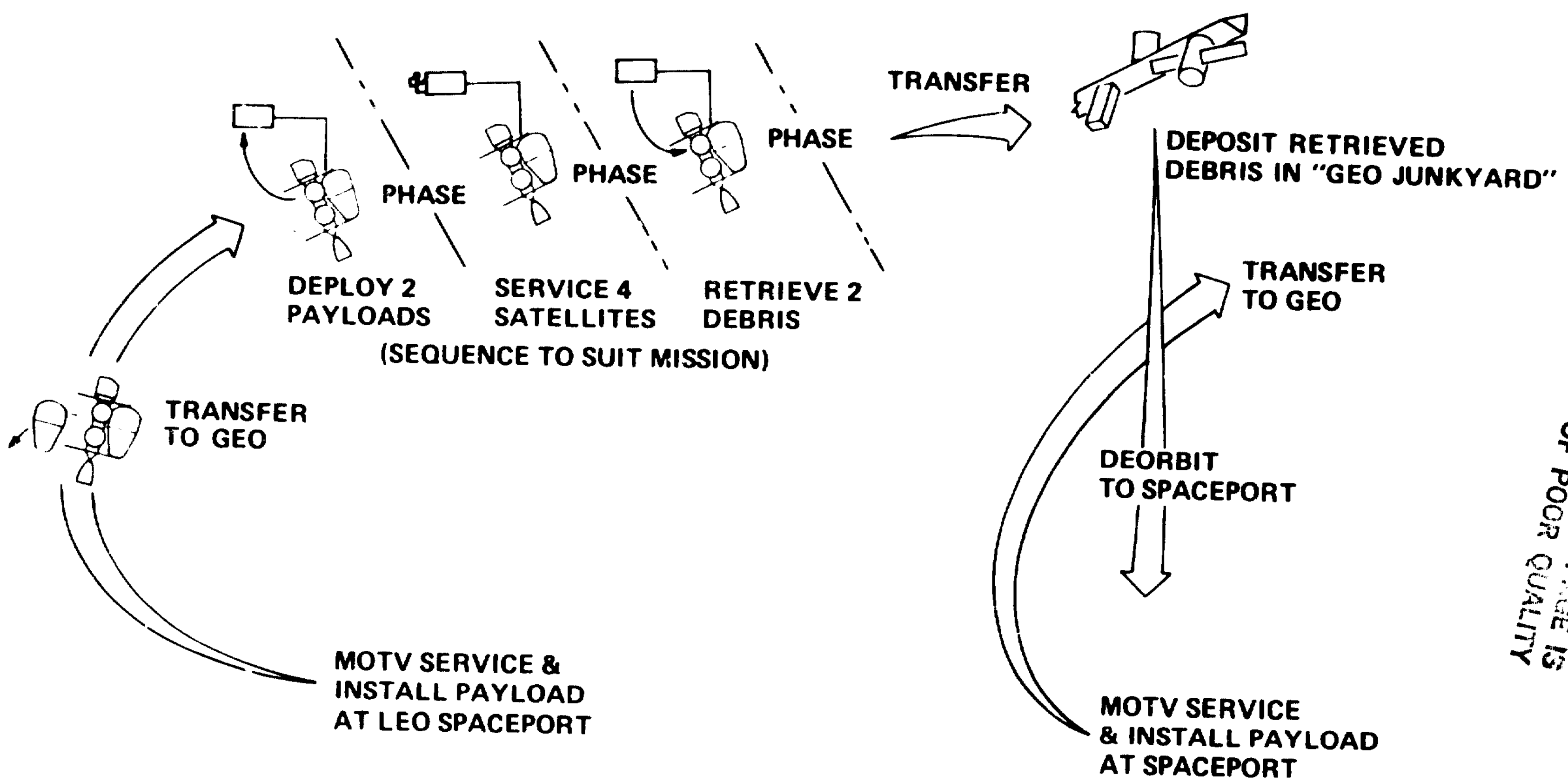
To illustrate a nominal mission, we have elected to deploy an SPC and a LEASAT Satellite; to service four satellites by replacing an MMS module on each; to retrieve an L-SAT and an INTELSAT 5; and to deposit them at a "junkyard" located at GEO + 2000-n-mi orbit. The "junkyard" is assumed to be a long structural beam onto which dead satellites and structures can be mounted.

The scenario portrayed on the opposite page shows that a 1 1/2-stage MOTV has been serviced at the LEO spaceport. It then transfers to GEO to perform the mission. The sequence for deployment/servicing/retrieving depends on the various locations of activities. Upon completion of this sequence, the MOTV transfers to the GEO "junkyard" where it deposits the retrieved debris. It then returns to the spaceport where it is serviced and made ready for the next mission.

MOTV

NOMINAL MISSION SCENARIO – SPACE BASED MOTV

GRUMMAN



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1154-070(T)

SPACE BASED 1 1/2-STAGE MOTV: CONFIGURED FOR NOMINAL MISSION

This MOTV is our current baseline space-based vehicle. It comprises a central spine that mounts two RL10 Category IIB engines at one end and a crew capsule at the other. Drop tanks and payload are mounted, as required, to the spine. The vehicle was fully described in our midterm briefing, together with the deployment, satellite servicing and debris removal operations that comprise the nominal mission.

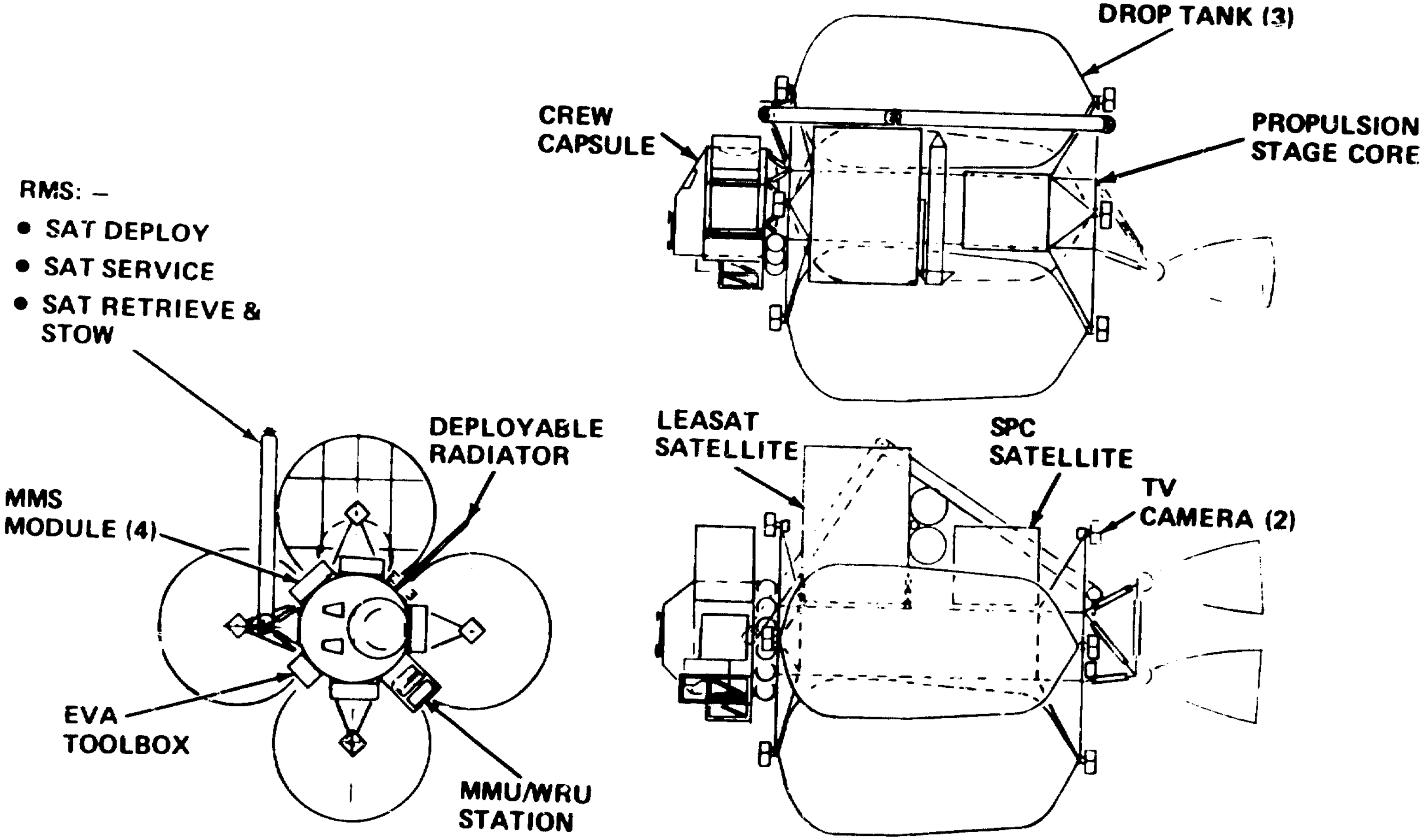
In summary, this mission requires three drop tanks for propellant. The mission is performed EVA and requires a pressure suited crewman operating an MMU/WRU, which is mounted to the crew capsule for transport to GEO and back.

An RMS is mounted to the propulsion stage structure to handle and capture satellites. In the forward end of the crew capsule, windows provide the RMS operator with a view of activities forward of the capsule. To view RMS activities in the propulsion stage when picking up or stowing satellites, TV cameras have been installed on forward and aft outriggers to view the two sides of the central spine where payloads can be mounted. A TV camera is also part of the RMS.

The two satellites to be deployed are stowed on the spine of the propulsion stage in an area that on a more demanding mission might mount another drop tank. Four MMS modules for satellite servicing are mounted to rails on the crew capsule exterior. A box containing EVA tools is also mounted to the crew capsule. The capsule has a paneled radiator that is folded during service but deployed during the mission.

SPACE BASED 1½ STAGE MOTV – CONFIGURED FOR NOMINAL MISSION

RMS: –
- SAT DEPLOY
- SAT SERVICE
- SAT RETRIEVE & STOW



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1154-071(T)

SPACE BASED 1 1/2-STAGE MOTV WEIGHT SUMMARY

The weight statement for the space based 1 1/2-stage MOTV as configured for the nominal mission is shown. The weights (in kg) for each of the components is shown in the apropriate column. The columns are then summed for the total weight.

The crew capsule dry weight includes a 25 percent contingency. Contingency for the propulsion stage and drop tanks is 15 percent of the dry weight.

The variation in propellants carried is due to shuttle manifesting. The shuttle that delivered drop tank No. 1 also delivered the GEO payload. As noted, this configuration can deliver and return the crew capsule shown and deliver an additional 6060 kg of payload to GEO orbit.

This weight statement reflects a three-shuttle launch MOTV with no external tank propellant scavenging.

MOTV

SPACE BASED 1½ STAGE MOTV CONFIGURED FOR NOMINAL MISSION WEIGHT SUMMARY, KG

GRUMMAN

	CREW CAPSULE	ZERO STAGE	CORE DROP TANK	DROP TANK #1	DROP TANK #2	TOTAL
STRUCTURE	1113	500	637	637	637	3524
SUBSYSTEMS	1074	501	5	5	5	1590
PROPULSION		433	298	298	298	1327
ACPS		368				368
SEPARATION/DEORBIT				152	152	304
TPS	33		154	154	154	495
CONTINGENCY	555	270	164	187	187	1363
DRY WEIGHT	2775	2072	1258	1433	1433	8971
CREW	163					163
MISSION EQUIPMENT	928					928
CONSUMABLES	234	675				909
RESERVES & RESIDUALS			364	242	242	848
B.O. WEIGHT	4100	2747	1622	1675	1675	11,819
PROPELLANTS			24,268	14,815	24,215	63,298
IGNITION WEIGHT	4100	2747	25,890	16,490	25,890	75,117

THIS CONFIGURATION FULLY UTILIZES THREE 65K SHUTTLE LAUNCHES AND CAN DELIVER 6060 KG TO GEO (OVER & ABOVE DELIVERY & RETURN OF CREW CAPSULE)

1154-072(T)

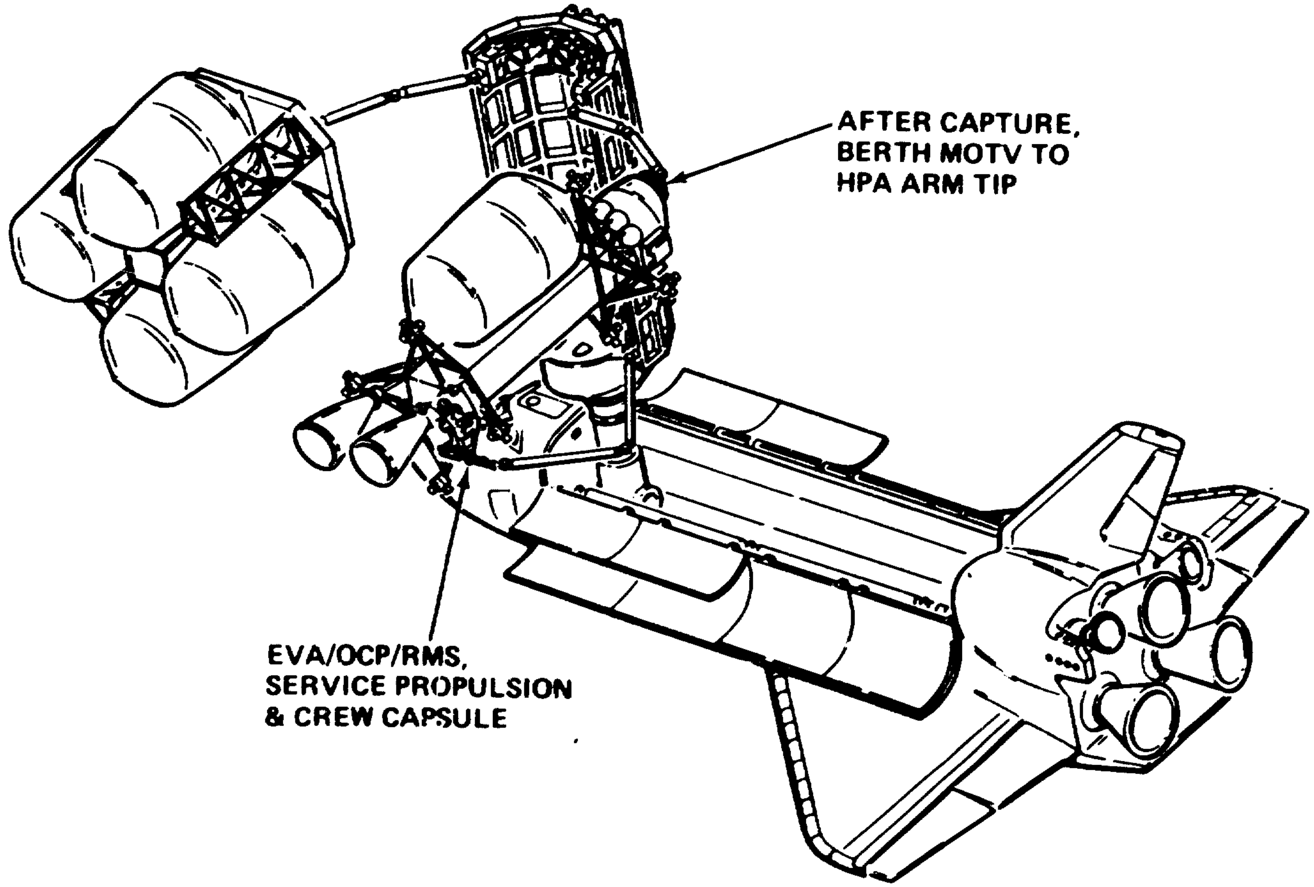
MIN SPACEPORT, ALL EVA TURNAROUND, 1 1/2-STAGE MOTV

As demonstrated on another chart, this facility can be transported to its operational location in LEO by a single shuttle flight. Once there, the orbiter extends its HPA arm, which mounts a berthing fixture at its tip. The orbiter standard RMS is used during construction to fetch and carry the spaceport component parts. The orbiter second RMS mounts the spaceport OCP at its tip to carry an EVA crewman, who monitors operations and assists in assembly.

Build sequence starts with a berthing ring being mated to the orbiter HPA berthing fixture. Assembled onto this ring are support struts that are fanned out to predetermined positions and then locked. A section of the spaceport structural cradle is now attached to the free ends of the appropriate support struts. This is followed by installation of another section of cradle and so on until the cradle is complete. The orbiter HPA articulates to move the cradle until it presents its open side for installation of the spacelab pallet and the spaceport HPA.

When assembly is completed, the OCP, which has been used during the process to support the EVA man, is mounted to a support on the spacelab pallet and left there for spaceport operations.

MIN SPACEPORT, EVA/IVA TURN-AROUND, 1½ STAGE MOTV – MOTV SERVICING



1154-080(T)

MIN SPACEPORT, EVA/IVA TURNAROUND, 1 1/2-STAGE MOTV: LAUNCH CONFIGURATION & WEIGHT

The operational configuration of this spaceport is illustrated on preceding charts. Its component parts, some of which are folded for launch, require 1 1/2 shuttle launches to LEO. This figure illustrates a general arrangement of the components on those launches. No attention has been paid to the combined cg of these masses so some rearrangement may be necessary to keep within the orbiter's allowable cg envelope. On both launches, EVA can be effected from the orbiter cabin without jettisoning any payload.

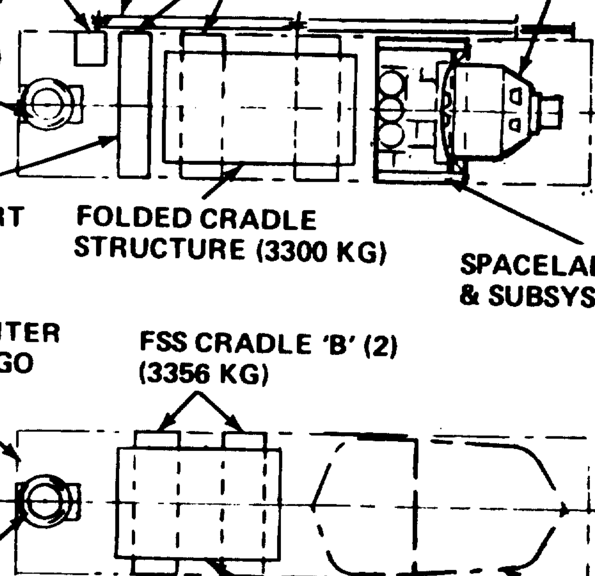
On launch No. 1, the folded components, namely the cradle structure and the drop tank stowage structure, are shown as envelopes. It has been determined by rough layouts that these structures can be folded within these envelopes. The FSS cradle "B" supports these items during launch. Although the cradle is a heavy design, as currently reported, if offers an "under development" mounting cradle that demands little cargo bay volume for itself. In any event, launch No. 1 is a volume limited launch and the weight is available for this cradle.

Launch No. 2 requires approximately one half of the cargo bay length to mount the docking module, to allow for EVA egress, and to mount the drop tank stowage structure. The remainder of the bay length is available for another payload. It is suggested that a drop tank occupy the aft half of the bay. Its propellant would be necessarily offloaded to allow for the masses of the docking module, the drop tank stowage structure, and ASE.

An orbiter docking module is carried on both launches to provide a berthing fixture and a means of shirtsleeve access to the spaceport crew capsule after is has been installed.

Weights are given for the major components on each launch, together with total payloads for each launch.

MIN SPACEPORT, EVA/IVA TURN-AROUND, 1½ STAGE MOTV – LAUNCH CONFIGURATION & WEIGHT



1½ STS LAUNCHES TO ORBIT

WEIGHTS SUMMARY (KG)

• LAUNCH #1	
SPACEPORT COMPONENTS	13,564
ASE	5,125
LAUNCH TOTAL	18,779
• LAUNCH #2	
SPACEPORT COMPONENTS	1,500
ASE	5,125
RENDEZVOUS	910
LAUNCH TOTAL	7,535

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1154-061(T)

GROUND BASED VS SPACE BASED MOTV: SUMMARY OF IMPACT ON MOTV SUBSYSTEM REQUIREMENTS

This chart assesses the gross impact on MOTV subsystem requirements for turn-around at a ground and at a space facility. The three main phases of activity considered are transport from ground to LEO, LEO to GEO operations, and servicing of the vehicle.

During transport to and from ground to LEO, few subsystems are active. The shuttle provides what is necessary in the way of power and thermal control. Data and communication are active to monitor and report on the status of the vehicle. The structure is active since the vehicle supports itself from the orbiter longeron and keel. A penalty of ground basing is that the vehicle is subjected to the launch/landing loads and dynamics spectrum on each mission flown by the MOTV.

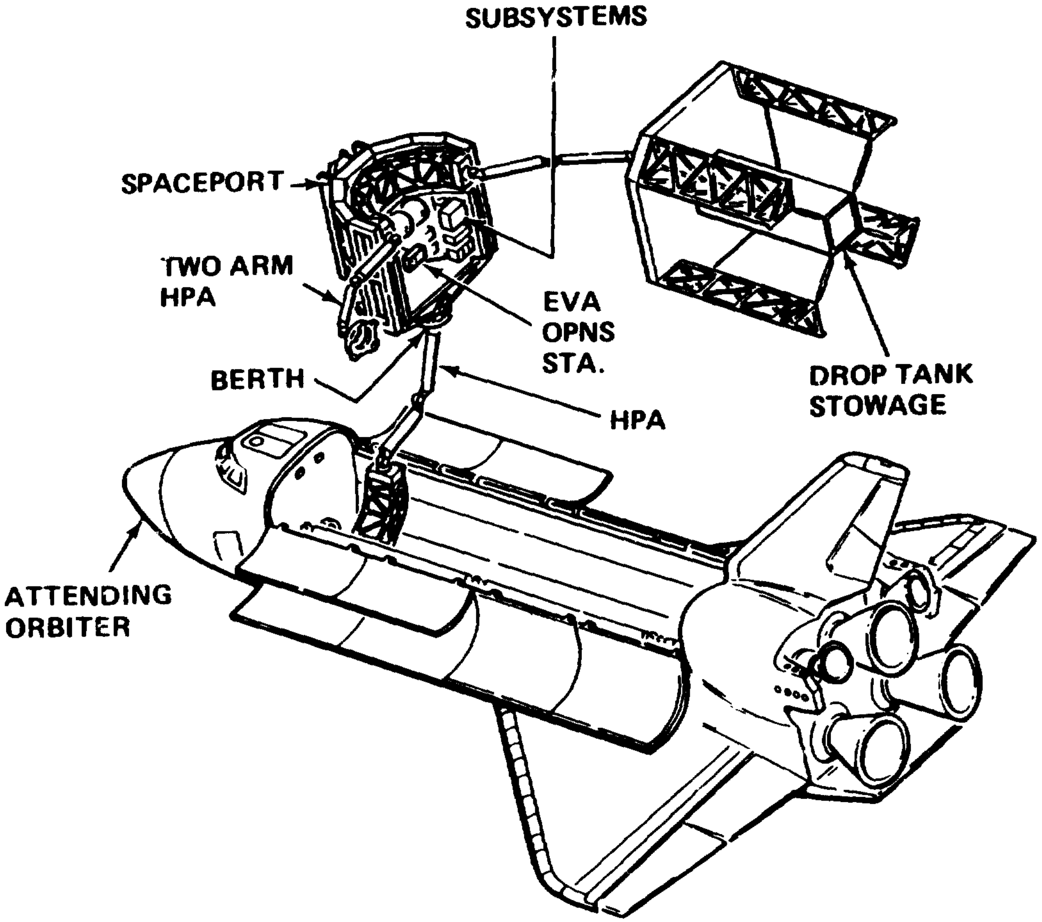
During their LEO to GEO (and return) mission operations, the subsystems have the same requirements, whether they are ground or space based.

Considering MOTV servicing, most subsystems are dormant, especially when ground based. Power is supplied by the servicing facility. Data and communications are active to monitor and report on the status of the vehicle. Ground based servicing will take place in a controlled environment so thermal control and ECLS will be inactive. However, these two subsystems may be active at least during part of space based servicing operations, since the crew capsule may be pressurized for a crewman to remove his EVA suit and work more freely to service/repair internal subsystems. Thermal control would then be activated on the crew capsule. Also thermal control might be necessary on the propulsion stage for fuel cells. This, then, is a penalty for space basing.

A more detailed level of servicing is likely if the MOTV is ground based. Space-based servicing will probably be at the sub-assembly level and this hardware has to be packed and stowed on ASE structure for launch to the servicing facility. This is a further penalty for space basing.

We have not quantified these panalties during this add-on study. This will be a task for any future extension.

MIN SPACEPORT, ALL EVA TURN-AROUND – 1½ STAGE MOTV



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C-2

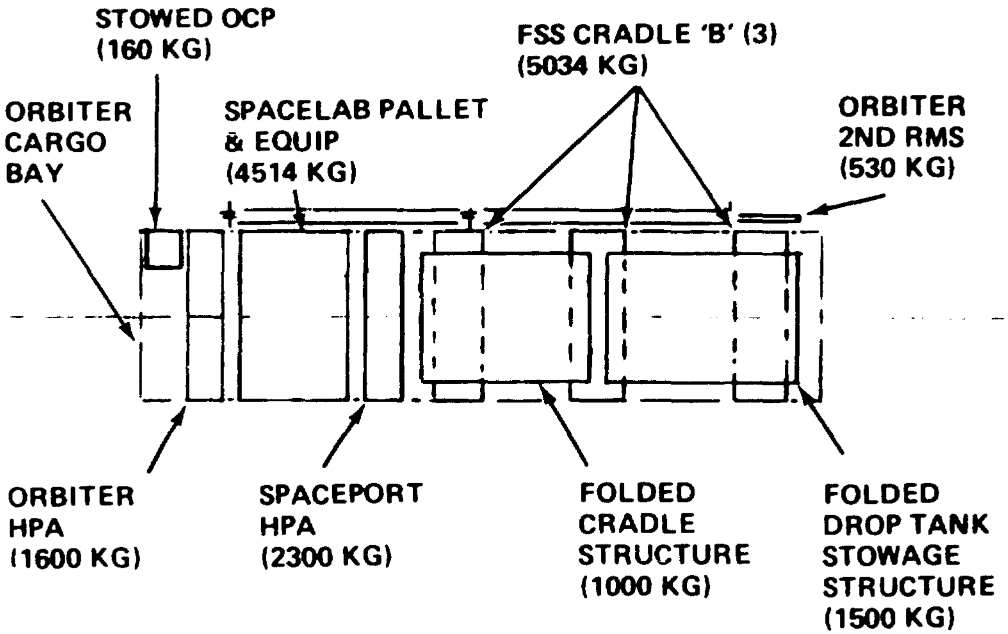
1154-073(T)

MIN SPACEPORT, ALL EVA TURNAROUND, 1 1/2-STAGE MOTV: LAUNCH CONFIGURATION AND WEIGHT

The operational configuration of this spaceport is illustrated on a preceding chart. Its component parts, some folded, can be transported to LEO on a single shuttle launch. This figure illustrates a general arrangement of the components on that launch. No attention has been paid to the combined cg of these masses and, therefore, some rearrangement may be necessary to keep within the allowable cg envelope. EVA can be effected from the orbiter cabin without jettinsoning any of the payload.

All components are shown as envelopes and do not show, for example, the equipments mounted on the spacelab pallet. It has been determined, by rough layouts, that the cradle structure and the drop tank stowage structure can be folded within the envelopes shown. The FSS cradle B supports these items during launch. Although the cradle is of a heavy design, as currently reported, this is a volume-limited launch and the weight is available for this proposed support cradle. Weights are given for the major components, together with the total payload for the launch.

MIN SPACEPORT, ALL EVA TURN-AROUND, 1½ STAGE MOTV – LAUNCH CONFIGURATION & WEIGHT



1 STS LAUNCH TO ORBIT

WEIGHTS SUMMARY (KG)

• SPACEPORT COMPONENTS	9,474
• ASE	7,164
LAUNCH TOTAL	16,638

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1154-074(T)

MIN SPACEPORT, ALL EVA TURNAROUND, 1 1/2-STAGE MOTV: DROP TANK DELIVERY

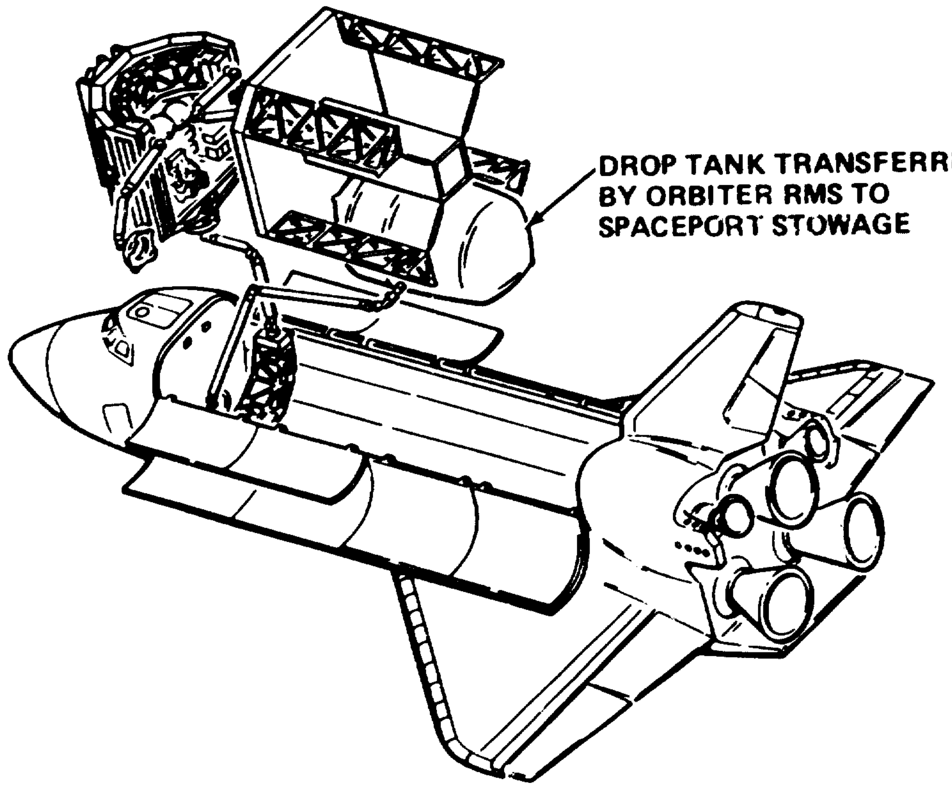
A drop tank is taken to orbit by the shuttle, which berths to the spaceport via its HPA. The orbiter is positioned so that its RMS can transfer the tank directly from the orbiter cargo bay to the drop tank stowage structure on the spaceport. An alternative method for transferring the tank is to deploy the drop tank from the cargo bay, using the PIDA system, and then to mate the stowage structure with the tank by indexing the spaceport HPA arm. This method entails the weight penalty of the PIDA system, which is chargeable to the shuttle payload and, there, offloads the drop tank propellant.

If the shuttle flight is to deliver the last drop tank required for the next MOTV mission, then it will probably be timed so that the orbiter remains at the spaceport to service the MOTV when it returns from is current mission. This drop tank's propellant will have been offloaded to allow for the transport to LEO of the next MOTV crew and, perhaps, payload and servicing them.

MOTV

MIN SPACEPORT, ALL EVA TURN-AROUND, 1½ STAGE MOTV – DROP TANK DELIVERY

GRUMMAN



1154-075(F)

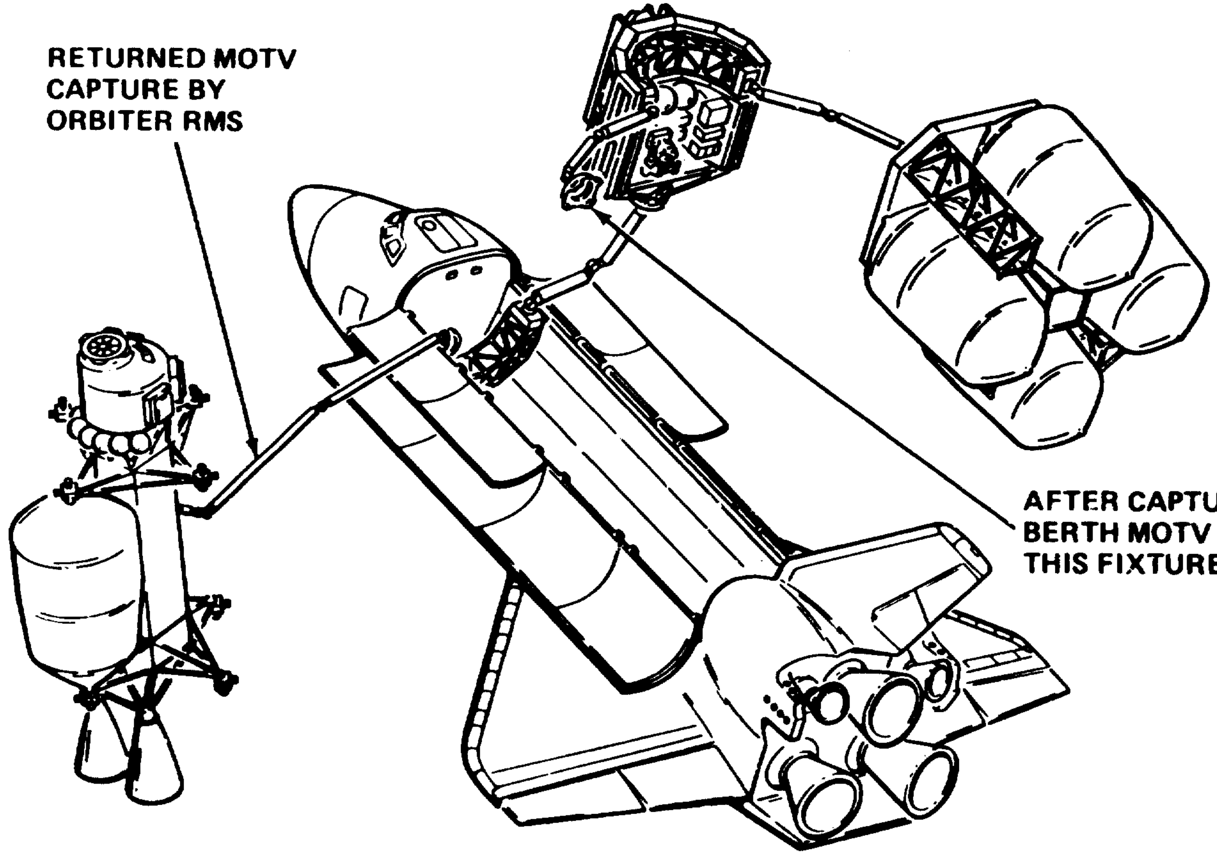
MIN SPACEPORT, ALL EVA TURNAROUND, 1 1/2-STAGE MOTV: CAPTURE & BERTHING

Having delivered the last drop tank required for the next mission, the orbiter, by its HPA, remains berthed to the spaceport for the capture and servicing of the MOTV when it returns from its current mission. On its return, the MOTV waits within sight of the RMS control station in the orbiter. The RMS is manipulated to grasp the MOTV capture fitting. Then, by actuating the orbiter HPA arm, the orbiter is re-oriented so that the RMS can berth the vehicle to the berthing fixture at the tip of the spaceport HPA arm. An EVA man is stationed at the spaceport HPA control panel, which is mounted on the spacelab pallet, a part of the spaceport. This operator controls the HPA arm and the end effector that monitors and assists in the berthing operation.

MOTV

MIN SPACEPORT, ALL EVA TURN-AROUND, 1½ STAGE MOTV – CAPTURE AND BERTH

GRUMMAN

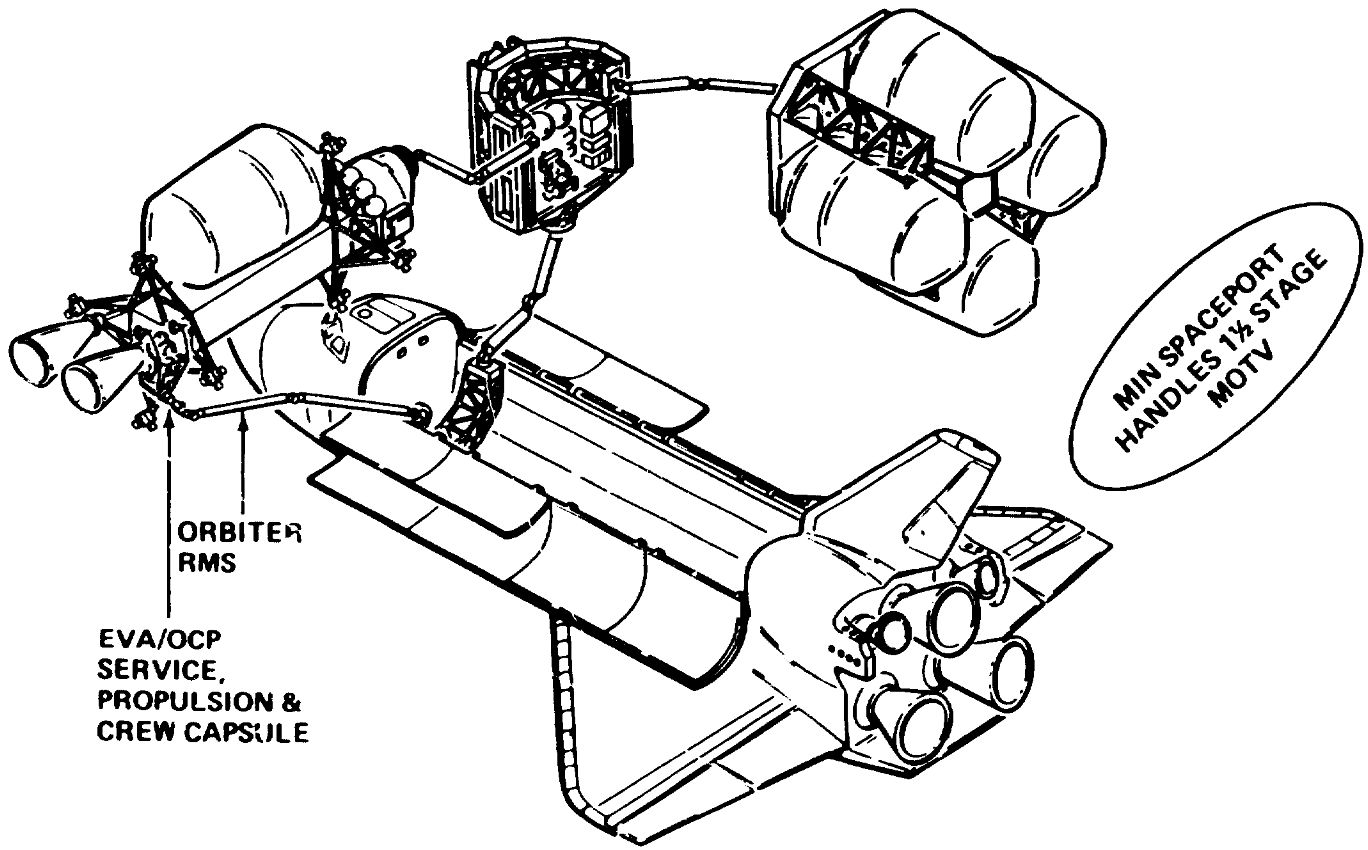


1154-076(T)

MIN SPACEPORT, ALL EVA TURNAROUND, 1 1/2-STAGE MOTV: MOTV SERVICING

Having captured and berthed the MOTV, the RMS end effector is disconnected from the vehicle. It is then indexed to pick up the OCP, which is stowed on the spaceport spacelab pallet. An EVA man boards the OCP that, by RMS actuation, moves him to the MOTV where he services the propulsion stage and the crew capsule with its subsystems. Service replacement items have been brought to LEO in the shuttle and the EVA man obtains the items he needs directly from the orbiter cargo bay. For these servicing operations, it is preferable that both the RMS and OCP be controlled by the EVA man from his control panel on the OCP, rather than have him control the OCP while the operator in the orbiter cabin controls the RMS.

MIN SPACEPORT, ALL EVA TURN-AROUND — 1½ STAGE MOTV — MOTV SERVICING



1154-077(T)

MIN SPACEPORT, ALL EVA TURNAROUND, 1 1/2-STAGE MOTV: INSTALL DROP TANKS

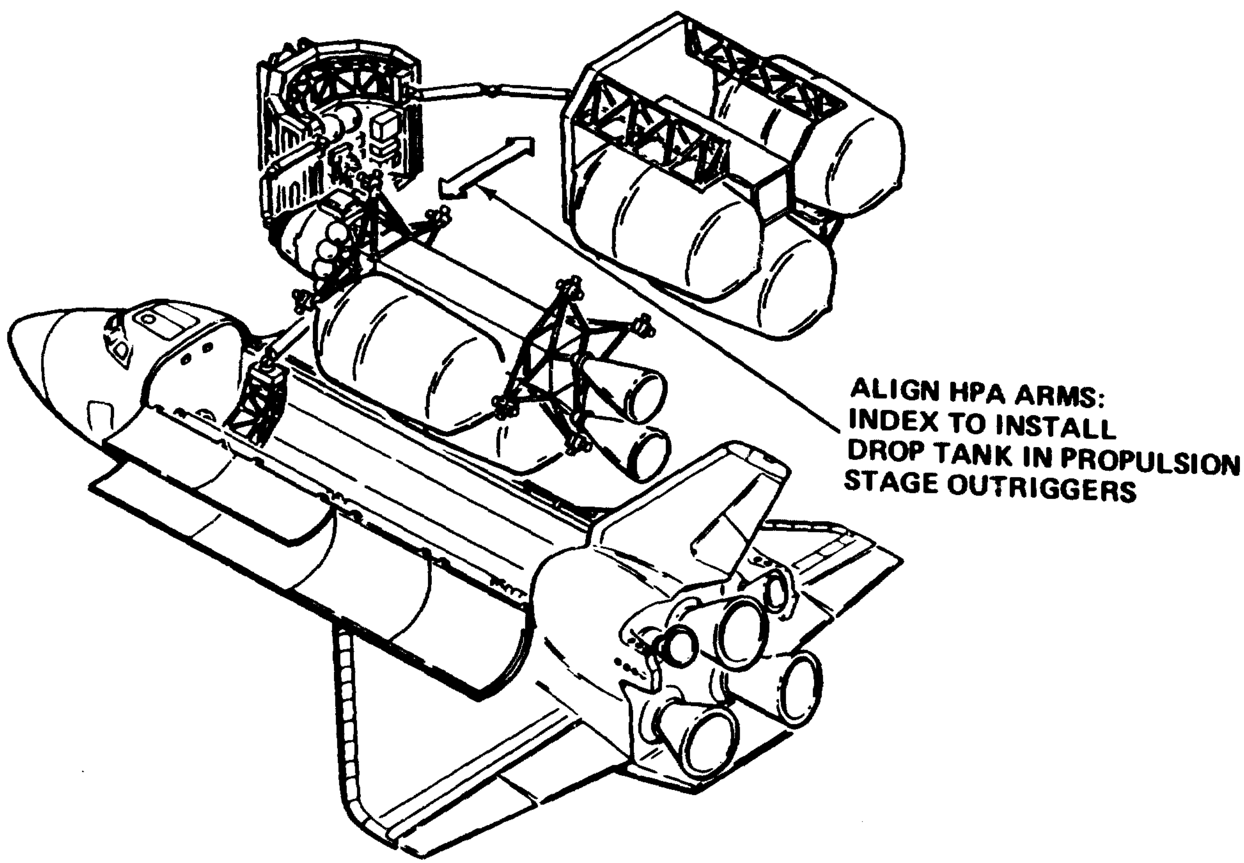
Part of the preparation for an MOTV mission is to install drop tanks on the serviced propulsion stage. The stage has one empty tank remaining from the preceding mission and the drop tank stowage has at least the number of tanks necessary for the next mission. The HPA arm that mounts the full drop tanks in their stowage structure is suitably positioned so the HPA arm to which the stage structure is mounted can move the structure to the drop tanks until a tank can be engaged with one of the four pairs of outriggers. After mating and attaching, the HPA moves back to disengage the bodies.

The sequence is that a full tank is mated to the stage and the bodies then disengage. The stage HPA arm then rotates the stage to bring the empty drop tank in line with the vacated tank stowage. Again, the same HPA articulates to engage the empty tank in this stowage. Following disengagement, both HPAs rotate the bodies they support to bring a full tank opposite a vacant pair of stage outriggers and the procedure continues.

MOTV

MIN SPACEPORT, ALL EVA TURN-AROUND, 1½ STAGE MOTV – INSTALL DROP TANKS

GRUMMAN



1154-078(T)

MIN SPACEPORT: EVA/IVA TURNAROUND, 1 1/2-STAGE MOTV: SPACEPORT CONFIGN & MOTV CAPTURE

This spaceport is somewhat similar to the "all EVA" spaceport for 1 1/2-stage MOTV turnaround. It does, however, provide a shirtsleeve environment for the crewman operating the spaceport HPA. This requires a pressurized vessel to house the HPA control station. An MOTV crew capsule is shown here as that vessel. The capsule mounts to the spacelab pallet and has windows added to its domed end for the HPA operator to view the work area. The standard ingress/egress port at the coned end of the capsule mounts a short, flexible tunnel that ends in a berthing ring supported off the spaceport structural cradle. This is where the orbiter berths using its docking module so that a crewman can enter the capsule to operate the spaceport HPA. As with the "all EVA" spaceport, the spacelab pallet mounts subsystems.

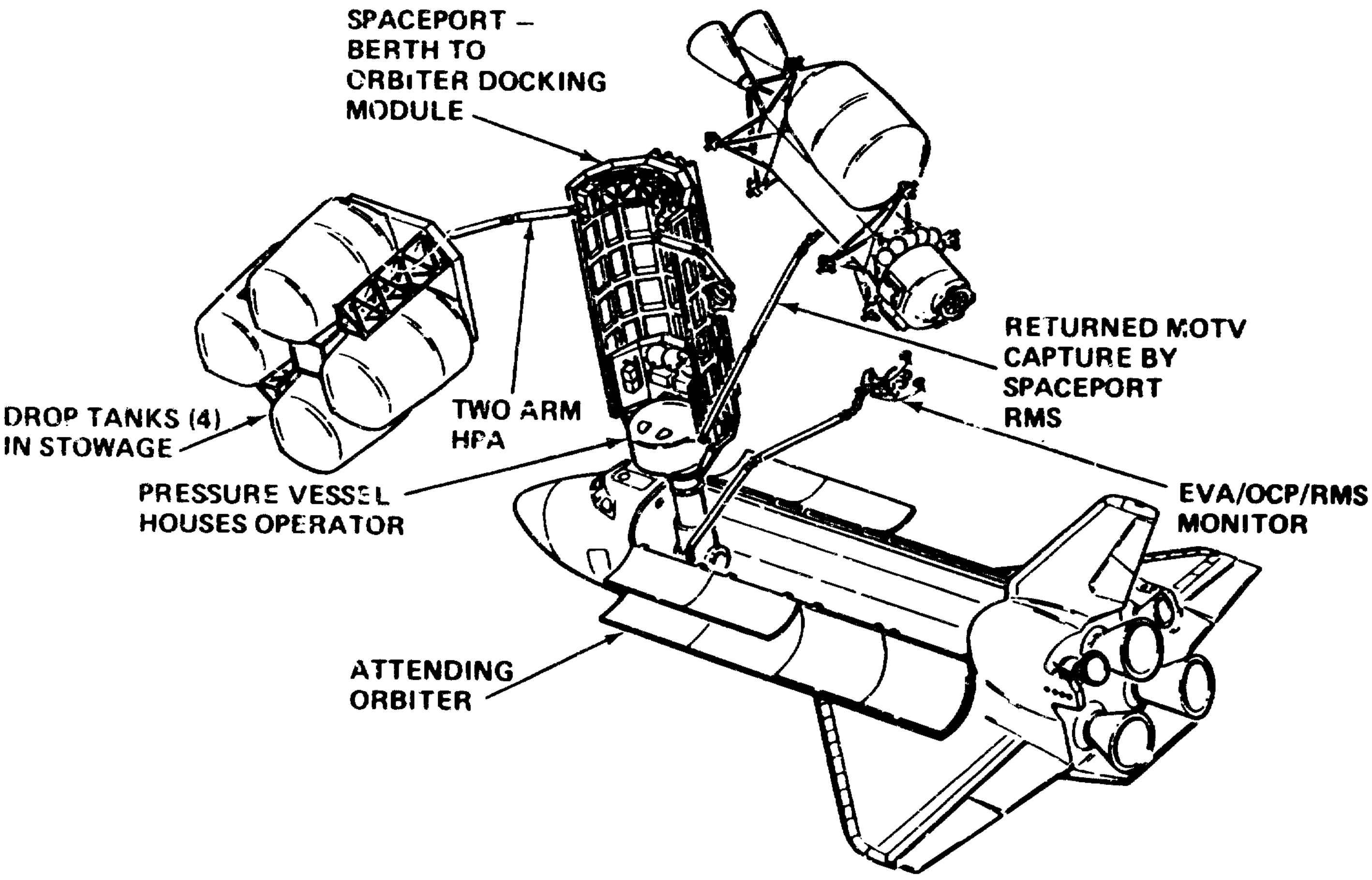
The cradle structure of this spaceport is lengthened so that the HPA can be located far enough from the operator in the capsule to enable him to see the work area through his windows. This HPA provides the same arm tip mounting facilities as does the "all EVA" spaceport HPA.

The HPA is now further from the berthed orbiter than it is with the "all EVA" spaceport. Also, since the orbiter is berthed to the spaceport by a docking module rather than an articulating HPA, the orbiter RMS reach is insufficient for work to be performed on the HPA mounted workpieces within view of the operator's windows. A spaceport mounted RMS is now necessary to handle the workpieces, such as drop tanks and the MOTV. This RMS is operated form the spaceport capsule.

Capture of the returned MOTV for servicing is performed by the spaceport RMS within view of the RMS operator's window. This operation can be monitored directly, as shown, by an EVA man aboard the spaceport OCP mounted on the orbiter RMS for this occasion.

The captured vehicle is berthed to the spaceport HPA arm end effector.

MIN SPACEPORT, EVA/IVA TURN-AROUND, 1½ STAGE MOTV – SPACE-PORT CONFIGN & MOTV CAPTURE



1154-079(T)

MIN SPACEPORT EVA/IVA TURNAROUND: 1 1/2-STAGE MOTV: MOTV SERVICING

Having captured and berthed the MOTV, the spaceport RMS end effector is disconnected from the vehicle. It is then indexed to pick up the OCP stowed on the spaceport cradle structure. An EVA man boards the OCP that, by RMS actuation, moves him to the MOTV where he services the propulsion stage and the crew capsule with its subsystems. Service replacement items have been brought to LEO in the shuttle and the EVA man obtains the items he needs directly from the orbiter cargo bay. For these servicing operations, it is preferable that both the RMS and OCP be controlled by the EVA man from his control panel on the OCP, rather than have him control the OCP while the operator in the spaceport crew capsule controls the RMS.

After servicing, drop tanks are installed in preparation for the next mission. This procedure follows that described on a preceding chart for the "all EVA" turnaround of a 1 1/2-stage MOTV.

MOTV

GROUND BASED VS SPACE BASED MOTV — SUMMARY OF IMPACT ON MOTV SUBSYSTEMS REQMTS

GRUMMAN

SUBSYS \ MISSN PHASE	GROUND TO LEO TRANSFER			LEO TO GEO OPERATIONS		MOTV SERVICING		
	GB	SB	COMMENT	GB	SB	GB	SB	COMMENT
GN & C	NA	NA				NA	NA	
POWER	NA	NA	STS SUPPLIES			NA	NA	EXT. SUPPLY
THERMAL	NA	NA	STS SUPPLIES			NA	ACTIVE	FUEL CELLS, ETC
ECLS	NA	NA		SAME REQMTS		NA	ACTIVE	CREW CAPSULE
DATA	ACTIVE	ACTIVE	MONITOR STATUS			ACTIVE	ACTIVE	MONITOR STATUS
COMM	ACTIVE	ACTIVE	RELAY STATUS			ACTIVE	ACTIVE	RELAY STATUS
PROPULSION	NA	NA				NA	NA	
MECHMS	NA	NA				NA	NA	
STRUCTURE	ACTIVE	ACTIVE				NA	NA	

STS ENVIRON
– EACH MISSN

STS ENVIRON
– INITIAL LAUNCH
– MAJOR O'HAULS

DETAIL LEVEL
SERVICE

SUBASSY LEVEL
SERVICE

PENALTIES:
G.B. – STS ENVIRON – EACH MISSION
SB – SERVICE TO SUB ASSY LEVEL
– THERMAL & ECLS REQ'D
DURING SERVICING OPNS

GB = GROUND BASED MOTV
SB = SPACE BASED MOTV
NA = NOT ACTIVE

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1154-082(T)

2-STAGE COMMON MOTV CONFIGURATION FOR GROUND & SPACE BASED OPERATIONS

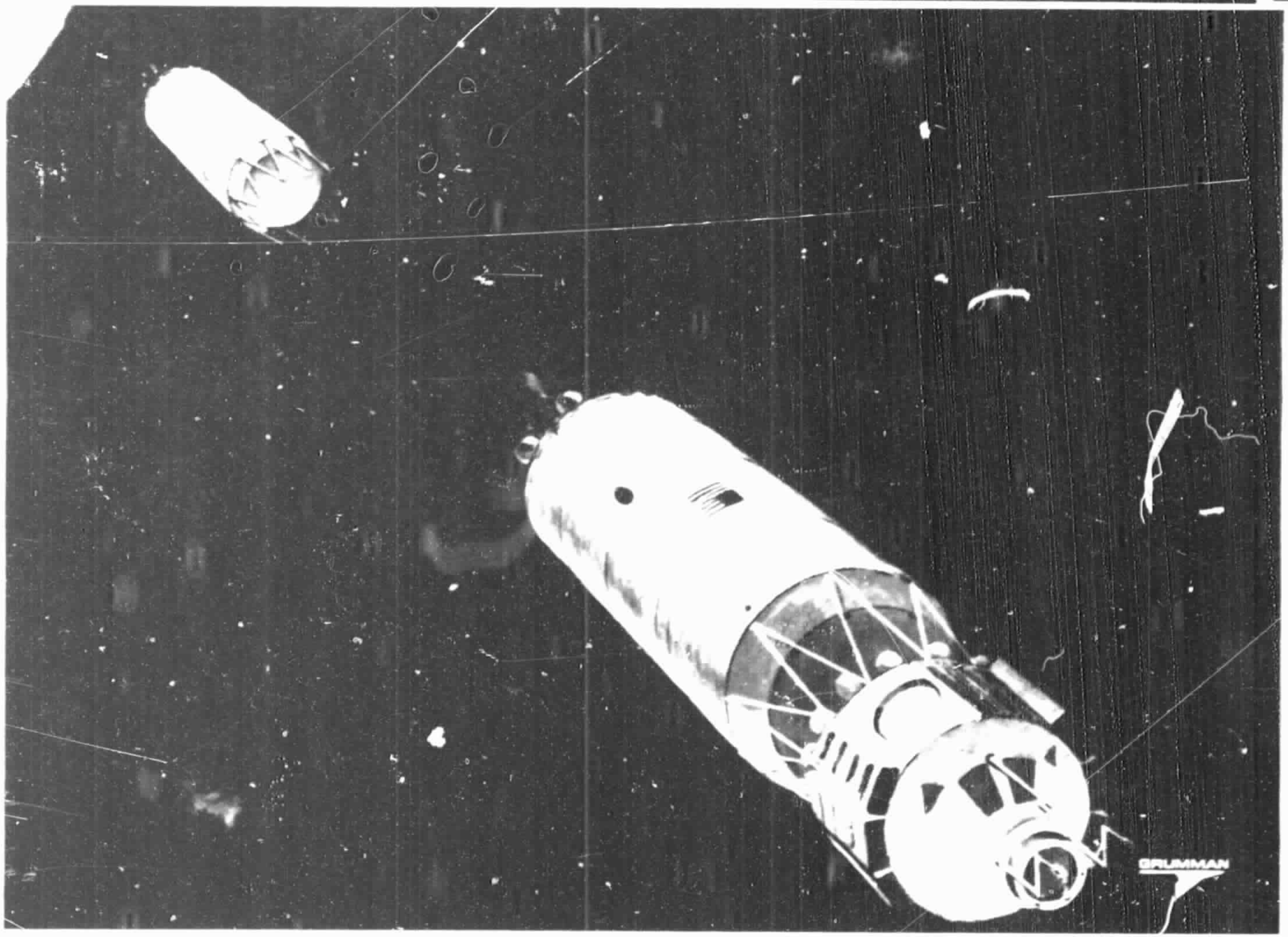
This illustration shows an MOTV with two common propulsion stages. At burnout, the first stage separates from the vehicle and returns to LEO. The second stage and payload continue to GEO, perform the mission, and then they too return to LEO.

When ground based, both stages cannot be delivered to orbit in one shuttle launch. They are, therefore, delivered to LEO on successive shuttle launches. During some part of the MOTV mission, each stage, since each flies on its own, has guidance and control capability. It follows then that the ability to look after itself in orbit is not a factor in determining the order of delivery. Propellant boil-off would be the same, no matter which stage was left parked in orbit. The crew capsule, however, has high pressure bottles stored externally. For this reason, the first stage will be taken to LEO by the first shuttle, deployed by RMS and left parked in orbit. The shuttle will then return to earth. A second shuttle launch to LEO will carry a docking module as well as the MOTV second stage with its attached crew capsule. The scenario will be to rendezvous with the orbiting first stage, then to deploy the second stage from the orbiter cargo bay, using the RMS, and mount it by the crew capsule to the docking module. The orbiter RMS will then capture the first stage and berth it to the second stage. At this point, the MOTV crew will board the MOTV crew capsule via the docking tunnel. Checkout and separation follow.

Depending upon the length of the MOTV mission, this second launched orbiter will loiter in orbit for the return of the second stage with the crew capsule, which it will capture, and berth to to the docking module until the crew exists, after which it stows the vehicle in the cargo bay and then returns to earth. The first stage will be retrieved on a convenient, subsequent orbiter flight.

Space based turnaround is described on following charts.

2 STAGE COMMON MOTV CONFIGURATION FOR GROUND & SPACE BASED OPERATIONS



1154-083(T)

GROUND BASED 2-STAGE COMMON MOTV WEIGHT SUMMARY

The weight statement for the ground based 2-stage common MOTV as configured for the nominal mission is shown. The weights (in kg) for each of the components is shown in the appropriate column. The columns are then summed for the total weight.

The crew capsule dry weight includes a 25 percent contingency. Contingency for the propulsion stage is 15 percent of the dry weight. The propulsion stage contingencies are included in the .880 propellant fraction that has been assumed for the two stage common vehicle.

This weight statement reflects a three shuttle launch MOTV with no external tank propellant scavenging. The two shuttle launches delivering the propulsion stages fully utilize the shuttle capability. The launch delivering the crew capsule could deliver propellants to be transferred to the propulsion stages but propellant transfer is groundruled as a space based operation. The third shuttle flight, therefore, cannot be fully utilized. This restriction limits this MOTV capability, and it cannot deliver and return the crew capsule.

GROUND BASED – 2 STAGE COMMON MOTV CONFIGURED FOR NOMINAL MISSION: WEIGHT SUMMARY, KG

	CREW CAPSULE	PROPLSN STAGE	PROPLSN STAGE	TOTAL
STRUCTURE	1113			
SUBSYSTEMS	1074			
PROPULSION				
ACPS				
TPS	33			
CONTINGENCY	555	ASSUMED A PROPELLANT FRACTION (λ') OF .880 FOR 2 STAGE COMMON		
DRY WEIGHT	2775			
CREW	163			
MISSION EQUIPMENT	928			
CONSUMABLES	234			
RESERVES & RESIDUALS				
B.O. WEIGHT	4100	3136	3136	10,372
PROPELLANTS		23,000	23,000	46,000
IGNITION WEIGHT	4100	26,136	26,136	56,372

THIS CONFIGURATION CANNOT FULLY UTILIZE THE THIRD SHUTTLE FLIGHT. IT CANNOT DELIVER AND RETURN THE CREW CAPSULE.

1 54-084(T)

SPACE BASED 2-STAGE COMMON MOTV WEIGHT SUMMARY

The weight statement for the space based 2-stage common MOTV as configured for the nominal mission is shown. The weights (in kg) for each of the components is shown in the appropriate column. The columns are then summed for the total weight.

The crew capsule dry weight includes a 25 percent contingency. Contingency for the propulsion stages is 15 percent of the dry weight. The propulsion stage contingencies are included in the .880 propellant fraction that has been assumed for the 2-stage common vehicle.

This weight statement reflects a three shuttle launch MOTV with no external tank propellant scavenging. Since this configuration is space based, propellants are carried to orbit and transferred to the propulsion stages.

This configuration fully utilizes the three shuttle flights, can deliver and return the crew capsule shown, and can also deliver 2556 kg to GEO orbit.

SPACE BASED 2 STAGE COMMON MOTV CONFIGURED FOR NOMINAL MISSION WEIGHT SUMMARY, KG

GRUMMAN

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	CREW CAPSULE	PROPLSN STAGE	PROPLSN STAGE	TOTAL
STRUCTURE	1113			
SUBSYSTEMS	1074			
PROPULSION				
ACPS		ASSUMED A PROPELLANT FRACTION (λ') OF .880 FOR 2 STAGE COMMON		
TPS	33			
CONTINGENCY	555			
DRY WEIGHT	2775			
CREW	163			
MISSION EQUIPMENT	928			
CONSUMABLES	234			
RESERVES & RESIDUALS				
B.O. WEIGHT	4100	3894	3894	7994
PROPELLANTS		28,557	28,557	57,114
IGNITION WEIGHT	4100	32,451	32,451	65,108

THIS CONFIGURATION FULLY UTILIZES THREE 65K SHUTTLE FLIGHTS AND CAN DELIVER 2556 KG TO GEO (OVER & ABOVE DELIVERY & RETURN OF CREW CAPSULE)

1154-085(T)

2-STAGE SPACE BASED MOTV: STAGE REFUELLING OPTIONS

Having serviced the engines and subsystems at the space facility, the next step in preparation for a mission is to load propellant. This propellant is transferred to the space facility by the shuttle. Five candidate ways to transport this propellant and load it on the OTV are illustrated here.

The first option suggests that the operational tanks be filled on the ground, taken to orbit by shuttle, and then mated directly to the propulsion unit. This obviates the need for propellant storage and transfer in orbit and, therefore, may be the simplest system; but it restricts the tanks loading-to-payload capability of the shuttle system. At the end of the mission, the tanks would be returned to earth by the orbiter for reuse.

Second option has a propellant holding tank at the space facility which is resupplied by shuttle tanker flights. In this case, the OTV operational tanks remain in orbit as part of the OTV. They are refuelled from the storage tank. This system requires two propellant transfer operations (i.e., into the storage tank and then into the operational tanks) but it de-couples the need for shuttle propellant supply flights to match the MOTV mission timetable. The storage tank volume is restricted by the orbiter cargo bay that initially takes it to orbit.

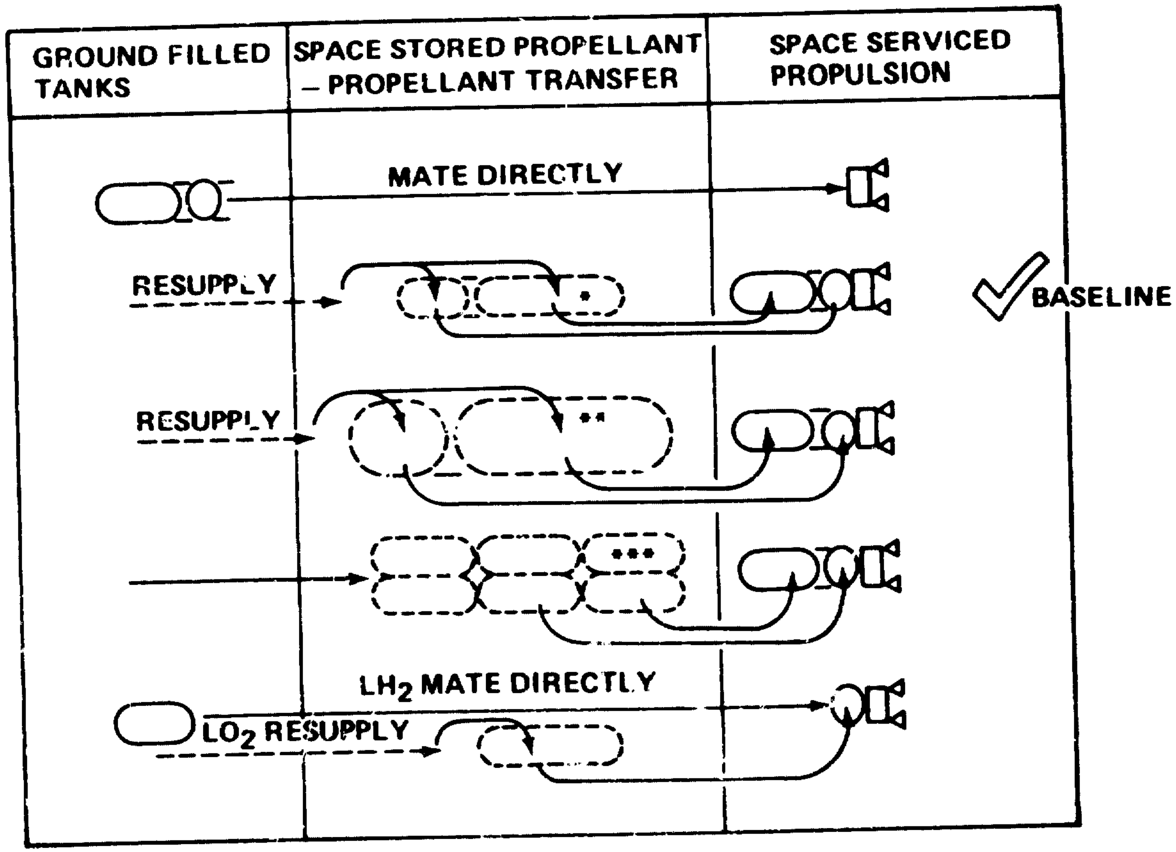
The third option is a variation of the second, whereby an STS external tank is used as the storage tank. It is taken to orbit as an extension of a spaceport delivery flight.

The fourth option suggests that ground filled storage tanks be taken to the space facility, as convenient, where they form a tank farm from which propellant is transferred, as required, to the OTV. This, again, divorces the need to match shuttle flights with the MOTV mission timetable but also entails one propellant transfer operation.

The fifth option is a compromise between the first and second. The first option tank capacity was restricted by shuttle capability. This option suggests that the LH_2 operational tank be ground filled to the mission required capacity and taken up in the shuttle to mate directly with the propulsion. The mas of the required LO_2 is too high for a single shuttle launch and, there, this fuel is transferred from a storage tank to the operational tank.

For this study, the conventional system, option 2, is selected as the baseline.

2 STAGE SPACE BASED MOTV – STAGE REFUELLING OPTIONS



*HOLDING TANKS -- SIZED FOR ORB. CARGO BAY ENVELOPE
**STS EXTERNAL TANK – ADAPTED
***GROUND FILLED TANK FARM

1154-086(T)

MIN SPACEPORT, ALL EVA TURNAROUND, 2-STAGE MOTV

This spaceport is configured to turn around a two stage common OTV, using propellant transfer to refuel the stages. It is a shuttle tended operation.

This concept uses an HPA with a yoke end effector to mount a stage being serviced and a single degree-of-freedom mounted yoke fitting to stow a stage that has been serviced. The control panel for these yokes is located on a spacelab pallet, which provides a foot restraint platform to hold an EVA crewman while he is controlling operation of the fixtures. Other subsystem equipment is mounted on the pallet. A cradle structure, which provides the same attachment points as does the orbiter cargo bay, mounts the HPA and pallet. Thus the equipment designed to be carried in the orbiter cargo bay can be used directly in this facility.

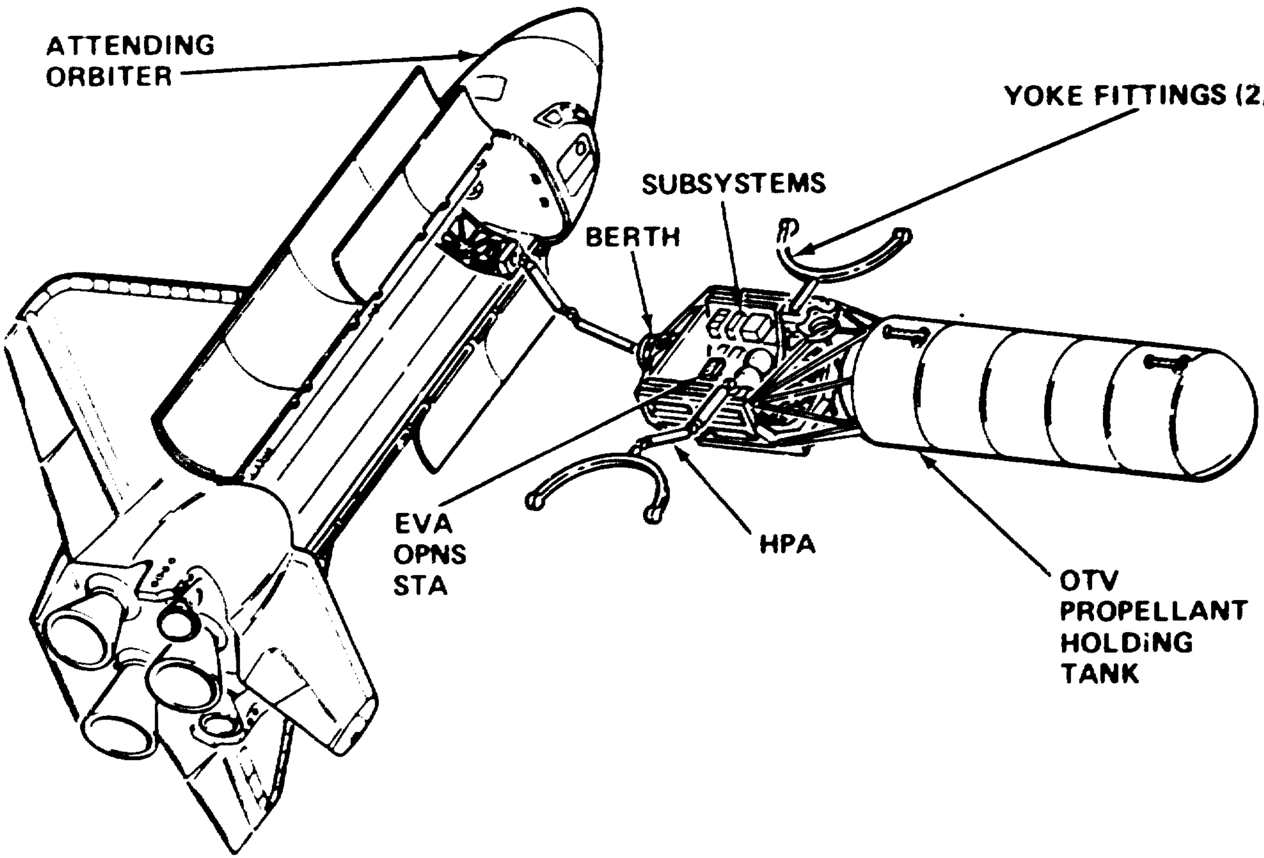
A holding tank for storing propulsion stage propellant is mounted on support struts from the cradle. Swing out refuelling points are provided from the tank to refuel the OTV. These same points can be used when transferring propellants from an orbiter tanker to the storage tank.

Three berthing rings are provided on the spaceport. Two of them are to berth and locate the orbiter for various phases of the service and resupply activities. The third ring is to stow a crew capsule if the next mission is OTV only. Support rails run the length of the cradle to provide stowage for MOTV payloads.

MOTV

MIN SPACEPORT, ALL EVA TURN-AROUND, 2 STAGE MOTV

GRUMMAN



1154-087(T)

MIN SPACEPORT, ALL EVA TURNAROUND, 2-STAGE MOTV: LAUNCH CONFIGURATION & WEIGHT

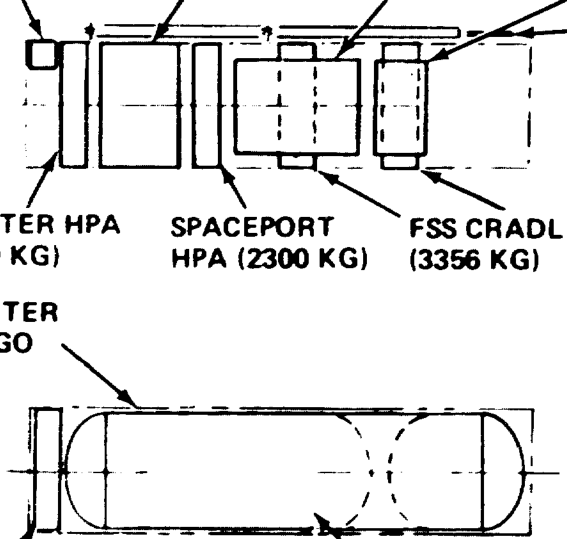
The operational configuration of this spaceport is illustrated on a preceding chart. Its component parts, some of which are folded for launch, require two shuttle launches to LEO. This figure illustrates a general arrangement of the components on those launches. No attention has been paid to the combined cg of these masses and, therefore, some rearrangement may be necessary to keep within the orbiter's allowable cg envelope.

Considering launch No. 1, the folded components, namely the cradle structure and the holding tank support structure, are shown as envelopes. It has been determined by rough layouts that these structures can be folded within these envelopes. The FSS cradle B supports these items during launch. Although the cradle is a heavy design, as currently reported, it offers an under-development mounting cradle that demands little cargo bay volume for itself. In any event, launch No. 1 is a volume limited launch, and weight is available for the cradle. An orbiter HPA is carried on this launch as a fixture on which to build the spaceport. EVA can be effected from the orbiter cabin without jettisoning any payload.

Launch No. 2 delivers an on-orbit propellant holding tank that is sized to fill the orbiter cargo bay except for volume necessary to maintain orbiter HPA, which provides berthing and indexing during installation of the tank. The HPA truss frame depth is designed to clear the EVA hatch from the orbiter cabin, and the crew can EVA without jettisoning payload.

Weights are given for the major components on each launch, together with the total payload for each launch.

MIN SPACEPORT, ALL EVA TURN-AROUND, 2 STAGE MOTV – LAUNCH CONFIGURATION & WEIGHT



2 STS LAUNCHES TO ORBIT

WEIGHTS SUMMARY (KG)

• LAUNCH #1	
SPACEPORT COMPONENTS	9,574
ASE	5,486
LAUNCH TOTAL	15,060
• LAUNCH #2	
TANK	6,000
PROPELLANT	18,990
ASE	3,600
RENDEZVOUS	910
LAUNCH TOTAL	29,500

1154-085(T)

MIN SPACEPORT, ALL EVA TURNAROUND, 2-STAGE MOTV: BUILD UP SEQUENCE

This chart illustrates the sequence of build for the spaceport. Components carried on each of the two shuttle flights that deliver the facility are identified on the launch configuration chart.

On launch No. 1, the orbiter standard RMS is used during build to fetch and carry the spaceport component parts. The orbiter's second RMS mounts the spaceport CCP at its tip to carry an EVA crewman, who monitors operations and assists in assembly. The orbiter RMS picks up the spaceport berthing ring A from its stowage in the cargo bay and mounts it to the tip of the orbiter HPA extended arm. Support struts are added and locked in position. The cradle segments are now added to the supports. Thus, the basic structure is built. Berthing ring B is mounted to the cradle to provide a stowage for the MOTV crew capsule if a strictly OTV mission is to be flown. The orbiter HPA is now indexed to present the open side of the structural cradle to the orbiter RMS and cargo bay for installation of the spacelab pallet with its equipment and the spaceport HPA. Support struts for the undelivered storage tank are now added to the cradle. Finally, berthing ring C support struts are added and then the ring itself.

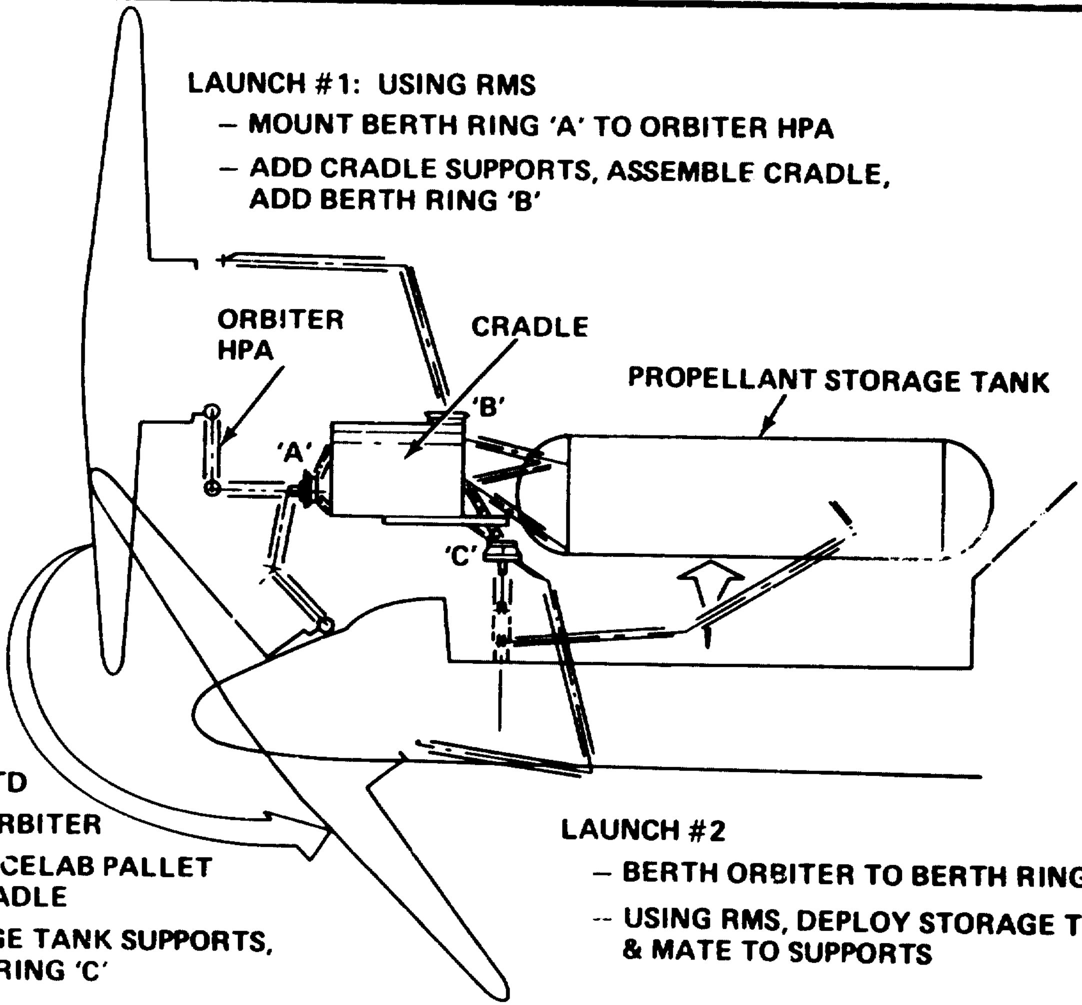
Launch No. 2 orbiter uses its HPA to berth to ring C so that the orbiter RMS can transfer the propellant storage tank from the cargo bay to mate with the support struts on the spaceport.

MOTV

MIN SPACEPORT, ALL EVA TURN-AROUND, 2 STAGE MOTV – BUILDUP SEQUENCE

GRUMMAN

LAUNCH #1: USING RMS
- MOUNT BERTH RING 'A' TO ORBITER HPA
- ADD CRADLE SUPPORTS, ASSEMBLE CRADLE, ADD BERTH RING 'B'



LAUNCH #1 CONTD
- REORIENT ORBITER
- INSTALL SPACELAB PALLET & HPA IN CRADLE
- ADD STORAGE TANK SUPPORTS, ADD BERTH RING 'C'

LAUNCH #2
- BERTH ORBITER TO BERTH RING 'C'
- USING RMS, DEPLOY STORAGE TANK & MATE TO SUPPORTS

1154-089(T)

MIN SPACEPORT, ALL EVA TURNAROUND, 2-STAGE MOTV: 1ST STAGE SERVICE

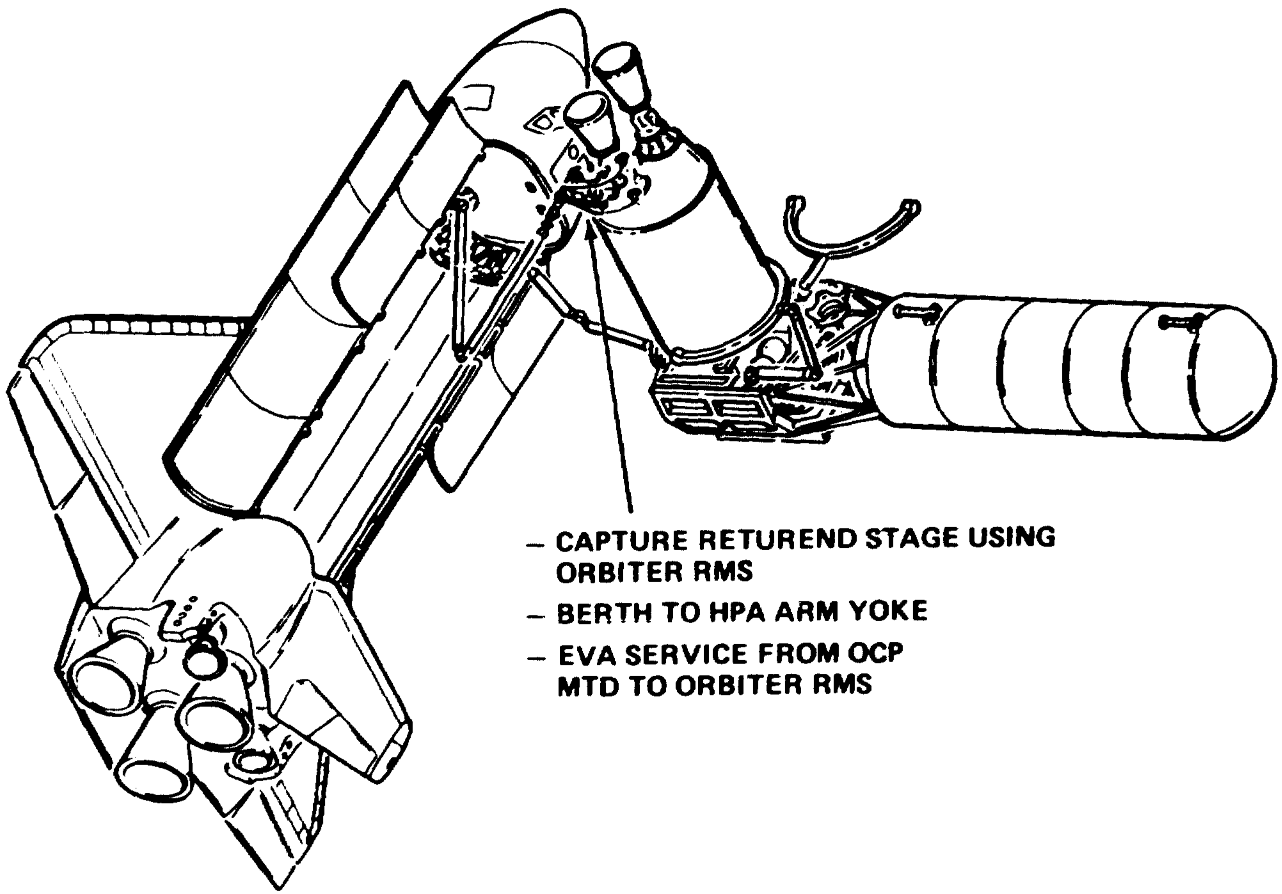
On a 2-stage mission, the first stage returns to rendezvous with the spaceport where it is captured, berthed, and then serviced.

Being a shuttle tended service operation, the orbiter berths by its HPA to the spaceport.

The orbiter indexes to provide a clear view of the returned stage. Its RMS now captures the stage and berths it to the yoke end effector at the tip of the spaceport HPA arm. If necessary, the orbiter indexes to achieve this berthing. The RMS end effector disengages from the berthed stage and then indexes to pick up the spaceport OCP stowed on the spacelab pallet. An EVA man boards the OCP that, by RMS actuation, moves him to the MOTV where he services the berthed stage. Service replacement items have been brought to LEO in the shuttle and the EVA man obtains the items he needs directly from the orbiter cargo bay. For these servicing operations, it is preferable that both the RMS and OCP be controlled by the EVA man from his control panel on the OCP.

At completion of this servicing operation, the orbiter RMS transfers the stage from its mount on the HPA arm to be stowed on the other yoke fitting.

MIN SPACEPORT, ALL EVA TURN-AROUND, 2 STAGE MOTV – 1st STAGE SERVICE



1154-090(T)

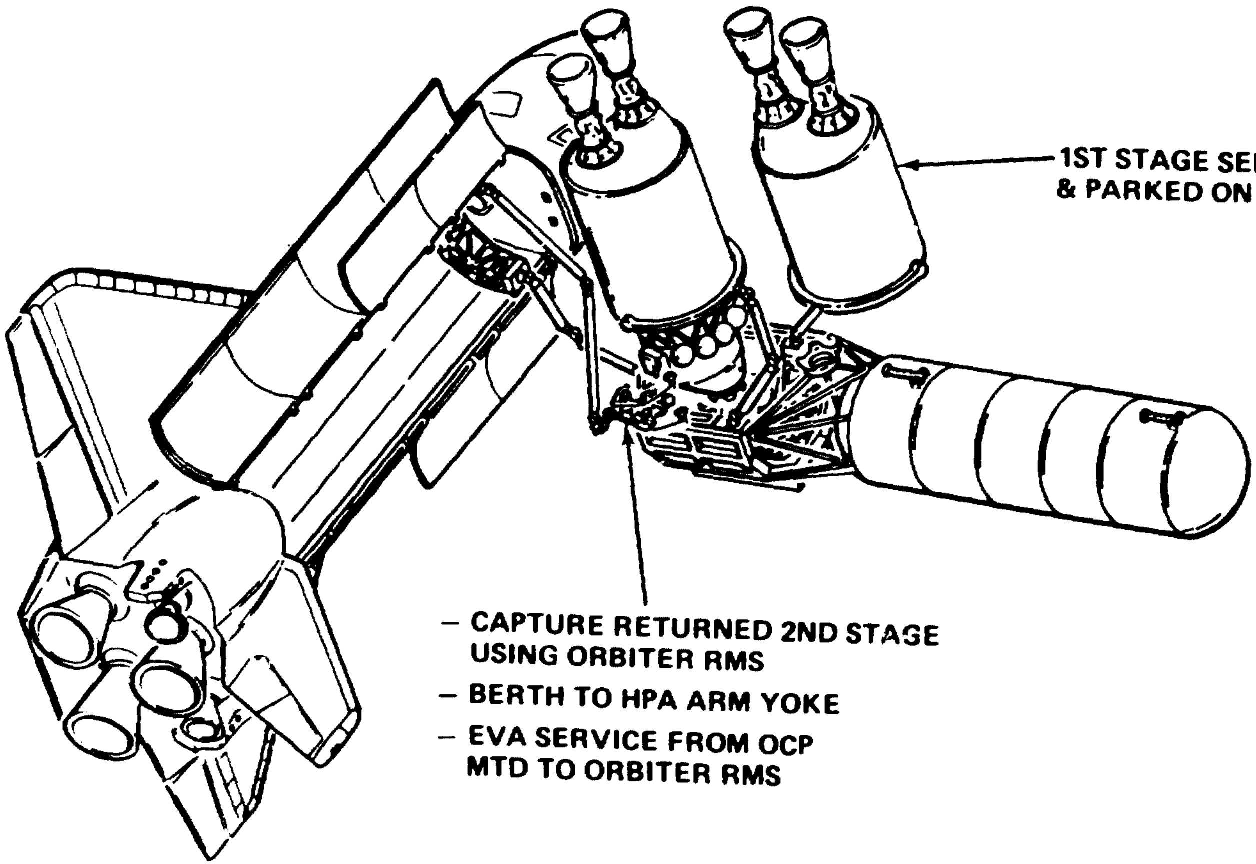
MIN SPACEPORT, ALL EVA TURNAROUND, 2-STAGE MOTV: 2ND-STAGE SERVICE

At completion of its mission, the second stage of a 2-stage MOTV returns to rendezvous with the spaceport for propulsion and crew capsule servicing.

The orbiter on this shuttle tended operation indexes to provide a clear view of the returned stage. Its RMS now captures the stage and berths it to the yoke end effector at the tip of the spaceport HPA arm. If necessary, the orbiter indexes to achieve this berthing. The RMS end effector disengages from the berthed stage, then indexes to pick up the spaceport OCP, which is stowed on the spacelab pallet. An EVA man boards the OCP that, by RMS actuation, moves him to the MOTV where he services the propulsion stage and crew capsule. Service replacement items have been brought to LEO in the shuttle and the EVA man obtains the items he needs directly from the orbiter cargo bay. For these servicing operations, it is preferable that both the RMS and OCP be controlled by the EVA man from his control panel on the OCP.

The orbiter HPA, the spaceport HPA, and the orbiter RMS can all be indexed to put the servicing EVA man at his necessary locations.

MIN SPACEPORT, ALL EVA TURN-AROUND, 2 STAGE MOTV – 2nd STAGE SERVICE



1154-091(T)

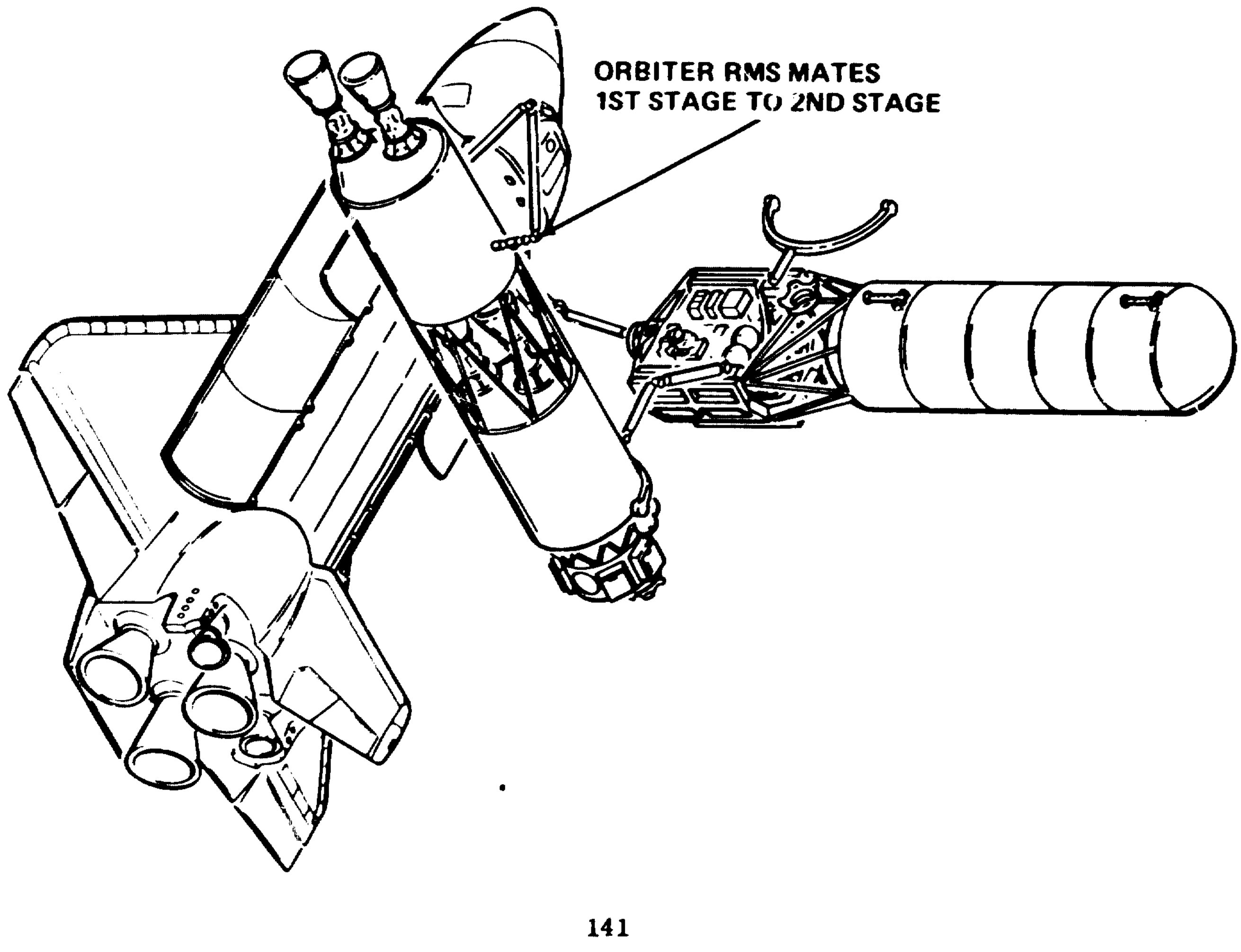
MIN SPACEPORT, ALL EVA TURNAROUND, 2-STAGE MOTV ASSEMBLY

The first and second stages and the crew capsule have now been serviced. The orbiter indexes to enable its RMS end effector to attach to the berthed first stage, which then is released from its yoke mounting. Orbiter HPA, spaceport HPA, and the orbiter RMS are indexed, as necessary, to transfer the first stage and to mate it to the second stage. An interstage skirt is part of the first stage assembly and other necessary interfaces are made.

MOTV

MIN SPACEPORT, ALL EVA TURN-AROUND, 2 STAGE MOTV ASSY

GRUMMAN



1154-092(T)

MIN SPACEPORT, ALL EVA TURNAROUND, 2-STAGE MOTV REFUELLING

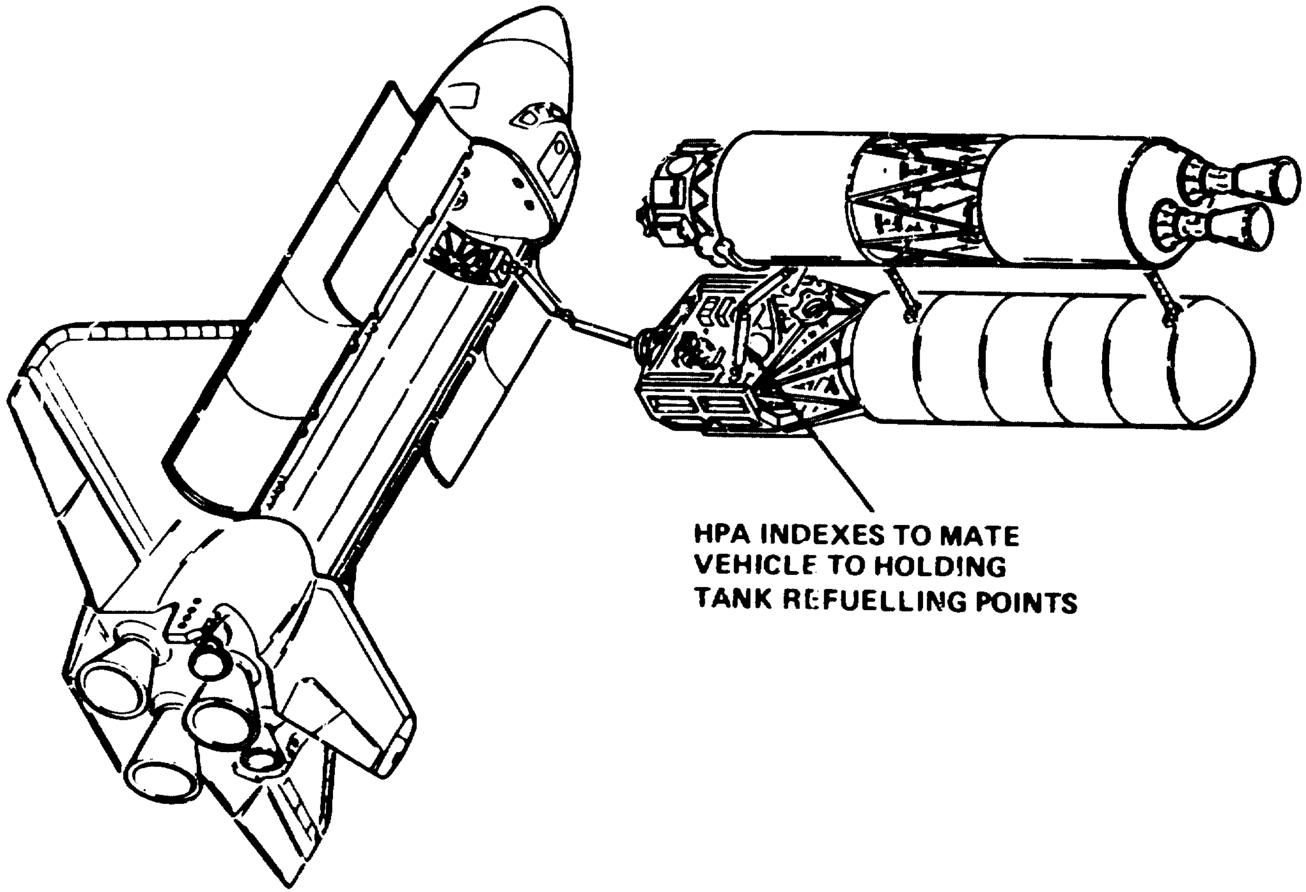
To refuel this vehicle, propellant is transferred from a storage tank. The tank has two sets of swing-out refuelling probes, suitable located to match the inlets on a paired two stage vehicle.

When assembled, the MOTV is relocated by indexing its HPA support arm to place the fuel inlet valves on each stage in line with the storage tank probes. They are then mated and the fuel transferred.

MOTV

MIN SPACEPORT, ALL EVA TURN-AROUND, 2 STAGE MOTV REFUELLING

GRUMMAN



1154-093(T)

MIN SPACEPORT, EVA/IVA TURNAROUND, 2-STAGE MOTV: LAUNCH CONFIGURATION & WEIGHT

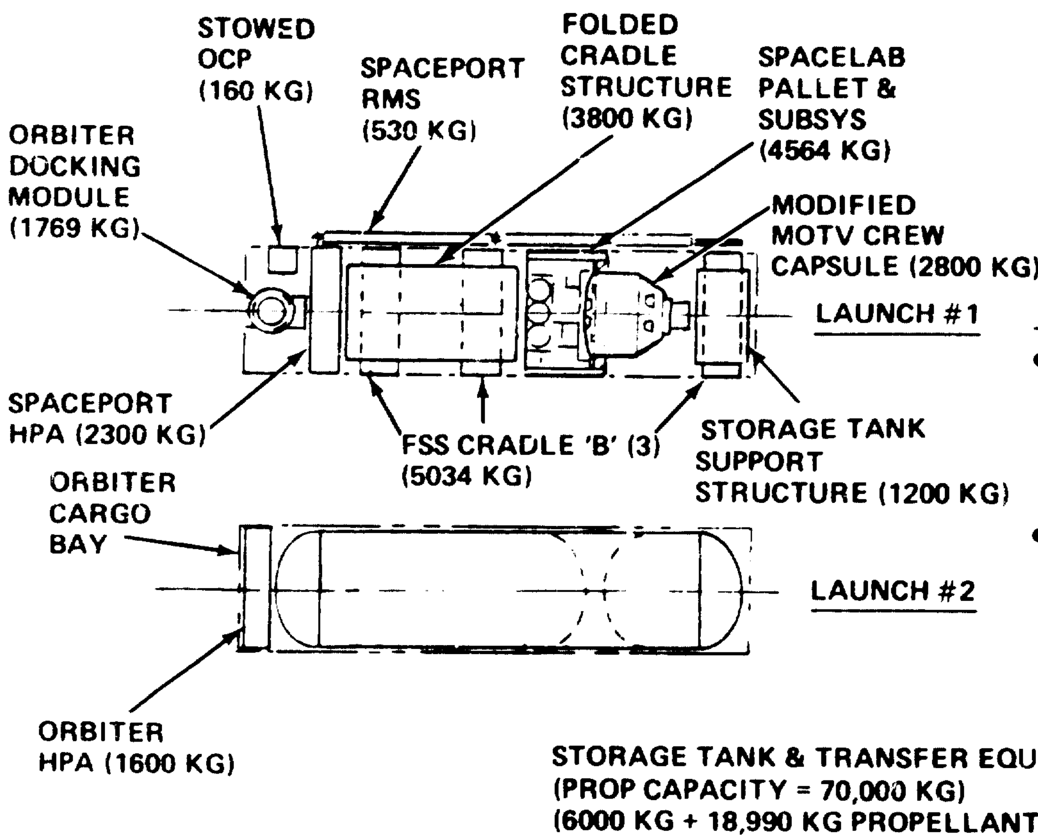
The operational configuration of this spaceport is similar to that for the 1 1/2-stage, EVA/IVA turnaround facility, except that this spaceport requires a propellant storage tank for MOTV refuelling by propellant transfer. A following chart showing servicing at this spaceport illustrates its general arrangement. Component parts of the facility, some of which are folded for launch, require two shuttle launches to LEO. This figure illustrates a general arrangement of the components on those launches. No attention has been paid to the combined cg of these masses and, therefore, some rearrangement may be necessary to keep within the orbiter's allowable cg envelope.

Considering launch No. 1, the folded components, namely the cradle structure and the holding tank support structure, are shown as envelopes. It has been determined by rough layouts that these structures can be folded within these envelopes. The FSS cradle B supports these items during launch. Although the cradle is a heavy design, as currently reported, it offers an under-development mounting cradle that demands little cargo bay volume for itself. In any event, launch No. 1 is a volume limited launch and weight is available for the cradle. An orbiter docking module is carried on this launch to provide a fixture on which to assemble the spaceport structure and to provide a means of shirtsleeve access to the spaceport crew capsule after is has been installed.

Launch No. 2 delivers an on-orbit propellant storage tank sized to fill the orbiter cargo bay, except for volume necessary to mount an orbiter HPA that provides berthing and indexing during installation of the tank. The HPA truss frame depth is designed to clear the EVA hatch from the orbiter cabin, and the crew can EVA without jettisoning payload.

Weights are given for the major components on each launch, together with the total payload for each launch.

MIN SPACEPORT, EVA/IVA TURNAROUND – 2 STAGE MOTV – LAUNCH CONFIGURATION & WEIGHT



2 STS LAUNCHES TO ORBIT

.IGHTS SUMMARY (KG)

- LAUNCH #1

SPACEPORT COMPONENTS	15,354
ASE	6,803
LAUNCH TOTAL	22,157

- LAUNCH #2

TANK	6,000
PROPELLANT	18,990
ASE	3,600
RENDEZVOUS	910
LAUNCH TOTAL	29,500

1154-094(T)

MIN SPACEPORT, EVA/IVA TURNAROUND, 2-STAGE MOTV: 2ND STAGE SERVICE

Turnaround of a 2-stage MOTV at this spaceport has been virtually covered by descriptions of operations at the all-EVA 2-stage MOTV spaceport and at the 1 1/2-stage MOTV spaceports.

As with the 1 1/2-stage, all EVA operated spaceport, the HPA is controlled from a spaceport crew capsule that also controls the spaceport RMS. A propellant storage tank is mounted to the spaceport cradle structure, just as it is with the all-EVA 2-stage MOTV spaceport.

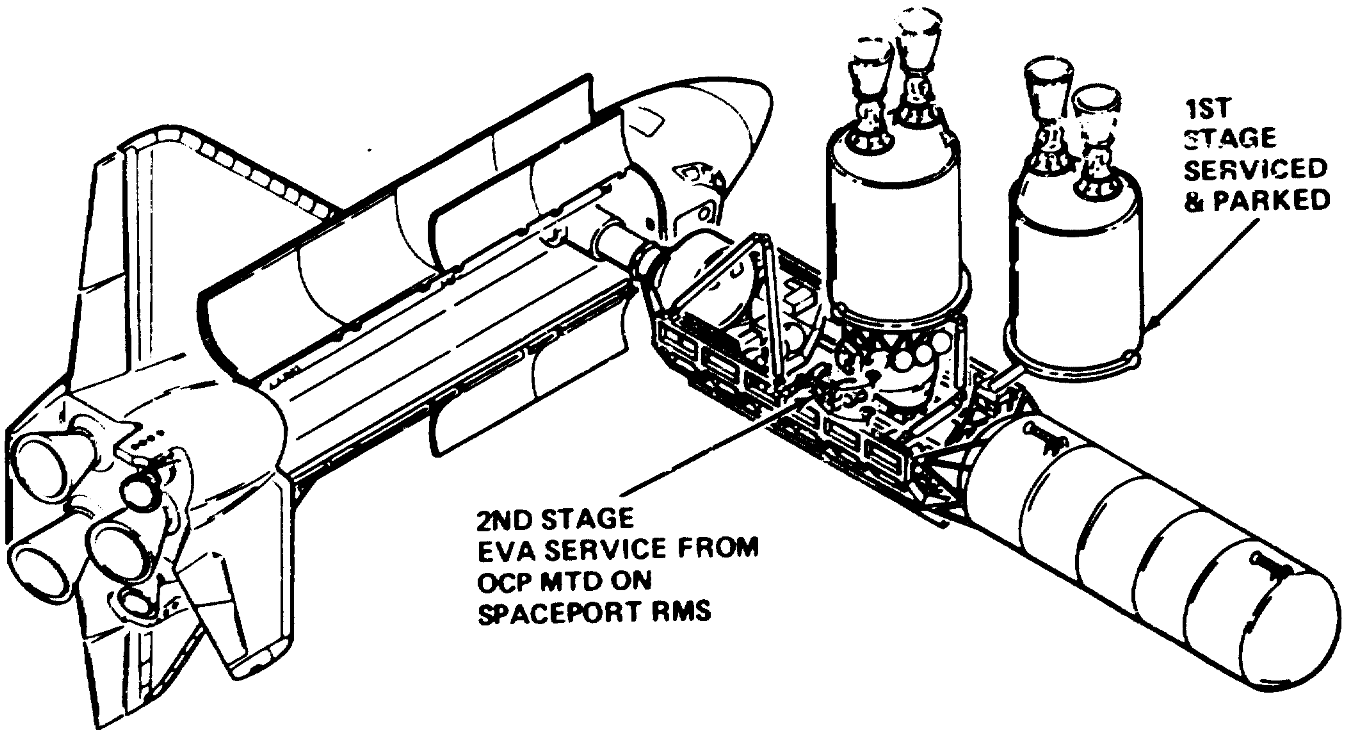
This chart is illustrative of operations at this spaceport. The first stage of the two stage vehicle has returned to the facility, been captured, berthed, serviced, and stowed on the yoke fixture. As with the 1 1/2-stage vehicle at its EVA/IVA facility, the orbiter RMS does the capturing and berthing to the spaceport HPA. Then the spaceport RMS performs the servicing functions.

The second stage is serviced as illustrated here. Its capture and berthing follows that just described for the first stage. After servicing and when being readied for the next mission, the stages are assembled and refuelling as described for the 2-stage, all-EVA serviced MOTV.

MOTV

MIN SPACEPORT, EVA/IVA TURN-AROUND, 2 STAGE MOTV – 2nd STAGE SERVICE

GRUMMAN



1154-095(T)

MOTV TURNAROUND: SUMMARY & CONCLUSIONS

One parameter governing the configuration of a space vehicle is its suitability to be turned around at a particular base. In considering 1 1/2-stage vehicles, it was found that the lightest vehicle that could be conveniently turned around at a ground facility comprised a core tank, with its attendant engines, subsystems, and payload mountings, plus common drop tanks. These vehicle components would be transported to LEO on successive shuttle launches and assembled there. Space base turnaround would be better served by containing all the propellants in common tanks that would be ground fueled, taken by shuttle to the space base, then mounted to a zero stage. This zero stage comprises a central spine that mounts engines, subsystems, and payload. The space based vehicle carries a weight penalty of 500 Kg compared to the ground based vehicle performing the same nominal mission.

Two-stage common vehicles have the same overall configuration, whether they are ground or space based. The space based vehicle is refuelled by propellant transfer from holding tanks topped up by shuttle tanker flights and, perhaps, propellant scavenging.

The nominal mission used as a baseline for this part of the study requires three STS launches to support the mission, whether it be ground or space based. The MOTV mission model used in this study does not contain a mission that can be supported by two 65K STS launches.

MOTV

MOTV TURNAROUND – SUMMARY & CONCLUSIONS

GRUMMAN

- 1½ STAGE GROUND & SPACE BASED MOTV's CONFIGURATION DIFFER
  - GROUND BASED HAS CORE TANK PLUS COMMON DROP TANKS
  - SPACE BASED HAS COMMON TANKS MOUNTED ON ZERO STAGE CORE AND IS REFUELED IN SPACE BY TANK EXCHANGE (GROUND FILLED)
- 2 STAGE COMMON GROUND & SPACE BASED MOTV's HAVE SAME CONFIGURATION BUT SPACE BASE IS REFUELED BY PROPELLANT TRANSFER
- GROUND OR SPACE BASED MOTV, RESTRICTED TO TWO-65K STS LAUNCHES, CANNOT PERFORM ANY MISSION IN OUR MOTV MODEL

MOTV TURNAROUND: SUMMARY & CONCLUSIONS (CONT'D)

Ground based vehicles can be turned around at a facility virtually unrestricted by size or weight considerations. Space basing, on the other hand, is very much concerned with size and mass. Not only does the facility have to be transported by shuttle to its location in LEO, but orbital decay, a function of size and mass, has to be made up by firing propellant.

A minimum space facility to turn around a 1 1/2-stage MOTV is shuttle tended to provide manpower, some subsystems, and the orbiter RMS. The facility itself has a cradle structure shaped to simulate the orbiter cargo bay for the convenient mounting of orbiter designed equipment. This equipment consists of an HPA and a spacelab pallet that mounts subsystems and a control station operated by an EVA crewman. The whole turnaround operation is EVA, except for the orbiter RMS control from the orbiter cabin.

The same general facility will turn around a 2-stage MOTV. The basic differences are in the end effectors for the HPA arms and in the addition of a propellant storage tank for storing propellant for transfer to the MOTV when refuelling.

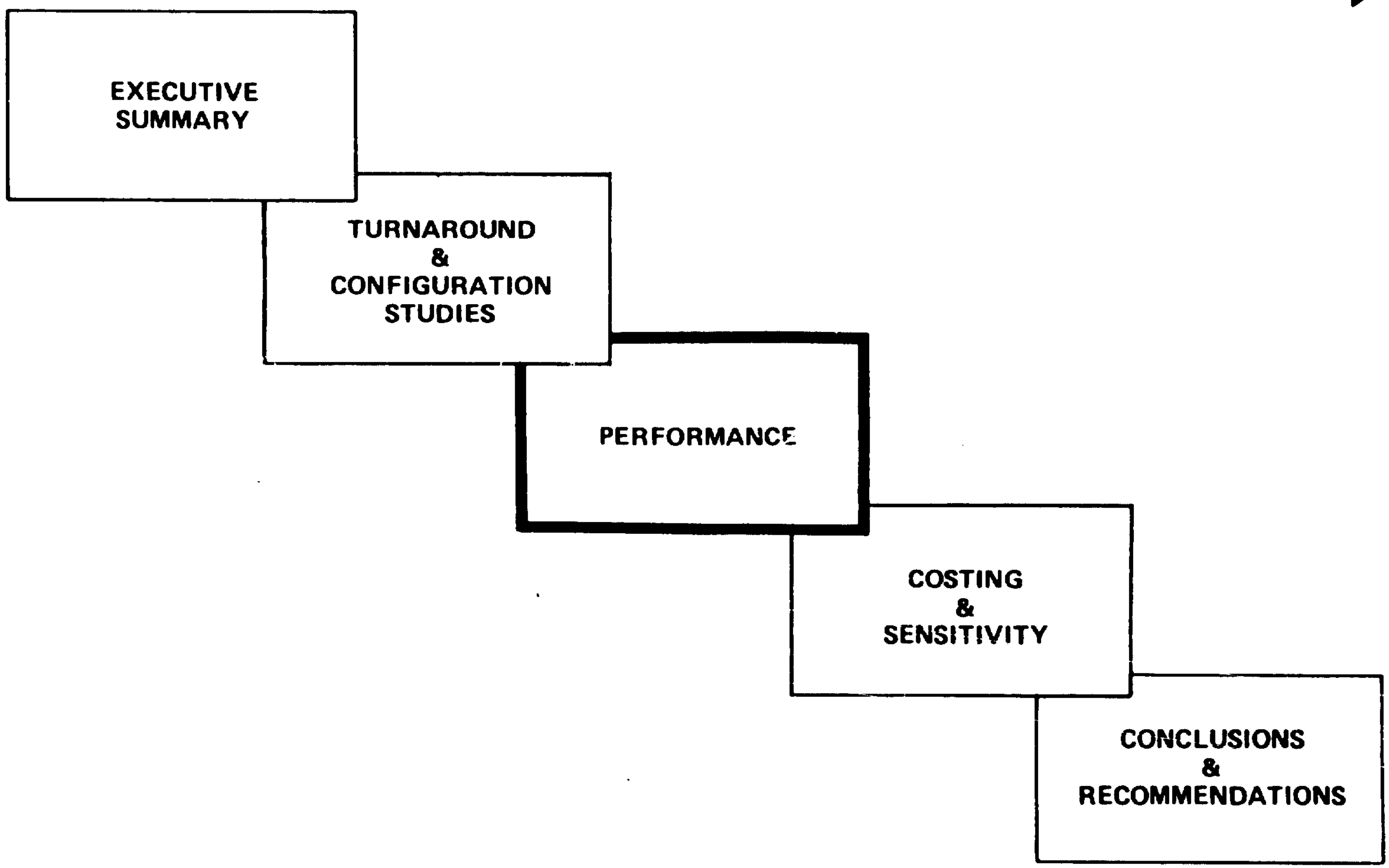
A growth of this all-EVA spaceport capability might be to provide a shirtsleeve environment for the HPA controls operator. This requires a pressurized module to house the control station in place of the console and foot restraint for an EVA operator. The EVA operator could rotate the console and foot restraint as desired to view the work area. Putting the operator in the pressure module restricts his viewing to what he can see through a reasonable sized window. This means that the structure separating the operator from the HPA must be extended to separate the two and thus provide adequate viewing. A weight penalty of 5,680 kg results from this added capability.

MOTV

MOTV TURNAROUND – SUMMARY & CONCLUSIONS (CONTD)

GRUMMAN

- MINIMUM FACILITY TO TURNAROUND 1½ STAGE MOTV
  - – IS SHUTTLE TENDED
  - – COMPRISES A STRUCTURE TO MOUNT BERTHING PORT, HPA, CONTROL STATION, NECESSARY SUBSYSTEMS
  - – IS AN 'ALL EVA' SERVICE OPERATION
- MINIMUM FACILITY TO TURNAROUND 2 STAGE MOTV IS SIMILAR TO 1½ STAGE WITH ADDITION OF PROPELLANT HOLDING TANK FOR OTV REFUELLING
- IVA OPERATION OF HPA CONTROL STATION REQUIRES PRESSURE MODULE & ENLARGES THE FACILITY
  - – WEIGHT PENALTY = 5,680 KG


EXECUTIVE SUMMARY
TURNAROUND & CONFIGURATION STUDIES
PERFORMANCE
COSTING & SENSITIVITY
CONCLUSIONS & RECOMMENDATIONS

MOTV

MOTV GROUND VS SPACE BASED PERFORMANCE

GRUMMAN

- GROUND RULES & ASSUMPTIONS
  - OBJECTIVE
  - MOTV MISSIONS
  - PROPELLANT SCAVENGING
  - STS MANIFESTING
- 3-65K SHUTTLE FLIGHTS
  - LAUNCH SCENARIO 1½ STAGE
  - LAUNCH SCENARIO 2 STAGE
  - STS MANIFESTING
  - APOTV PAYLOAD CAPABILITIES (TABLE)
  - APOTV PAYLOAD CAPABILITIES W/O SCAVENGING
  - APOTV PAYLOAD CAPABILITIES WITH SCAVENGING
- 2 SHUTTLE FLIGHTS (STANDARD & GROWTH VERSIONS)
  - LAUNCH SCENARIO 1½ STAGE
  - LAUNCH SCENARIO 2 STAGE
  - STS MANIFESTING
  - APOTV PAYLOAD CAPABILITIES (TABLES)
  - APOTV PL CAP'Y @ 4 STS SIZES W/O SCAVENGING
  - APOTV PL CAP'Y @ 4 STS SIZES WITH SCAVENGING
  - APOTV RT CAP'Y VS STS PL W/O SCAVENGING
  - APOTV RT CAP'Y VS STS PL WITH SCAVENGING
- COMPARISON OF 2 VS 3 SHUTTLE FLIGHTS
  - WITHOUT SCAVENGING
  - WITH SCAVENGING
- CONCLUSIONS

1154-025(T)

MOTV

MOTV PERFORMANCE

GRUMMAN

OBJECTIVE: COMPARE SPACE BASED & GROUND BASED MOTV, IDENTIFY BENEFITS & IMPLICATIONS OF SPACE BASING

- EXAMINE
  - 1½ STAGE & 2 STAGE CONFIGURATIONS
  - 2 & 3 STS LAUNCHES
  - WITH & WITHOUT ET PROPELLANT SCAVENGING
  - GROWTH STS CONFIGURATIONS

1154-026(T)

MOTV

MOTV PERFORMANCE GENERAL GROUNDRULES & ASSUMPTIONS

GRUMMAN

- GROUND BASED: ASSEMBLY IN SPACE OCCURS @ 100 N Mi, 28½°
- SPACE BASED: SPACEPORT @ 200 N Mi, 28½°
- STANDARD SHUTTLE PAYLOAD CAPABILITY TO BOTH IS 29,500 KG
- LAST SHUTTLE FLIGHT REMAINS ON ORBIT & RETURNS CREW (PLUS CAPSULE & STAGE FOR GROUND BASED)
- MOTV PAYLOAD IS DELIVERED BY STS
- ALL STS FLIGHTS REQUIRE BERTHING CAPABILITY
- STAGE TANK WEIGHTS ARE SIZED TO THE PROPELLANT DELIVERY CAPABILITIES OF THE STS STANDARD & GROWTH LAUNCH VEHICLES

1154-027(T)

MOTV

MOTV PERFORMANCE UNIQUE GROUND-RULES & ASSUMPTIONS

GRUMMAN

- GROUND BASED
  - GENERAL
    - FIRST STS FLIGHT DOES NOT REQUIRE RENDEZVOUS
    - LAST STS FLIGHT RETURNS CREW, CAPSULE & STAGE
  - 1½ STAGE
    - PROPULSION CORE TANK IS SMALLER THAN DROP TANKS (CREW CAPSULE & PROPULSION CORE SHARE 1 SHUTTLE LAUNCH)
  - 2 STAGE COMMON
    - FIRST STS FLIGHT RETURNS PREVIOUS MOTV FLIGHT 1ST STAGE

1154-028(T)

MOTV

MOTV PERFORMANCE UNIQUE GROUND-RULES & ASSUMPTIONS

GRUMMAN

- SPACE BASED
  - GENERAL
    - ALL STS FLIGHTS REQUIRE RENDEZVOUS
    - ALLOWANCES HAVE BEEN MADE FOR BOTH MOTV & SPACEPORT REFURBISHMENT
  - 1½ STAGE
    - ZERO STAGE ACCEPTS COMMON DROP TANKS
  - 2 STAGE COMMON
    - PROPELLANT CARRIED IN TRANSFER TANKS
    - SPACEPORT STORAGE TANK REQUIRED
    - PROPELLANT TRANSFER LOSSES = 10% (GD & TBC STUDIES)
    - TRANSFER TANKS RETURNED TO EARTH
    - NO PENALTY ASSESSED FOR STAGE REMAINING ON ORBIT (DEBRIS PROTECTION, ETC)

1154-023(T)

MOTV PERFORMANCE GROUND RULES & ASSUMPTIONS – EXTERNAL TANK SCAVENGING

- MECO PROPELLANT TRANSFER
  - NOMINAL WT LIMITED 65K SHUTTLE FLIGHTS PRODUCE MAXIMUM GUARANTEED PROPELLANTS OF 1587KG (REF NAR & GD STUDIES)
  - ET TANK & SHUTTLE MODS FOR PROPELLANT TRANSFER 454 KG (NAR STUDY)
  - OFF-LOADED SHUTTLE PRODUCES 1 KG OF PROPELLANT FOR EACH KG OF PAYLOAD OFFLOADED (REF NAR & GD STUDIES)
- LEO ORBIT PROPELLANT TRANSFER (2 STAGE GROUND BASED 3-65K STS LAUNCHES ONLY)
  - SHUTTLE PAYLOAD DEGRADATION OF 2614 KG TO GET ET TO LEO ORBIT (GAC SPACE STATION STUDY)
  - ~ 3% PROPELLANT LOSS TO CHILL DOWN ON-ORBIT OTV TANKS (GD STUDIES)
  - ADDITIONAL LOSS DUE TO TANK HEATING, LIQUID/VAPOR MIXING & RESULTING OFF MR (GD STUDIES)

MOTV PERFORMANCE GROUND RULES & ASSUMPTIONS – STS MANIFESTING

- MANIFEST STS FLIGHTS TO DETERMINE OTV PROPELLANT DELIVERY CAPABILITY
- CHARGE FOLLOWING ITEMS AGAINST STS PAYLOAD CAPABILITY AS APPLICABLE:
  - STS
    - BERTHING/DOCKING
    - RENDEZVOUS
    - AIRBORNE SERVICE EQUIPMENT
    - ET TANK SCAVENGING EQUIPMENT
    - SCAVENGED PROPELLANT (+)
    - ON ORBIT STAY REQUIREMENTS
  - MOTV
    - CREW CAPSULE/CREW
    - GEO PAYLOADS
    - PROPULSION STAGES
    - DROP TANKS
    - PROPELLANT TRANSFER TANKS
    - MOTV & SPACEPORT REFURBISHMENTS

1154-032(T)

MOTV

MOTV PERFORMANCE GROUND RULES & ASSUMPTIONS – MOTV MISSIONS

GRUMMAN

- MEASURE MOTV PERFORMANCE AGAINST MINIMUM & TYPICAL GEO MISSION REQUIREMENTS
  - – MINIMUM MISSION – EMERGENCY REPAIR OF ONE SATELLITE
    - ○ FUNCTIONAL MINIMUM 2 MAN CAPSULE – 4 DAY MISSION (3100 KG)
    - ○ MISSION EQUIPMENT TO EFFECT REPAIR (500 KG)
    - ○ MISSION PAYLOAD TO REPAIR SATELLITE (500 KG)
    - ○ MOTV REQUIREMENTS:

      DELIVER 4100 KG

      RETURN 3600 KG
  - – TYPICAL MISSION AS DEFINED IN MIDTERM REVIEW – DELIVER 2 SATELLITES; REPAIR 5 SATELLITES; REMOVE 2 SATELLITES TO "JUNKYARD"
    - ○ FUNCTIONAL MINIMUM 2 MAN CAPSULE – 4 DAY MISSION (3100 KG)
    - ○ DELTA CONSUMMABLES FOR EXTENDED STAY (120 KG)
    - ○ MISSION EQUIPMENT TO EFFECT REPAIR (880 KG)
    - ○ MISSION PAYLOAD:

      2 DELIVERY SATELLITES (3000 KG)

      5 SERVICE MODULES (750 KG)

      PROPELLANT TO SERVICE MODULES (750 KG)

      PROPELLANT TO REMOVE SATELLITES (2700 KG)
    - ○ MOTV REQUIREMENTS:

      DELIVER 11,300 KG

      RETURN 4100 KG

1154-031(T)

THREE STS LAUNCH SCENARIO: 1 1/2-STAGE GROUND BASED

The 1 1/2-stage space based MOTV scenario for three 65-K shuttle launches is depicted on the opposite page. The scenario summarizes on-orbit & ground operations and shows the STS delivery and return requirements for each of the three flights.

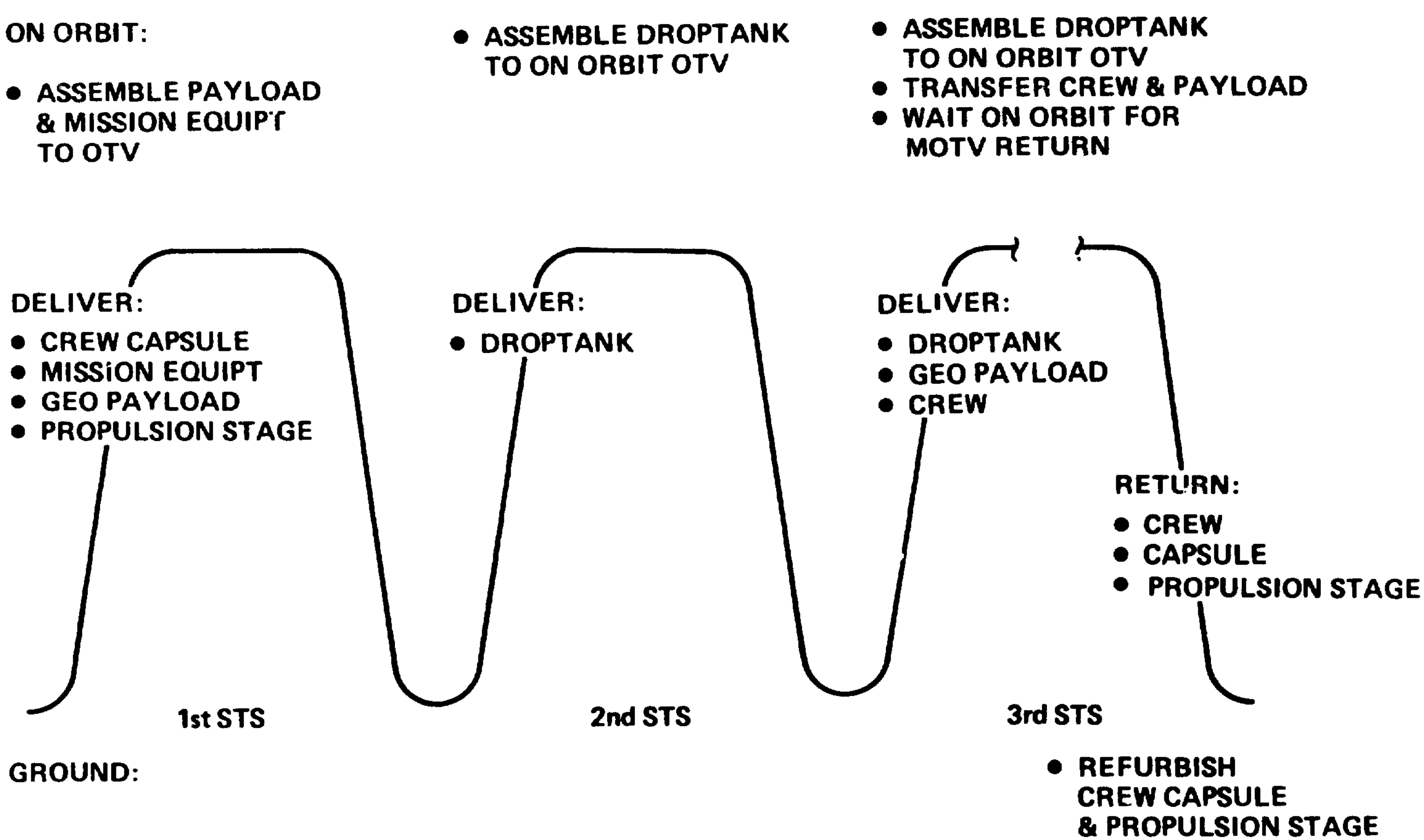
Note that the third shuttle flight remains on orbit and awaits the MOTV return. The crew, crew capsule, and propulsion stage are then loaded aboard the shuttle and returned to earth for refurbishment.

The first STS launch delivers the crew capsules and the propulsion stage. This combination has the capability to remain on orbit and provide a cooperative target for rendezvous of the second shuttle launch.

MOTV

3 STS LAUNCH SCENARIO-1½ STAGE GROUND BASED

GRUMMAN



1154-033(T)

THREE STS LAUNCH SCENARIO: 1 1/2-STAGE SPACE BASED

The 1 1/2 stage space based MOTV scenario for three 65-K shuttle launches is depicted on the opposite page. The scenario summarizes on-orbit & ground operations and shows the STS delivery and return requirements for each of the three flights.

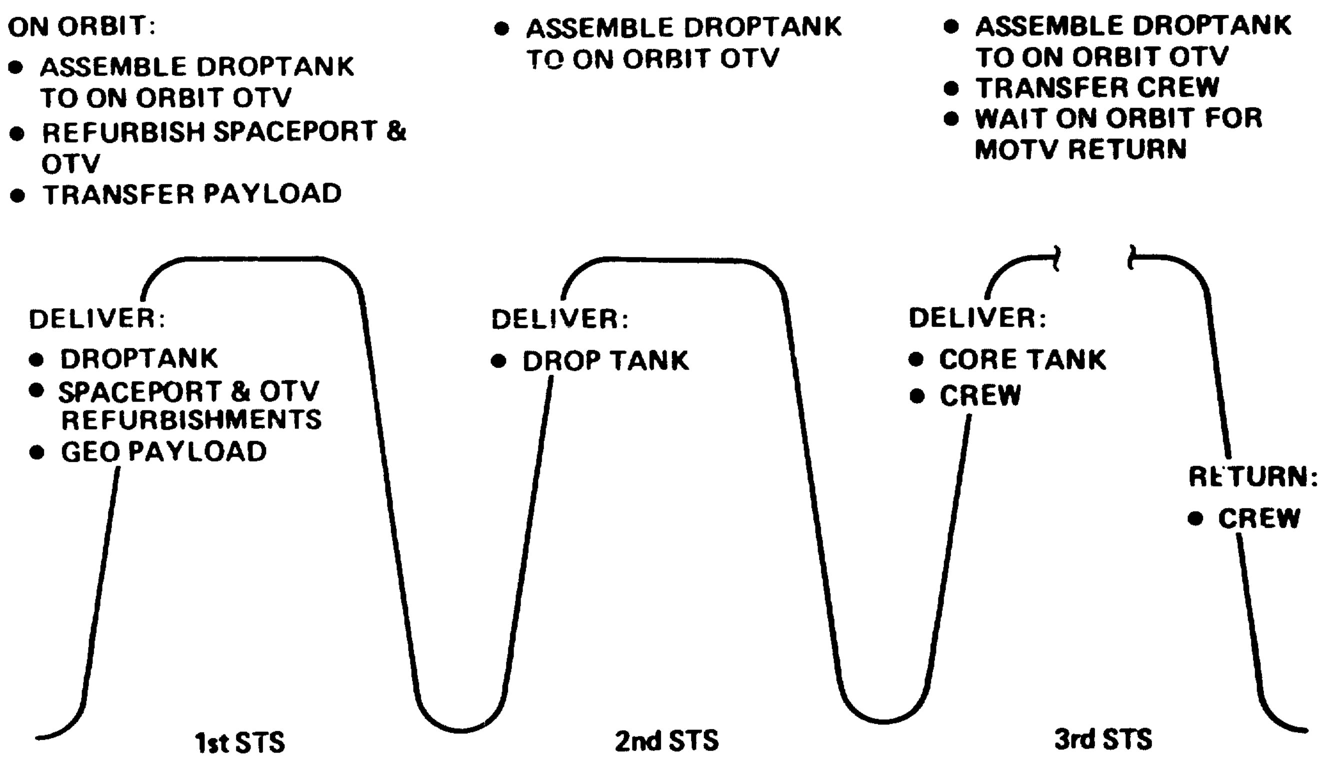
In this scenario the crew capsule and the zero stage remain on orbit at a tended spaceport. The first shuttle launch delivers MOTV and spaceport refurbishments. Refurbishing is accomplished while the spaceport is tended (may continue during the tended phase of the second and third shuttle launches).

The third STS launch again waits on orbit for the MOTV return but only the MOTV crew are returned to earth. The crew capsule and the zero stage remain at the spaceport.

MOTV

3 STS LAUNCH SCENARIO – 1½ STAGE SPACE BASED

GRUMMAN



1154-034(T)

THREE STS LAUNCH SCENARIO: 2-STAGE COMMON GROUND BASED

The 1 1/2-stage space based MOTV scenario for three 65-K shuttle launches is depicted on the opposite page. The scenario summarizes on-orbit & ground operations and shows the STS delivery and return requirements for each of the three flights.

Note that the first shuttle must capture and return the first stage from the previous MOTV flight. It is assumed that each of the MOTV common stages has the capability to remain in a stable orbit and provide a cooperative target for the shuttle.

The third shuttle waits on orbit for the MOTV to return. The crew, crew capsule, and the second stage are loaded aboard the shuttle and returned to earth.

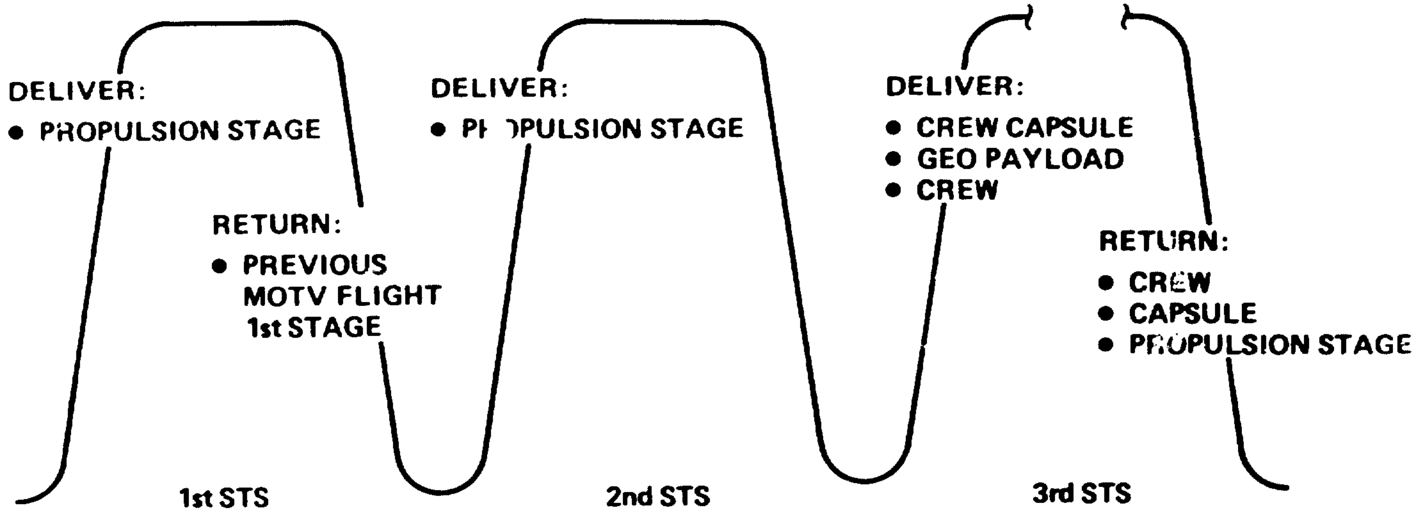
3 STS LAUNCH SCENARIO – 2 STAGE COMMON GROUND BASED

MOTV

GRUMMAN

ON ORBIT:

- CAPTURE PREVIOUS MOTV FLIGHT 1st STAGE
- MATE PROPULSION STAGES
- MATE CREW CAPSULE
- TRANSFER CREW & PAYLOAD
- WAIT ON ORBIT FOR MOTV RETURN



GROUND:

- REFURBISH PROPULSION STAGE
- REFURBISH CREW CAPSULE & PROPULSION STAGE

THREE STS LAUNCH SCENARIO: 2-STAGE COMMON SPACE BASED

The 1 1/2 stage space based MOTV scenario for three 65-K shuttle launches is depicted on the opposite page. The scenario summarizes on-orbit & ground operations and shows the STS delivery and return requirements for each of the three flights.

In this scenario the crew capsule and both propulsion stages remain at a tended spaceport, which includes a propellant storage tank. Propellants are delivered in shuttle mounted propellant transfer tanks which are returned to earth.

The first shuttle launch delivers MOTV and spaceport refurbishments. Refurbishing is accomplished while the spaceport is tended (may continue during the tended phase of the second and third shuttle launches).

The third STS launch waits on orbit for the MOTV return but only the MOTV crew are returned to earth. The crew capsule and both stages remain at the spaceport.

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MOTV

3 STS LAUNCH SCENARIO – 2 STAGE COMMON SPACE BASED

GRUMMAN

1st STS	2nd STS	3rd STS
ON ORBIT: • TRANSFER PROPELLANT TO STORAGE TANK • REFURBISH SPACEPORT & OTV • TRANSFER PAYLOAD	• TRANSFER PROPELLANT TO STORAGE TANK	• TRANSFER PROPELLANT TO STORAGE TANK • FILL STAGES • TRANSFER CREW • WAIT ON ORBIT FOR MOTV RETURN
DELIVER: • TRANSFER TANK • SPACEPORT & OTV REFURBISHMENTS • GEO PAYLOAD	DELIVER: • TRANSFER TANK	DELIVER: • TRANSFER TANK • CREW
RETURN: • TRANSFER TANK	RETURN: • TRANSFER TANK	RETURN: • TRANSFER TANK • CREW

1154-036(T)

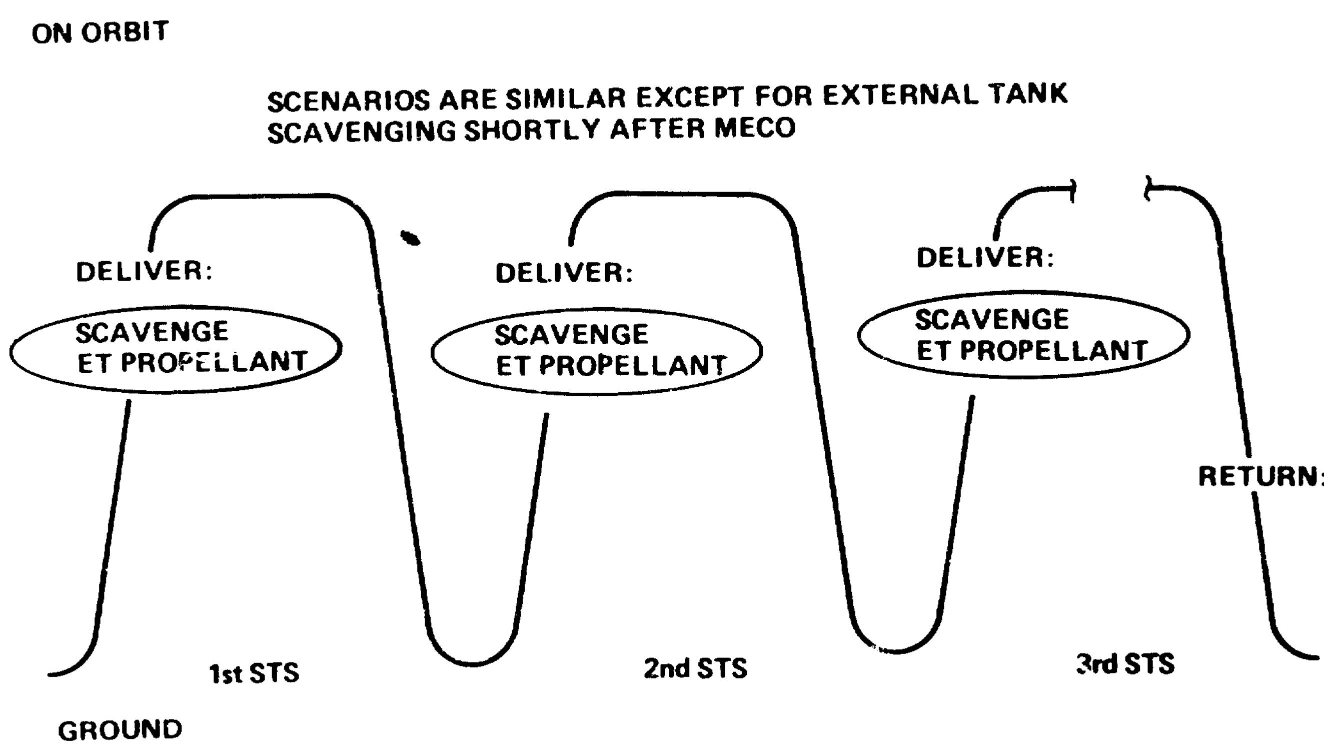
THREE STS LAUNCH SCENARIO: WITH SCAVENGING

With the exception of the 2-stage common ground based MOTV configuration, the scenarios with external tank propellant scavenging are similar to those already shown.

During the shuttle ascent phase, shortly after meco, (main engine cut off) excess propellants are scavenged from the external tank to the stage or the tank in the shuttle cargo bay. A net gain of 1133 Kg of propellant for each weight limited 65-K shuttle flight has been assumed.

The MOTV tanks are sized to accept the additional propellants.

3 STS LAUNCH SCENARIO – 1½ STAGE SPACE BASED & GROUND BASED & 2 STAGE COMMON SPACE BASED WITH SCAVENGING



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1154-037(T)

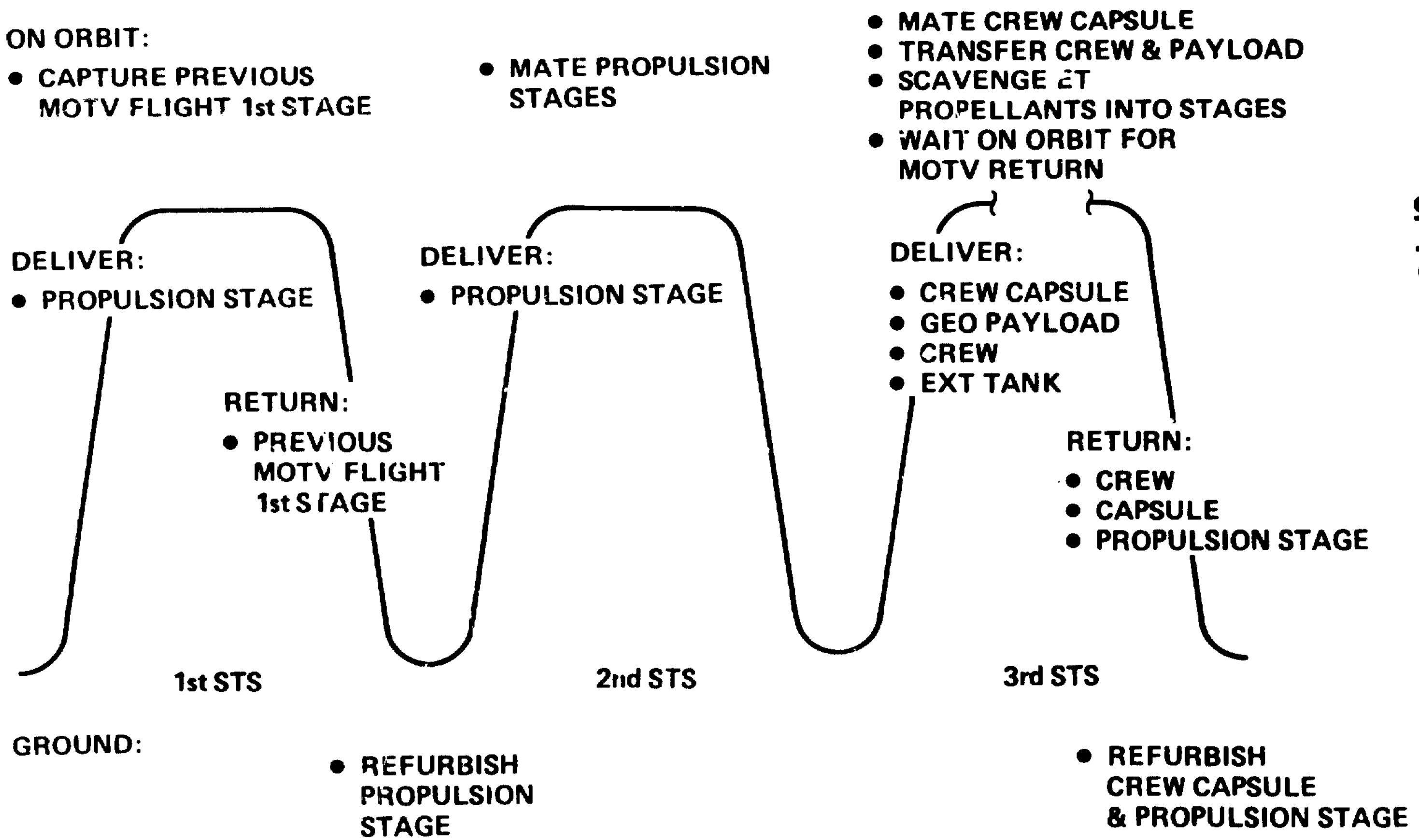
THREE STS LAUNCH SCENARIO: 2-STAGE COMMON GROUND BASED, WITH SCAVENGING

This is a unique scavenging scenario. The first two shuttle launches use scavenged propellant as previously described. The third STS launch, however, has no stage to scavenge propellant into. In order to take advantage of the scavengable propellant, we have elected to take the external tank to orbit and transfer the propellants directly to the on-orbit stages. The losses (as described in the ground rules and assumptions) are large, but there is a net gain of propellant.

MOTV

3 STS LAUNCH SCENARIO – 2 STAGE COMMON GROUND BASED WITH SCAVENGING

GRUMMAN



1154-038(T)

1 1/2-STAGE GROUND BASED SHUTTLE MANIFESTING

The cargo and STS changeable equipment carried aboard each of the shuttle flights has been determined and is shown in the chart. Scenarios with and without external tank propellant scavenging have been manifested. All configurations transport 3750 Kg of GEO payload to LEO.

All STS flights have been manifested to use the full shuttle payload capability.

MOTV

1½ STAGE GROUND BASED SHUTTLE MANIFESTING – ALL WEIGHTS IN KG

GRUMMAN

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	WITHOUT SCAVENGING STS LAUNCHES			WITH SCAVENGING STS LAUNCHES		
	1st	2nd	3rd	1st	2nd	3rd
CAPSULE & MISSION EQUIPMENT	4100			4100		
PROPULSION STAGE, BO WT	4030			4070		
DROP TANK ..O WT		1675	1675		1675	1675
PROP TRANSFER TANK						
GEO PAYLOAD	750		3000	750	3000	
MOTV PROPELLANTS	16,470	24,215	18,665	17,563	21,548	23,598
CAPSULE/ ^ REFURBISHMENTS						
AIRBORNE SUPPORT EQUIPMENT	2550	1100	1900	2550	1900	1100
DOCKING	1600	1600	1600	1600	1600	1600
RENDEZVOUS		910	910		910	910
STS ON ORBIT EXPENDITURES			1750			1750
STS ET SCAVENGING EQUIPT				454	454	454
SCAVENGED PROPELLANT				-1587	-1587	-1587
STS PAYLOAD	29,500	29,500	29,500	29,500	29,500	29,500

- TOTAL USABLE PROPELLANT WITHOUT SCAVENGING = 59,350 KG
- TOTAL USABLE PROPELLANT WITH SCAVENGING = 62,709 KG

1 1/2-STAGE SPACE BASED SHUTTLE MANIFESTING

The cargo and STS changeable equipment carried aboard each of the shuttle flights has been determined and is shown in the chart. Scenarios with and without external tank propellant scavenging have been manifested. All configurations transport 3750 Kg of GEO payload to LEO.

All STS flights have been manifested to use the full shuttle capability.

As indicated in the scenario this space based MOTV does not transport the crew capsule or zero stage to LEO (they remain on orbit). Spaceport and MOTV refurbishments, however, are transported to LEO aboard the shuttle.

MOTV

1½ STAGE SPACE BASED SHUTTLE MANIFESTING-ALL WEIGHTS IN KG

GRUMMAN

	WITHOUT SCAVENGING STS LAUNCHES			WITH SCAVENGING STS LAUNCHES		
	1st	2nd	3rd	1st	2nd	3rd
CAPSULE & MISSION EQUIPMENT						
PROPULSION STAGE, BO WT						
DROP TANK, BO WT	1675	1675	1622	1622	1675	1675
PROP TRANSFER TANK						
GEO PAYLOAD	3750				3750	
MOTV PROPELLANTS	16,565	24,215	22,518	22,301	20,798	23,598
CAPSULE/SOC REFURBISHMENTS	2500			2500		
AIRBORNE SUPPORT EQUIPMENT	2500	1100	1100	1700	1900	1100
DOCKING	1600	1600	1600	1600	1600	1600
RENDEZVOUS	910	910	910	910	910	910
STS ON ORBIT EXPENDITURES			1750			1750
STS ET SCAVENGING EQUIPT				454	454	454
SCAVENGED PROPELLANT				-1587	-1587	-1587
STS PAYLOAD	29,500	29,500	29,500	29,500	29,500	29,500

- TOTAL USABLE PROPELLANT WITHOUT SCAVENGING = 63,298 KG
- TOTAL USABLE PROPELLANT WITH SCAVENGING = 66,697 KG

1154-040(T)

2-STAGE COMMON GROUND BASED SHUTTLE MANIFESTING

The cargo and STS changeable equipment carried aboard each of the shuttle flights has been determined and is shown in the chart. Scenarios with and without external tank propellant scavenging have been manifested. All configurations transport 3750 Kg of GEO payload to LEO.

The 2-stage common ground based MOTV without scavenging does not fully utilize three shuttle launches. The first two shuttles carry fully loaded propellant stages, the third shuttle carries the crew capsule and the GEO payload. There is no way (short of propellant transfer, which in our scenario means space based) to carry additional propellants on that third shuttle.

The 2-stage common ground based MOTV with E.T. propellant scavenging can utilize the full third shuttle payload capability by taking the external tank to orbit. E.T. propellants are then scavenged directly into the on-orbit stages.

MOTV

2 STAGE COMMON GROUND BASED SHUTTLE MANIFESTING – ALL WEIGHTS IN KG

GRUMMAN

	WITHOUT SCAVENGING STS LAUNCHES			WITH SCAVENGING STS LAUNCHES		
	1st	2nd	3rd	1st	2nd	3rd
CAPSULE & MISSION EQUIPMENT			4100			4100
PROPULSION STAGE, BO WT	3136	3136		3850	3850	
DROP TANK, BO WT						
PROP TRANSFER TANK						
GEO PAYLOAD			3750			3750
MOTV PROPELLANTS	23,464	22,554		23,883	22,973	12,909
CAPSULE/SOC REFURBISHMENTS						
AIRBORNE SUPPORT EQUIPMENT	1300	1300	2500	1300	1300	3000
DOCKING	1600	1600	1600	1600	1600	1600
RENDEZVOUS		910	910		910	910
STS ON ORBIT EXPENDITURES			1750			1750
STS ET SCAVENGING EQUIPT				454	454	454
SCAVENGED PROPELLANT				-1587	-1587	-1587
EXT TANK TO ORBIT						2614
STS PAYLOAD	29,500	29,500	14,610	29,500	29,500	29,500

- CONFIGURATION WITHOUT SCAVENGING CANNOT FULLY UTILIZE THIRD SHUTTLE FLIGHT
- TOTAL USEABLE PROPELLANT WITHOUT SCAVENGING = 46,018 KG
- CONFIGURATION WITH SCAVENGING TAKE EXTERNAL TANK TO ORBIT
- TOTAL USEABLE PROPELLANT WITH SCAVENGING = 53,091 KG (59,765 KG LESS E.T. TRANSFER LOSSES)

1154-041(T)

2-STAGE COMMON SPACE BASED SHUTTLE MANIFESTING

The cargo and STS changeable equipment carried aboard each of the shuttle flights has been determined and is shown in the chart. Scenarios with and without external tank propellant scavenging have been manifested. All configurations transport 3750 Kg of GEO payload to LEO.

This configuration carries propellant transfer tanks in the shuttle and transfers the propellant to a space based storage tank on the spaceport. In this manner all STS flights can be manifested to use the full shuttle capability. There are, however, fuel transfer loses. Studies by G.D. and Boeing indicate losses of 10 to 12.5%. We have used 10% propellant transfer loss for this study.

MOTV

2 STAGE COMMON SPACE BASED SHUTTLE MANIFESTING – ALL WEIGHTS IN KG

GRUMMAN

	WITHOUT SCAVENGING			WITH SCAVENGING		
	STS LAUNCHES			STS LAUNCHES		
	1st	2nd	3rd	1st	2nd	3rd
CAPSULE & MISSION EQUIPMENT						
PROPULSION STAGE, BO WT						
DROP TANK, BO WT						
PROP TRANSFER TANK	1270	1270	1270	1270	1270	1270
GEO PAYLOAD	3750			3750		
MOTV PROPELLANTS	16,470	24,620	22,870	17,603	25,753	24,003
CAPSULE/SOC REFURBISHMENTS	3000			3000		
AIRBORNE SUPPORT EQUIPMENT	2500	1100	1100	2500	1100	1100
DOCKING	1600	1600	1600	1600	1600	1600
RENDEZVOUS	910	910	910	910	910	910
STS ON ORBIT EXPENDITURES			1750			1750
STS ET SCAVENGING EQUIPT				454	454	454
SCAVENGED PROPELLANT				-1587	-1587	-1587
STS PAYLOAD	29,500	29,500	29,500	29,500	29,500	29,500

- TOTAL USABLE PROPELLANT WITHOUT SCAVENGING = 57,114 (63,960 KG LESS 10% TRANSFER LOSSES)
- TOTAL USABLE PROPELLANT WITH SCAVENGING = 60,623 (67,359 LESS 10% TRANSFER LOSSES)

1154-042(T)

APOTV GEO PAYLOAD CAPABILITIES: THREE 65-K SHUTTLE LAUNCHES

The GEO payload capabilities of the APOTVs described in the preceding scenarios and manifestings are shown in the accompanying chart.

Delivered, returned, and roundtrip GEO payload capabilities have been calculated and are presented.

All configurations benefit substantially from external tank propellant scavenging. The 1 1/2-stage space based configuration is the best performer.

MOTV

APOTV GEO PAYLOAD CAPABILITIES 3-65K SHUTTLE LAUNCHES

GRUMMAN

	GEO PAYLOADS, KG		
	DELIVERED	RETURNED	ROUNDTRIP
1½ STAGE			
GROUND BASED	19,397	7406	5359
GROUND BASED WITH SCAVENGING	21,066	8046	5822
SPACE BASED	20,894	7981	5775
SPACE BASED WITH SCAVENGING	22,630	8644	6255
2 STAGE COMMON			
GROUND BASED	14,823	5209	3855
GROUND BASED WITH SCAVENGING	16,000	5589	4142
SPACE BASED	18,353	6434	4764
SPACE BASED WITH SCAVENGING	19,257	6751	4998

1154-043(T)

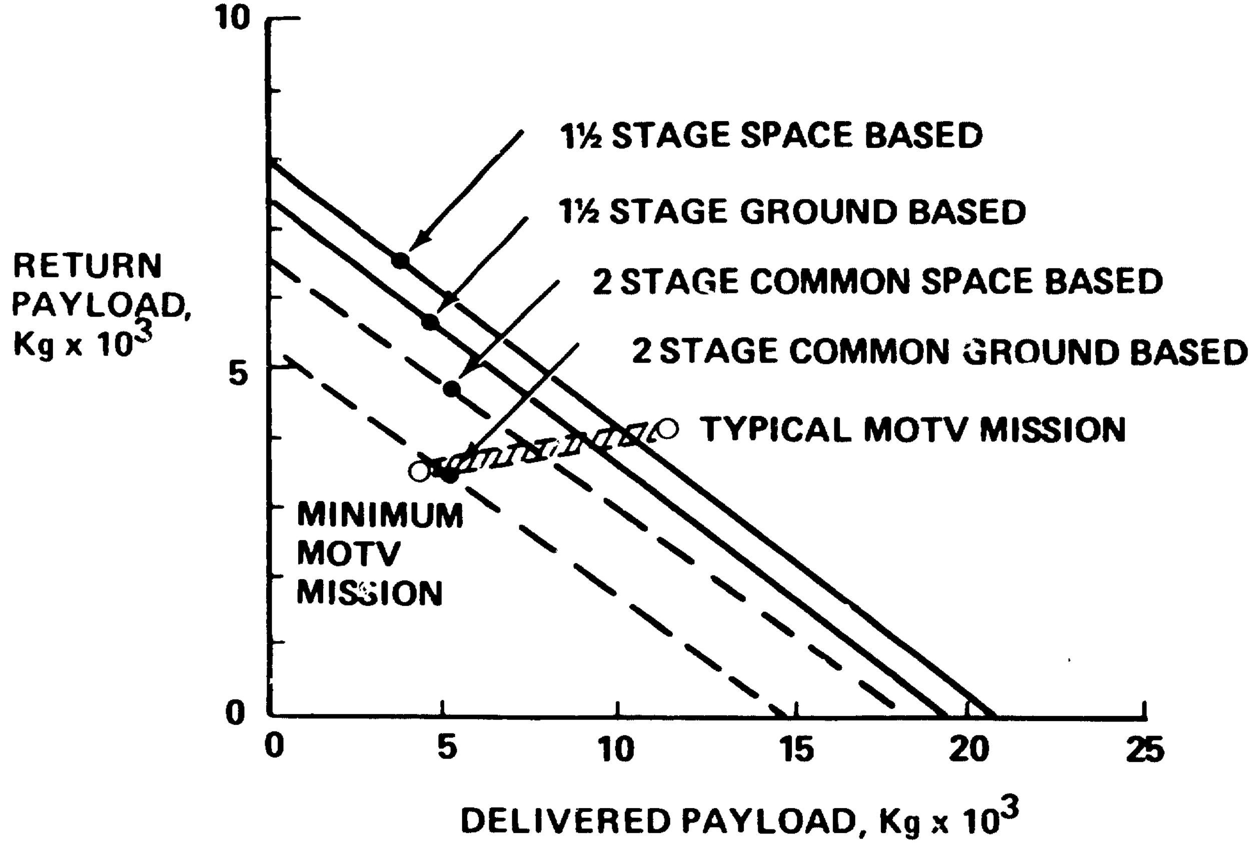
APOTV GEO PAYLOAD CAPABILITIES: THREE 65-K SHUTTLE LAUNCHES, NO SCAVENGING

The payload capabilities of the various configurations (without E.T. propellant scavenging) are shown on the familiar payload returned vs payload delivered plot.

Spotted on the curve are the minimum and the typical MOTV missions described in the ground rules and assumptions.

All configurations are capable of performing the minimum MOTV mission. None can perform the more ambitious "typical" MOTV mission.

APOTV GEO PAYLOAD CAPABILITIES 3 65K SHUTTLE LAUNCHES – NO SCAVENGING



1154-044(T)

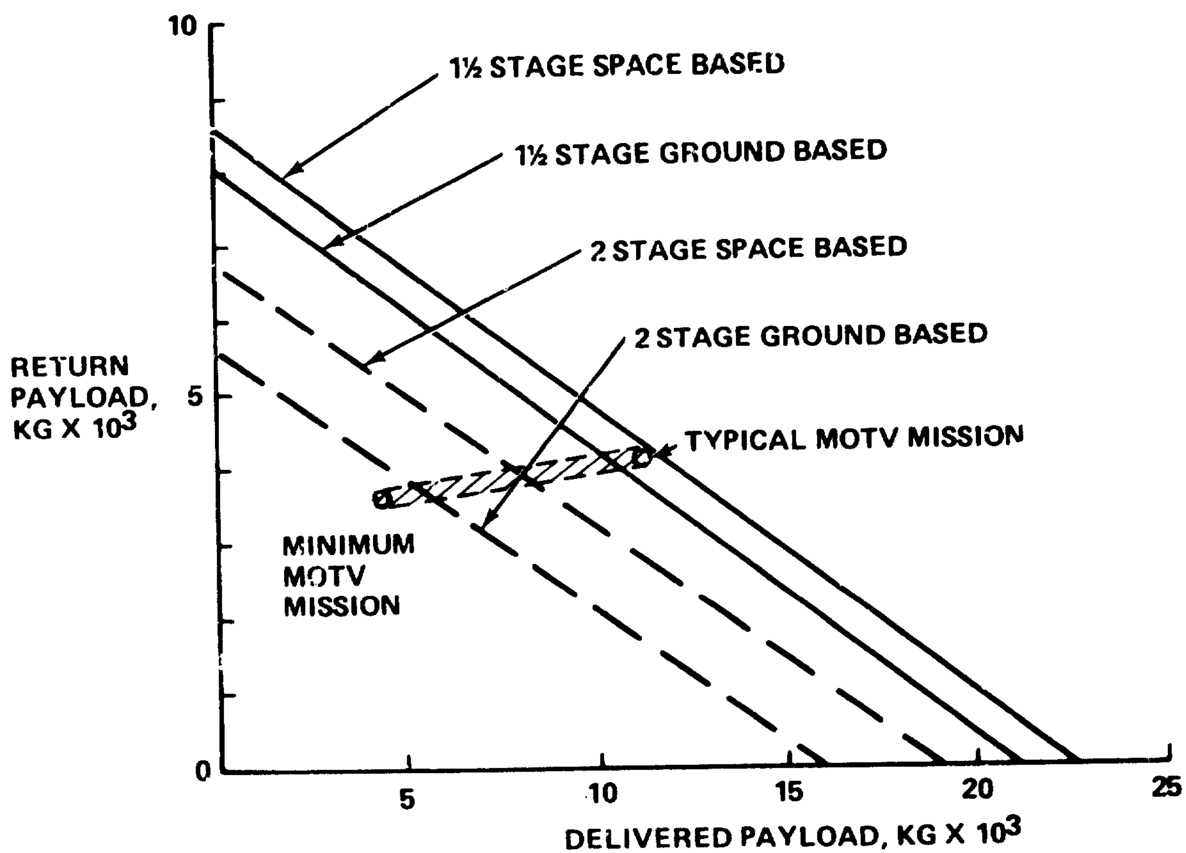
APOTV GEO PAYLOAD CAPABILITIES: THREE 65-K SHUTTLE LAUNCHES, WITH SCAVENGING

This plot shows the GEO payload capabilities of the various APOTV configuration with E.T. propellant scavenging.

Spotted on the curve are the minimum and the typical MOTV missions described in the ground rules and assumptions.

All configurations can perform the minimum MOTV mission. The 1 1/2-stage space based configuration can perform the typical MOTV mission.

APOTV GEO PAYLOAD CAPABILITIES 3 65K SHUTTLE LAUNCHES WITH SCAVENGING



1154-045(T)

TWO STS LAUNCH SCENARIO: 1 1/2-STAGE GROUND BASED

The 1 1/2-stage space based MOTV scenario for two 65-K shuttle launches is depicted on the opposite page. The scenario summarizes on-orbit & ground operations and shows the STS delivery and return requirements for each of the two flights.

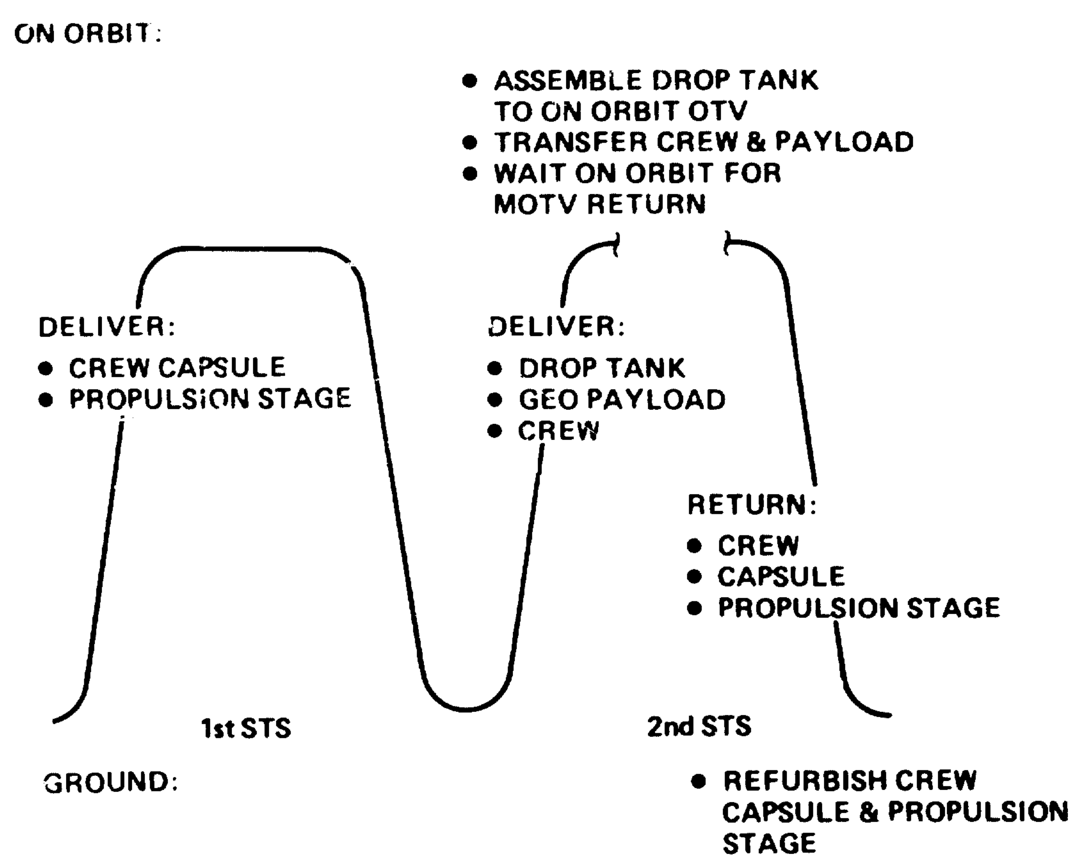
Note that the last shuttle remains on orbit and awaits the MOTV return.

The first shuttle delivers the crew capsule and the propulsion stage which have the capability to remain on orbit and provide a cooperative target for the second shuttle.

The second shuttle delivers the crew, GEO payload, and a drop tank. The drop tank is assembled to the crew capsule/propulsion stage; the crew and GEO payload are transferred aboard; the MOTV is checked out; and the MOTV leaves for GEO.

When the MOTV mission has been completed the crew capsule and propulsion stage rendezvous and berth with the waiting shuttle. The crew capsule and propulsion stage are returned to the shuttle payload bay; the crew transfers to the shuttle; and the MOTV is returned to earth for refurbishment.

2 STS LAUNCH SCENARIO – 1½ STAGE GROUND BASED



1154-046(T)

TWO STS LAUNCH SCENARIO: 1 1/2-STAGE SPACE BASED

The 1 1/2-stage space based MOTV scenario for two 65-K shuttle launches is depicted on the opposite page. The scenario summarizes on-orbit operations and shows the STS delivery and return requirements for each of the two flights.

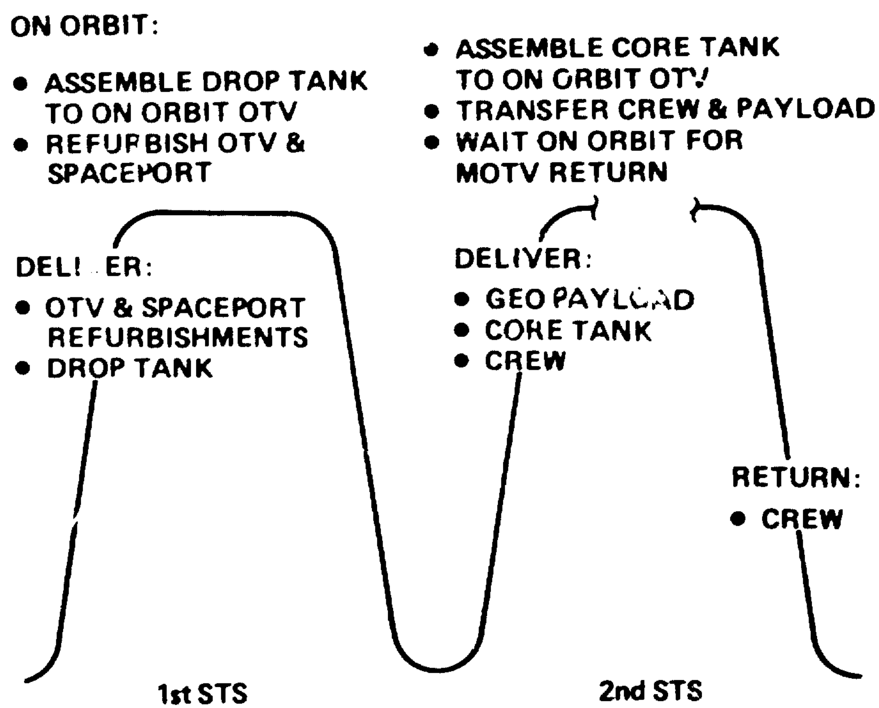
Note that the last shuttle remains on orbit and awaits the MOTV return.

The first shuttle delivers a fueled drop tank and MOTV and spaceport refurbishments. The drop tank is transferred to the spaceport and the crew capsule, propulsion stage, and spaceport are refurbished.

The second shuttle delivers the fueled core tank, the MOTV crew, and the GEO payload. The core tank is transferred to the spaceport and the crew and GEO payload are transferred to the MOTV. Then the MOTV tanks are installed, the MOTV is checked out, and the GEO mission commences.

On completion of the GEO mission, the MOTV rendezvous and berths with the spaceport and waiting shuttle. The crew is transferred to the shuttle and returned to earth.

2 STS LAUNCH SCENARIO — 1½ STAGE SPACE BASED



1154-047(T)

TWO STS LAUNCH SCENARIO: 2-STAGE GROUND BASED

The 1 1/2-stage space based MOTV scenario for two 65-K shuttle launches is depicted on the opposite page. The scenario summarizes on-orbit & ground operations and shows the STS delivery and return requirements for each of the two flights.

Note that the last shuttle remains on orbit and awaits the MOTV return.

The first shuttle delivers and deploys the crew capsule and the MOTV second stage. This combination has the capability to remain on orbit and provide a cooperative target. The shuttle then captures and returns the MOTV first stage from the previous flight to earth for refurbishment.

The second shuttle delivers the MOTV crew, the GEO payload, and the MOTV first stage. When assembled and checked out the MOTV departs on its GEO mission. When the MOTV first stage completes its propulsive function it returns to LEO in the vicinity of the shuttle and awaits its eventual retrieval.

On completion of the GEO mission the MOTV capsule and first stage return to LEO and rendezvous with the waiting shuttle. The crew, capsule, and first stage are taken aboard the shuttle and returned to earth for refurbishment.

The MOTV second stage remains on orbit to be retrieved by the next shuttle flight.

2 STS LAUNCH SCENARIO – 2 STAGE GROUND BASED

GRUMMAN

ON OF T:

- CAPTURE PREVIOUS MOTV FLIGHT 1st STAGE
- ASSEMBLE PROPULSION STAGE TO ON ORBIT OTV
- TRANSFER CREW & PAYLOAD
- WAIT ON ORBIT FOR MOTV RETURN

DELIVER:
- CREW CAPSULE
- PROPULSION STAGE

RETURN:
- PREVIOUS MOTV FLIGHT 1st STAGE

DELIVER:
- PROPULSION STAGE
- GEO PAYLOAD
- CREW

RETURN:
- CREW
- CAPSULE
- PROPULSION STAGE

1st STS

2nd STS

GROUND:
- REFURBISH PROPULSION STAGE
- REFURBISH PROPULSION STAGE & CREW CAPSULE

TWO STS LAUNCH SCENARIO: 2-STAGE SPACE BASED

The 1-1/2 stage space based MOTV scenario for two 65-K shuttle launches is depicted on the opposite page. The scenario summarizes on-orbit operations and shows the STS delivery and return requirements for each of the two flights.

Note that the last shuttle remains on orbit and awaits the MOTV return.

The first shuttle delivers propellant (in a cargo bay mounted propellant transfer tank) and MOTV and space port refurbishments. The propellants are transferred to a propellant storage tank on the space port. The crew capsule, propellant stages, and the spaceport are refurbished.

The second shuttle delivers additional propellants (in a transfer tank, MOTV crew and the GEO payload. The propellant is transferred to the spaceport; the MOTV is fueled; crew and payload are transferred to the MOTV; and it is checked out. The MOTV then leaves on its geo mission.

When expended the MOTV first stage returns to the spaceport to rendezvous and berth.

Upon completion of the GEO mission, the MOTV returns and berths to the spaceport. The crew transfers to the waiting shuttle and returns to earth.

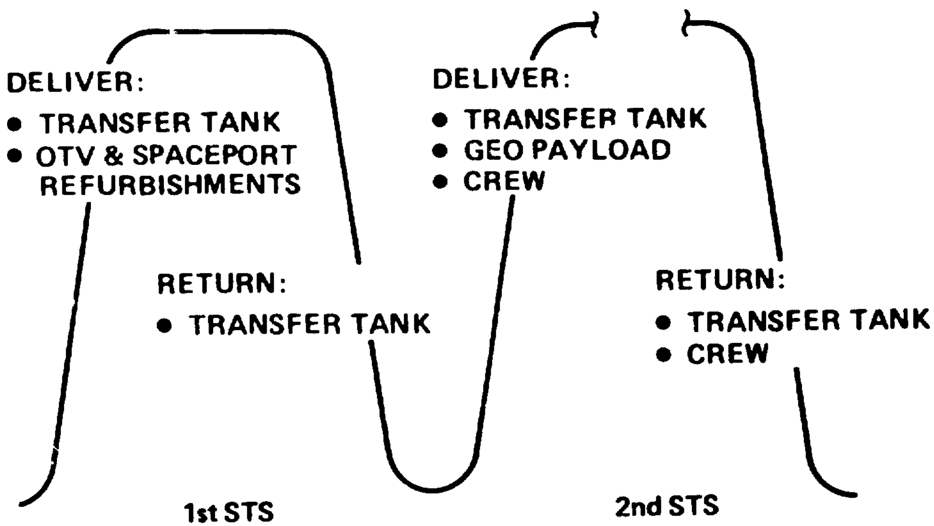
MOTV

2 STS LAUNCH SCENARIO – 2 STAGE SPACE BASED

GRUMMAN

ON ORBIT:

- TRANSFER PROPELLANT TO SOC STORAGE TANK
- REFURBISH OTV & SPACEPORT
- TRANSFER PROPELLANT TO SOC STORAGE TANK
- FILL PROPULSION STAGES
- TRANSFER CREW & PAYLOAD
- WAIT ON ORBIT FOR MOTV RETURN



1154-049(T)

TWO STS LAUNCH SCENARIO: ALL CONFIGURATIONS WITH SCAVENGING

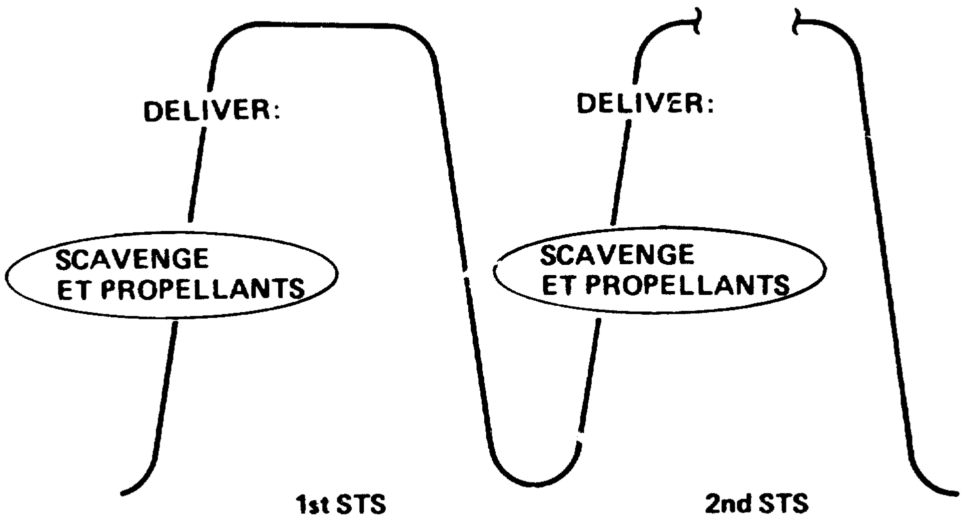
The two STS launch scenarios that have been presented remain fundamentally unchanged by external tank propellant scavenging. Shortly after MECO (main engine cut off) excess propellants are scavenged into the appropriate MOTV tanks in the shuttle cargo bay. (Tanks are sized to accept the additional propellant.)

MOTV

2 STS LAUNCH SCENARIO – ALL CONFIGURATIONS – WITH SCAVENGING

GRUMMAN

ALL SCENARIOS AS PREVIOUSLY PRESENTED EXCEPT EXTERNAL TANK PROPELLANTS ARE SCAVENGED SHORTLY AFTER MECO



1154-050(T)

MOTV

2 STS LAUNCH CONFIGURATIONS STS MANIFESTING

GRUMMAN

- 2 LAUNCH STS MANIFESTING WAS PERFORMED SIMILAR TO THE 3 LAUNCH MANIFESTING
- FOR CONSISTANCY ALL GROUND BASED CONFIGURATIONS WERE CHARGED FOR DELIVERY OF A 4100 KG CREW CAPSULE
- ALL CONFIGURATIONS CARRIED 3000 KG OF GEO PAYLOAD
- SPACE BASED CONFIGURATIONS WERE CHARGED FOR DELIVERY OF OTV & SPACEPORT REFURBISHMENT (2500 KG FOR 1½ STAGE; 3000 KG FOR 2 STAGE)
- "WITH SCAVENGING" CONFIGURATIONS WERE CHARGED FOR STS SCAVENGING CAPABILITY & CREDITED WITH ADDITIONAL PROPELLANT

APOTV GEO PAYLOAD CAPABILITIES: TWO 65-K SHUTTLE LAUNCHES

This chart shows the GEO payload capabilities of the various APOTV configurations considered for two 65-K shuttle launches. Payload capabilities with and without external tank propellant scavenging are shown. These payload capabilities are the product of the scenarios and shuttle manifesting previously described.

MOTV

APOTV GEO PAYLOAD CAPABILITIES
2-65K SHUTTLE LAUNCHES

GRUMMAN

	GEO PAYLOADS, KG		
	DELIVERED	RETURNED	ROUNDTRIP
1½ STAGE			
GROUND BASED	7763	2965	2145
GROUND BASED WITH SCAVENGING	8744	3340	2417
SPACE BASED	8844	3378	2444
SPACE BASED WITH SCAVENGING	9773	3733	2701
2 STAGE COMMON			
GROUND BASED	8910	3115	2308
GROUND BASED WITH SCAVENGING	9819	3403	2527
SPACE BASED	8905	3115	2308
SPACE BASED WITH SCAVENGING	9744	3379	2509

1154-052(T)

APOTV GEO PAYLOAD CAPABILITIES: TWO 75-K SHUTTLE LAUNCHES

This chart shows the GEO payload capabilities of the various APOTV configurations considered for two 75-K shuttle launches. Payload capabilities with and without external tank propellant scavenging are shown. These payload capabilities are the product of the scenarios and shuttle manifesting previously described.

C-3

MOTV

APOTV GEO PAYLOAD CAPABILITIES
2-75K SHUTTLE LAUNCHES

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	GEO PAYLOADS, KG		
	DELIVERED	RETURNED	ROUNDTRIP
1½ STAGE			
GROUND BASED	11,816	4513	3266
GROUND BASED WITH SCAVENGING	12,929	4938	3573
SPACE BASED	13,014	4971	3597
SPACE BASED WITH SCAVENGING	14,482	5532	4003
2 STAGE COMMON			
GROUND BASED	12,852	4478	3321
GROUND BASED WITH SCAVENGING	14,101	4923	3651
SPACE BASED	12,461	4312	3204
SPACE BASED WITH SCAVENGING	13,651	4764	3532

1154-053(T)

APOTV GEO PAYLOAD CAPABILITIES: TWO 85-K SHUTTLE LAUNCHES

This chart shows the GEO payload capabilities of the various APOTV configurations considered for two 85-K shuttle launches. Payload capabilities with and without external tank propellant scavenging are shown. These payload capabilities are the product of the scenarios and shuttle manifesting previously described.

APOTV GEO PAYLOAD CAPABILITIES 2-85K SHUTTLE LAUNCHES

	GEO PAYLOADS, KG		
	DELIVERED	RETURNED	ROUNDTRIP
1½ STAGE			
GROUND BASED	15,873	6063	4387
GROUND BASED WITH SCAVENGING	17,360	6631	4798
SPACE BASED	17,447	6664	4822
SPACE BASED WITH SCAVENGING	18,977	7249	5245
2 STAGE COMMON			
GROUND BASED	16,780	5882	4355
GROUND BASED WITH SCAVENGING	18,240	6400	4738
SPACE BASED	16,123	5646	4182
SPACE BASED WITH SCAVENGING	17,C38	5973	4423

APOTV GEO PAYLOAD CAPABILITIES: TWO 100-K SHUTTLE LAUNCHES

This chart shows the GEO payload capabilities of the various APOTV configurations considered for two 100-K shuttle launches. Payload capabilities with and without external tank propellant scavenging are shown. These payload capabilities are the product of the scenarios and shuttle manifesting previously described.

APOTV GEO PAYLOAD CAPABILITIES
2-100K SHUTTLE LAUNCHES

	GEO PAYLOADS, KG		
	DELIVERED	RETURNED	ROUNDTRIP
1½ STAGE			
GROUND BASED	20,912	7988	5780
GROUND BASED WITH SCAVENGING	22,323	8527	6170
SPACE BASED	22,108	8445	6111
SPACE BASED WITH SCAVENGING	25,056	9571	6926
2 STAGE COMMON			
GROUND BASED	21,752	7645	5657
GROUND BASED WITH SCAVENGING	23,434	8247	6100
SPACE BASED	20,762	7294	5397
SPACE BASED WITH SCAVENGING	22,348	7861	5815

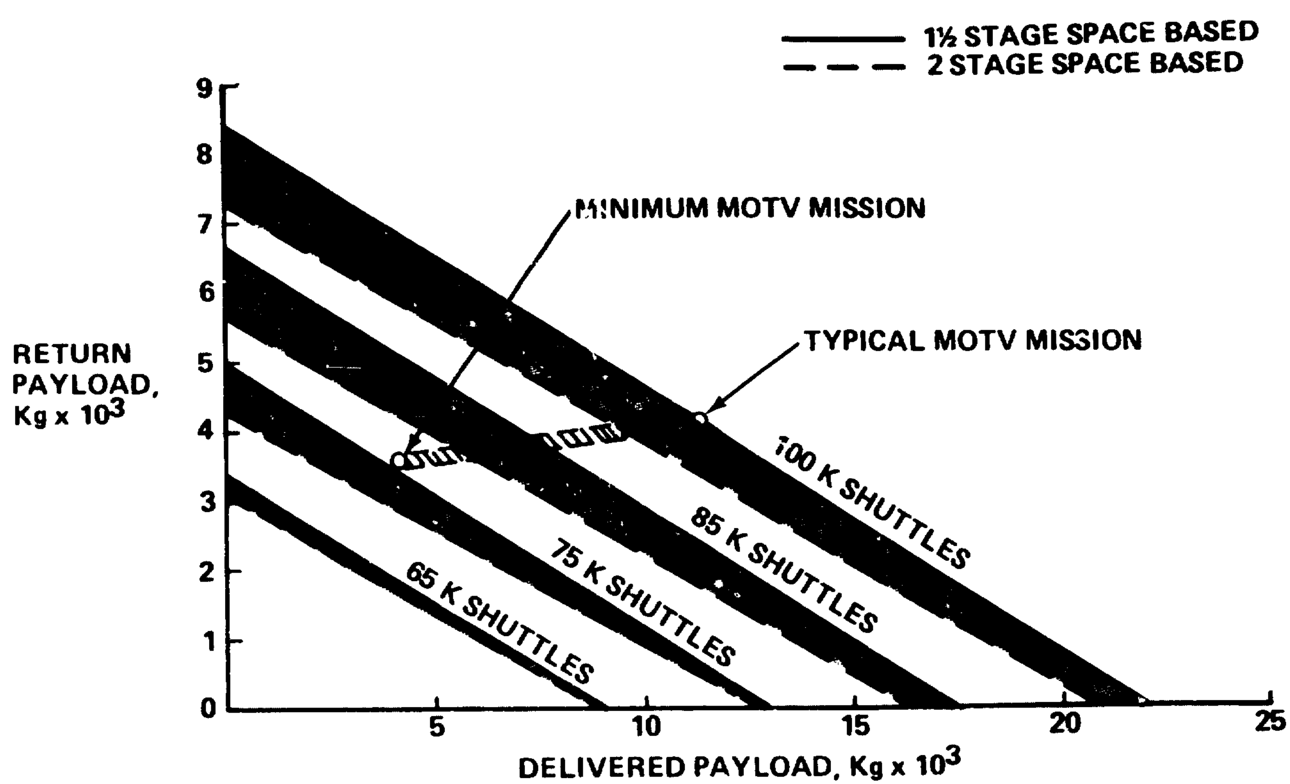
1154-055(T)

APOTV GEO PAYLOAD CAPABILITIES: TWO SHUTTLE LAUNCHES, NO SCAVENGING

This curve shows the delivery and return payload capability of two shuttle launch APOTVs. A band of APOTV capability is shown for each of the shuttle payload capabilities considered. In each case the 1 1/2-stage space based APOTV is the best performer and the 2-stage common space based APOTV is the worst performer. The other APOTV configurations (1 1/2-stage ground based and 2-stage common ground based) fall within the bands shown.

The minimum and the typical MOTV missions described in the performance ground rules and assumptions have been spotted on the curve. As indicated by this plot the minimum mission requires two 85-K shuttle launches while the typical mission can barely be attained with two 100K shuttle launches when there is no external tank propellant scavenging.

APOTV GEO PAYLOAD CAPABILITIES
2 SHUTTLE LAUNCHES
NO SCAVENGING



1154-056(T)

APOTV GEO PAYLOAD CAPABILITIES: TWO SHUTTLE LAUNCHES, WITH SCAVENGING

This curve shows the delivery and return payload capability of two shuttle launch APOTVs. A band of APOTV capability is shown for each of the shuttle payload capabilities considered. In each case the 1 1/2-stage space based APOTV is the best performer and the 2 stage common space based APOTV is the worst performer. The other APOTV configurations (1 1/2-stage ground based and 2-stage common ground based) fall within the bands shown.

The minimum and the typical MOTV missions described in the performance ground rules and assumptions have been spotted on the curve. As indicated by this plot the minimum mission requires two 75-K shuttle launches while the typical mission can easily be attained with two 100-K shuttle launches when external tank propellant scavenging is considered

APOTV GEO PAYLOAD CAPABILITIES 2 SHUTTLE LAUNCHES – WITH SCAVENGING

MOTV

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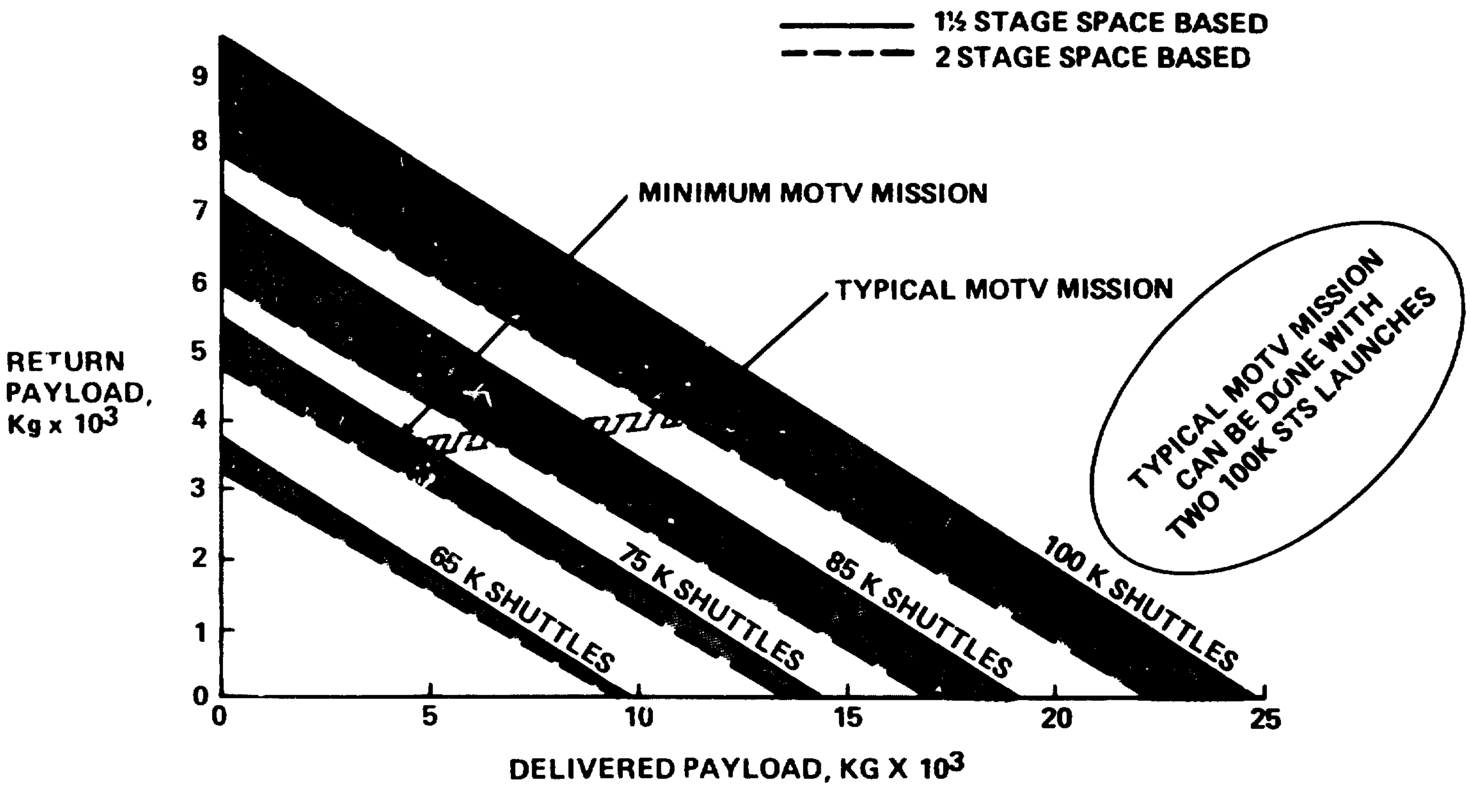

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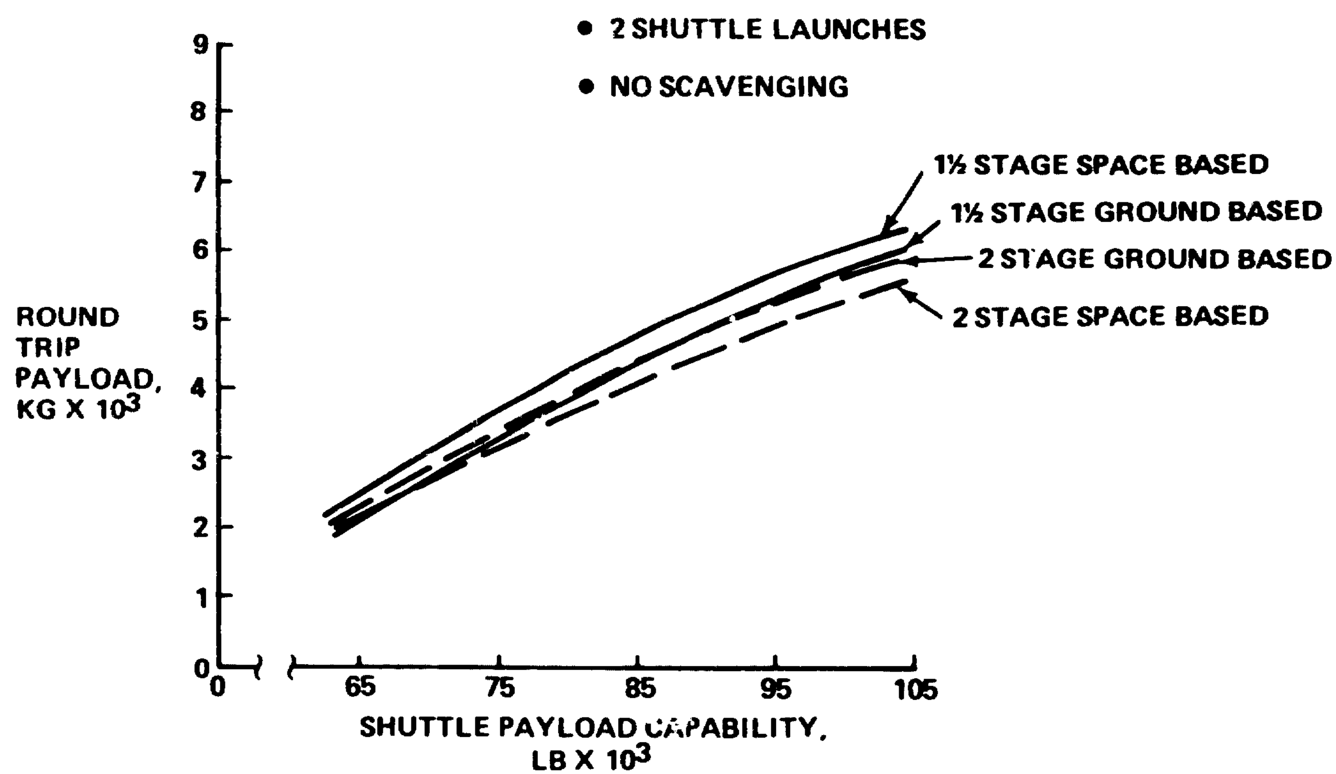
1154-057(T)

APOTV GEO ROUNDTRIP PAYLOADS VS SHUTTLE PAYLOAD CAPABILITY: TWO SHUTTLE LAUNCHES, NO SCAVENGING

This plot shows the roundtrip payload capability of the various APOTV configurations vs shuttle payload capability. All configurations fully utilize the payload capability of two shuttle launches. All configurations are constrained by the launch scenarios and shuttle manifesting previously described. The capabilities depicted on this curve are without external tank propellant scavenging.

APOTV GEO ROUND TRIP PAYLOADS VS SHUTTLE PAYLOAD CAPABILITY



1154-058(T)

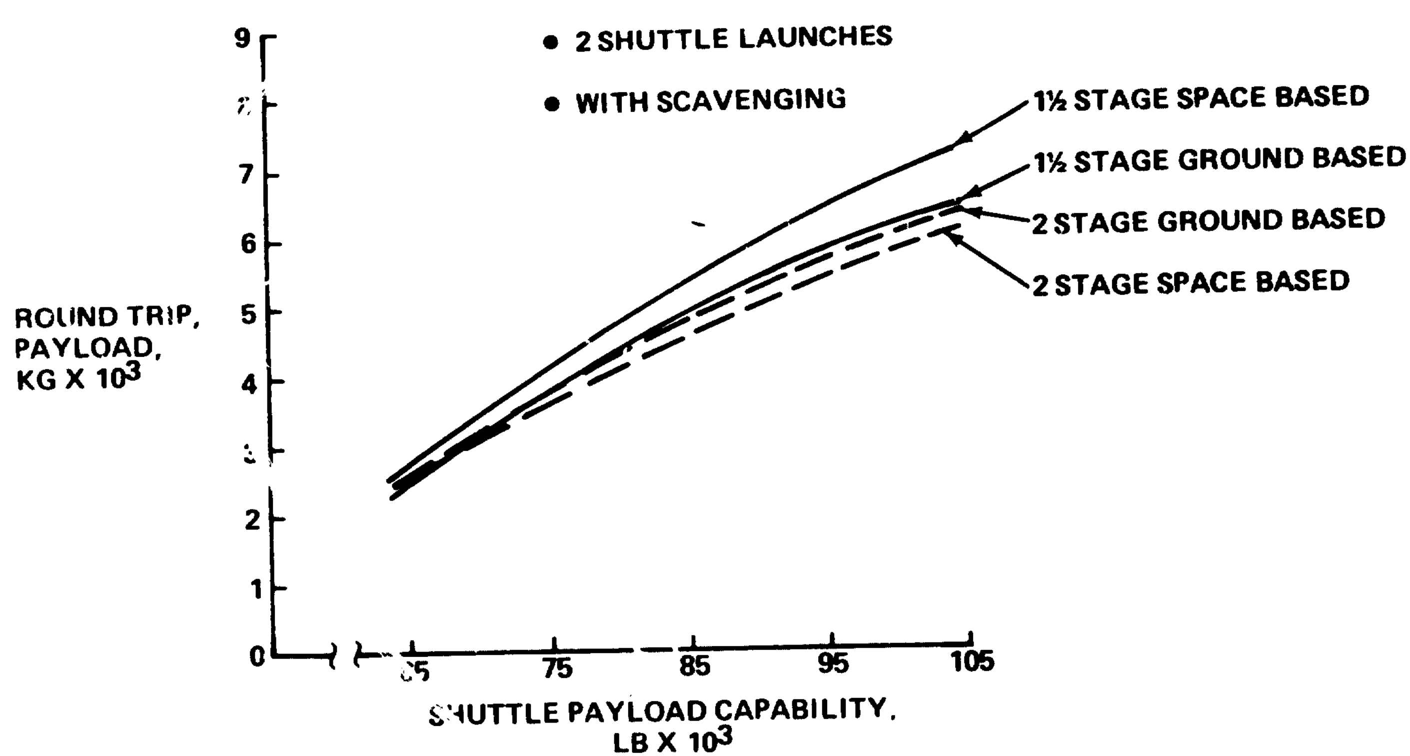
APOTV GEO ROUND TRIP PAYLOADS VS SHUTTLE PAYLOAD CAPABILITY: TWO SHUTTLE LAUNCHES, WITH SCAVENGING

This plot shows the round trip payload capability of the various APOTV configurations vs shuttle payload capability. All configurations fully utilize the payload capability of two shuttle launches and are constrained by the launch scenarios and shuttle manifesting previously described. The capabilities depicted on this curve are with external tank propellant scavenging.

MOTV

APOTV GEO ROUNDTRIP PAYLOADS VS SHUTTLE PAYLOAD CAPABILITY

GRUMMAN



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1154-059(T)

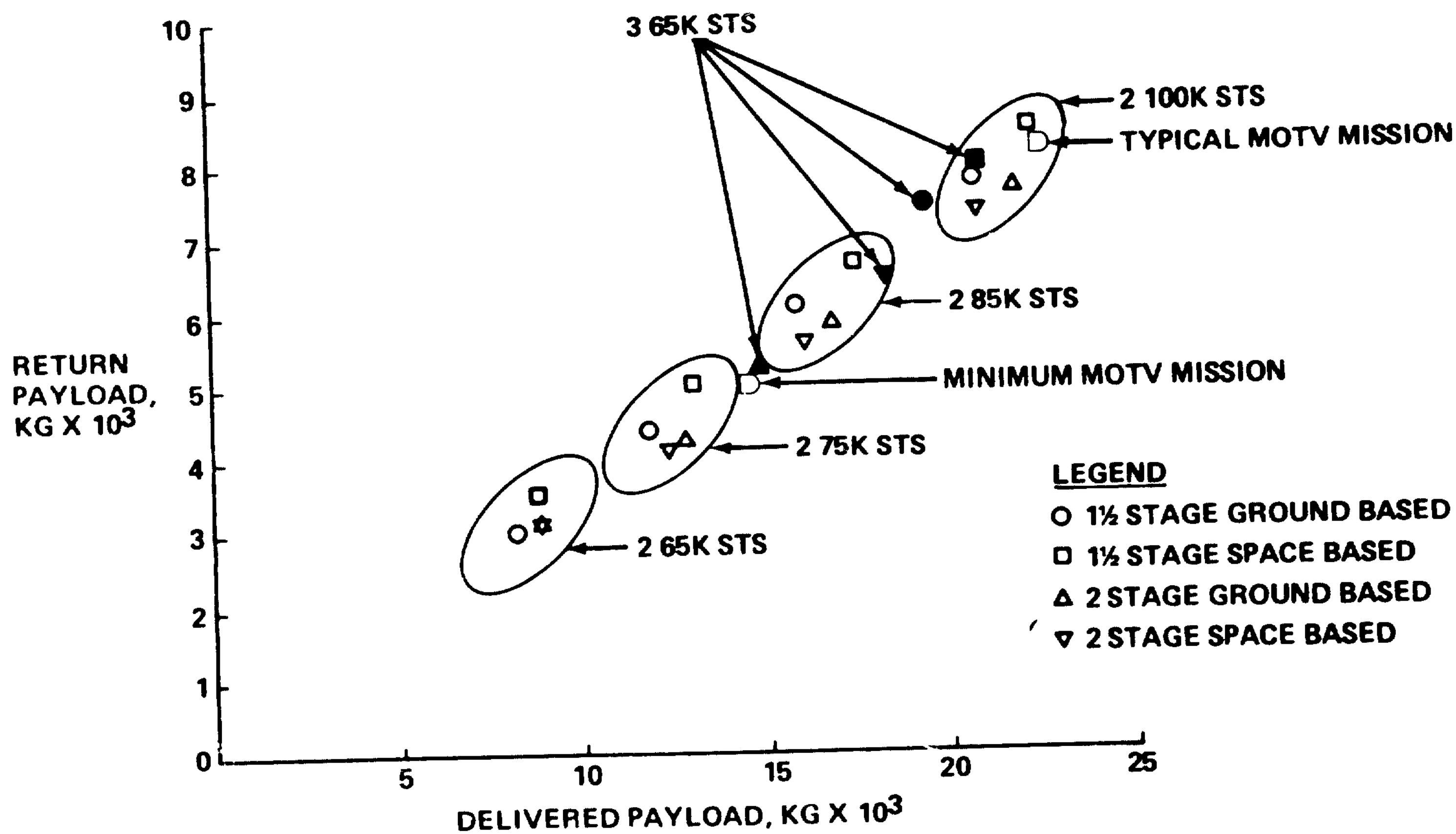
APOTV GEO PAYLOAD CAPABILITIES: NO SCAVENGING

This plot shows the return and delivery payload capabilities of the two shuttle launch and three shuttle launch APOTVs. The minimum and the typical MOTV mission described in the performance ground rules and assumptions are also shown as measures of performance.

The 1 1/2-stage space based APOTV is consistently the best performer. Its performance with three 65-K shuttle launches and two 100-K shuttle launches are roughly comparable.

The capabilities shown on this plot are without external tank propellant scavenging.

APOTV GEO PAYLOAD CAPABILITIES NO SCAVENGING



1154-061(T)

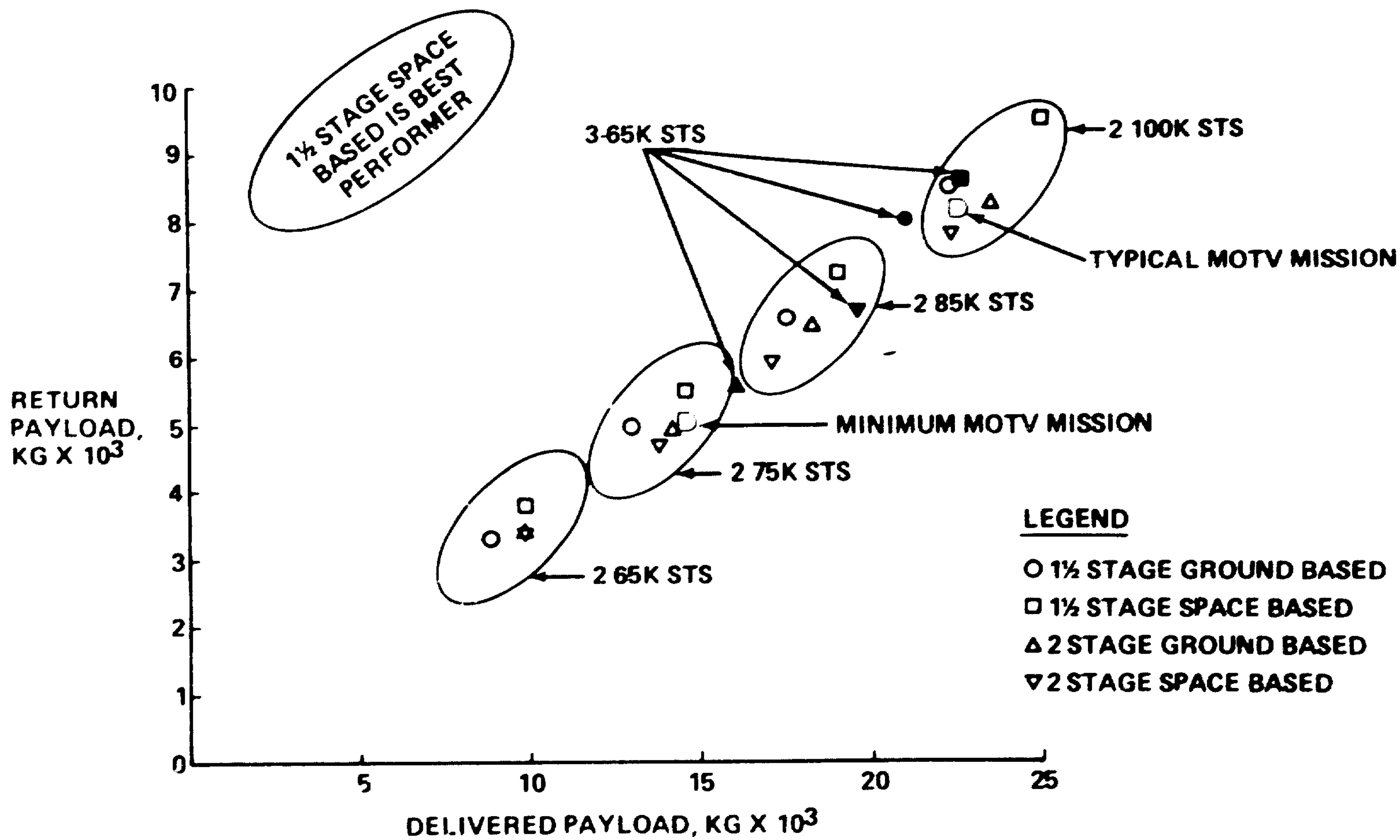
APOTV GEO PAYLOAD CAPABILITIES: WITH SCAVENGING

This plot shows the return and delivery payload capabilities of the two shuttle launch and three shuttle launch APOTVs. The minimum and the typical MOTV missions described in the performance ground rules and assumptions are also shown as measures of performance.

The 1 1/2-stage space based APOTV is consistently the best performer. Its performance with three 65-K shuttle launches and two 100-K shuttle launches are roughly comparable.

The capabilities shown on this plot are with external tank propellant scavenging.

APOTV GEO PAYLOAD CAPABILITIES WITH SCAVENGING



1151-0F01(T)

2-STAGE COMMON APOTV GEO PAYLOAD CAPABILITY: PERFORMANCE WITH ZERO PROPELLANT TRANSFER LOSSES

The fact that the 2-launch ground-based 2-stage common APOTV outperforms the space-based version is due to the propellant transfer losses. To determine the magnitude of the effect the transfer losses have on the APOTV payload capability, we calculated the performance assuming zero propellant transfer loss. The results of these calculations are tabulated here, along with the payload capabilities for the space based APOTV with 10% transfer losses and the ground-based APOTV.

It is apparent that if the transfer losses could be reduced to zero, the space-based 2-stage APOTV does outperform the ground-based vehicle.

MOTV

2 STAGE COMMON APOTV GEO PAYLOAD CAPABILITY – PERFORMANCE WITH ZERO PROPELLANT TRANSFER LOSS

GRUMMAN

	PAYLOAD DELIVERED, KG			PAYLOAD RETURNED, KG		
	SPACE BASED		GROUND BASED	SPACE BASED		GROUND BASED
	10% LOSSES	0 LOSSES		10% LOSSES	0 LOSSES	
3-65K SHUTTLES	18,353	20,445	14,823	6,434	7,185	5,209
3-65K SHUTTLES WITH SCAVENGING	19,257	21,538	16,000	6,751	7,570	5,589
2-65K SHUTTLES	8,905	10.631	8,910	3,115	3,692	3,115
2-65K SHUTTLES WITH SCAVENGING	9,744	11,652	9,819	3,379	4,053	3,403
2-75K SHUTTLES	12,461	14,505	12,852	4,312	5,065	4,478
2-75K SHUTTLES WITH SCAVENGING	13,651	15,735	14,101	4,764	5,480	4,923
2-85K SHUTTLES	16,123	18,359	16,780	5,646	6,438	5,882
2-85K SHUTTLES WITH SCAVENGING	17,038	19,939	18,240	5,973	7,000	6,400
2-100K SHUTTLES	20,762	24,020	21,752	7.294	8,460	7,645
2-100K SHUTTLES WITH SCAVENGING	22,348	25,672	23,434	7,861	9,048	8,247

1154-121(T)

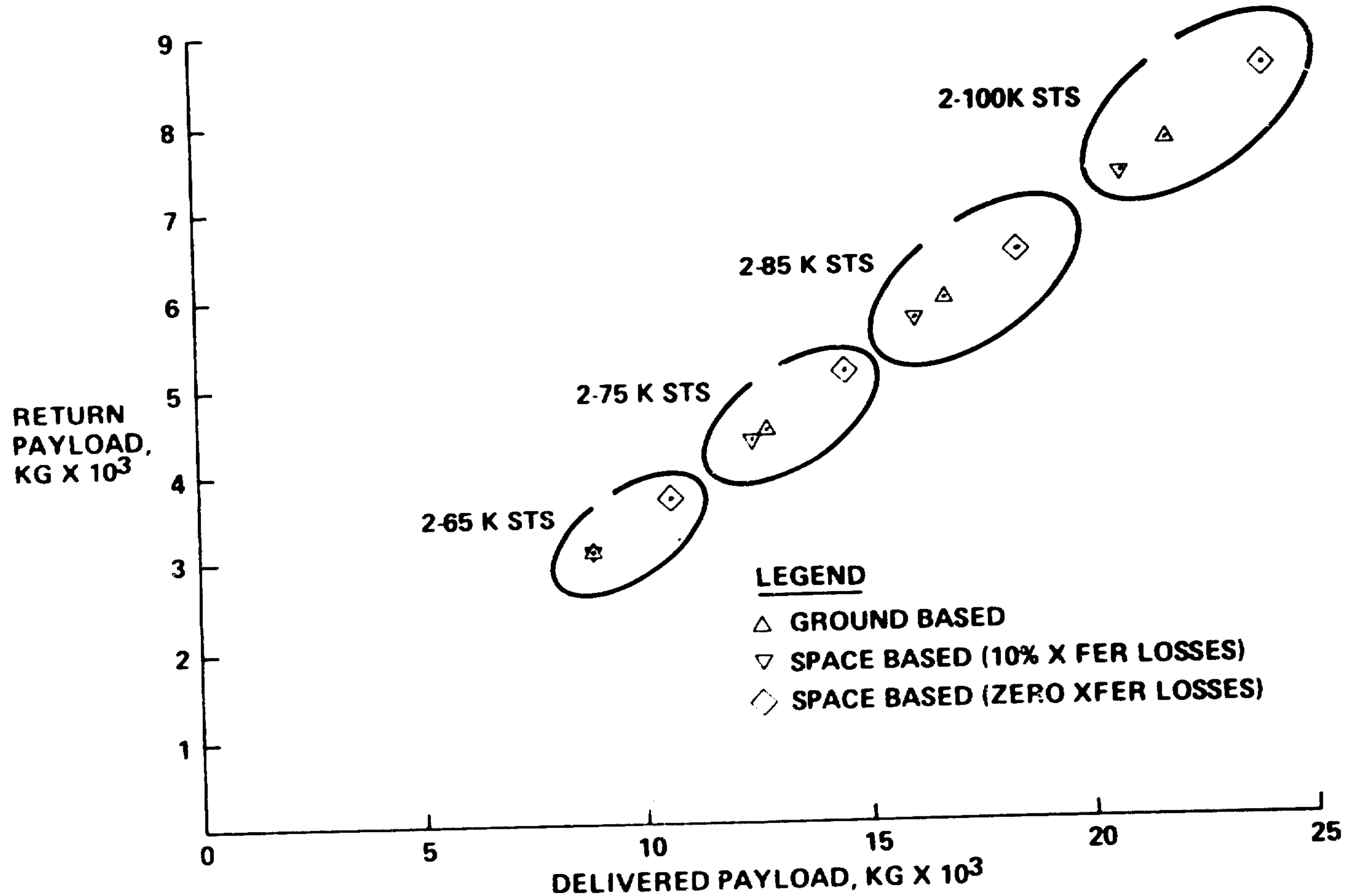
2-STAGE COMMON APOTV GEO PAYLAOD CAPABILITY: IMPACT OF PROPELLANT TRANSFER LOSSES

The payload capability of the ground-based and space-based (with 10% propellant transfer losses) 2-stage common APOTV have been plotted. Also plotted is the space-based APOTV payload capability if the propellant transfer losses were zero. The change in performance of the space-based APOTV is appreciable and leads us to question if there is a better way to provide the APOTV propellant.

MOTV

2 STAGE COMMON APOTV GEO PAYLOAD CAPABILITY – IMPACT OF PROPELLANT TRANSFER LOSSES

GRUMMAN



1154-111(T)

2-STAGE COMMON APOTV GEO PAYLOAD CAPABILITY: PERFORMANCE WITH PLUG IN TANKS

The tremendous performance loss because of propellant transfer losses prompted us to examine the use of plug-in tanks for the 2-stage common-space-based-APOTV.

A weight assessment was charged against each of the common stages, the shuttle manifesting was revised to reflect plug-in rather than transfer tanks, and the performance was calculated. The results are tabulated in the chart on the opposite page.

Performance improvement over the vehicle with 10% propellant transfer losses can be seen, and the space-based vehicle outperforms the ground-based vehicle.

MOTV

2 STAGE COMMON APOTV GEO PAYLOAD CAPABILITY — PERFORMANCE WITH PLUG-IN TANKS

GRUMMAN

	PAYLOAD DELIVERED, KG			PAYLOAD RETURNED, KG		
	SPACE BASED		GROUND BASED	SPACE BASED		GROUND BASED
	10% XFER LOSSES	PLUG-IN TANKS		10% TRANSFER LOSSES	PLUG-IN TANKS	
2-65K SHUTTLES	8,905	9,146	8,910	3,115	3,163	3,115
2-65K SHUTTLES WITH SCAVENGING	9,744	10,678	9,819	3,379	3,536	3,403
2-75K SHUTTLES	12,461	13,356	12,852	4,312	4,646	4,478
2-75K SHUTTLES WITH SCAVENGING	13,651	14,487	14,101	4,764	5.049	4,923
2-85K SHUTTLES	16,123	17,229	16,780	5,646	6,027	5,882
2-85K SHUTTLES WITH SCAVENGING	17,038	18,731	18,240	5,973	6,559	6.400
2-100K SHUTTLES	20,762	22,555	21,752	7,294	7,922	7,645
2-100K SHUTTLES WITH SCAVENGING	22,348	24,059	23,434	7,861	8,457	8,247

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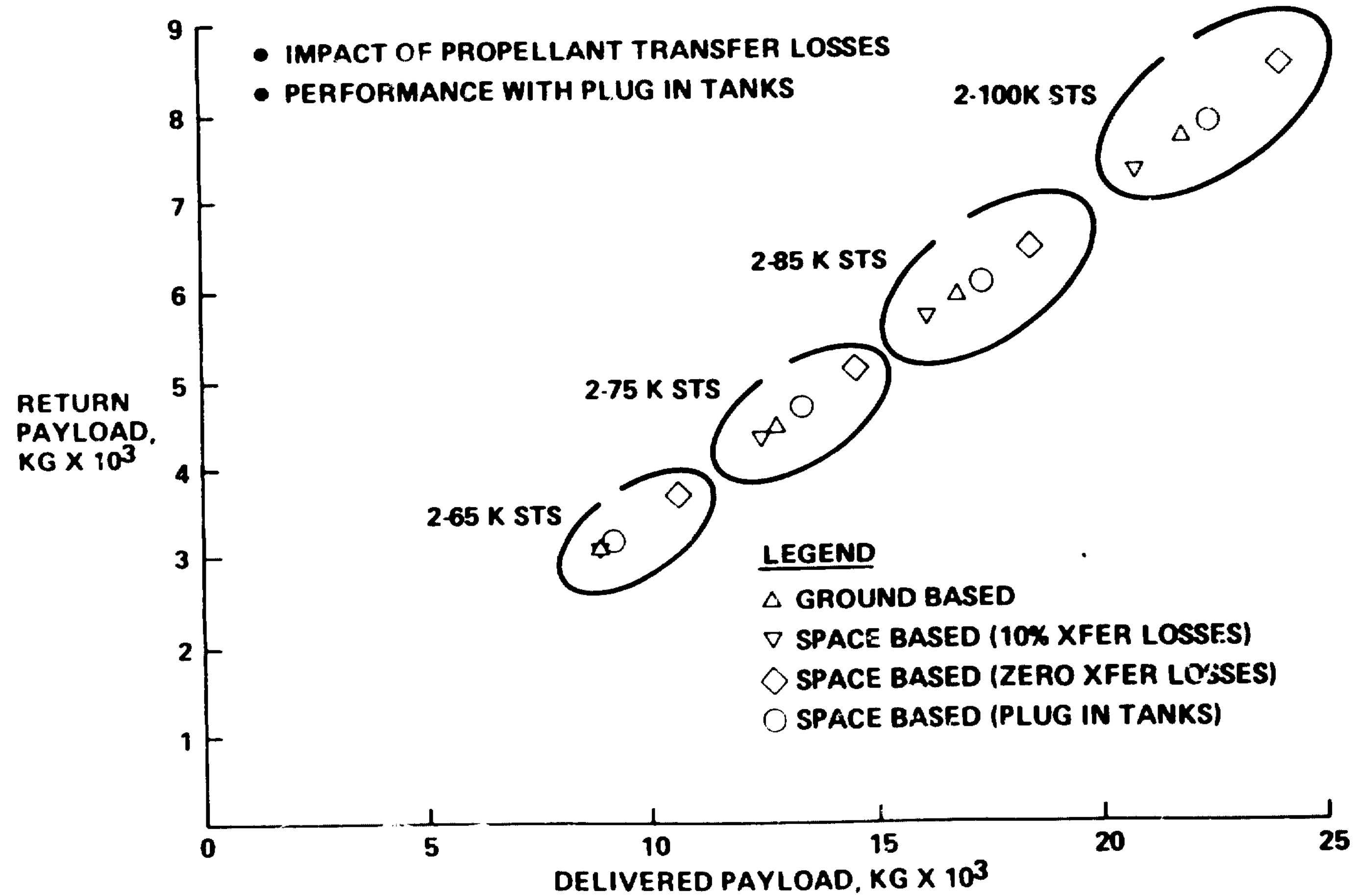
1154-120(T)

2-STAGE COMMON APOTV GEO PAYLOAD CAPABILITY: PERFORMANCE WITH PLUG IN TANKS

This plot shows the performance improvement when plug in tanks are used. As can be seen, this increase in performance is not as dramatic as the zero-transfer-loss case, but the probability of achieving it is far greater. With plug-in tanks, the space based APOTV outperforms the ground based vehicle.

2 STAGE COMMON APOTV GEO PAYLOAD CAPABILITY



1154-112(T)

MOTV

PERFORMANCE CONCLUSIONS

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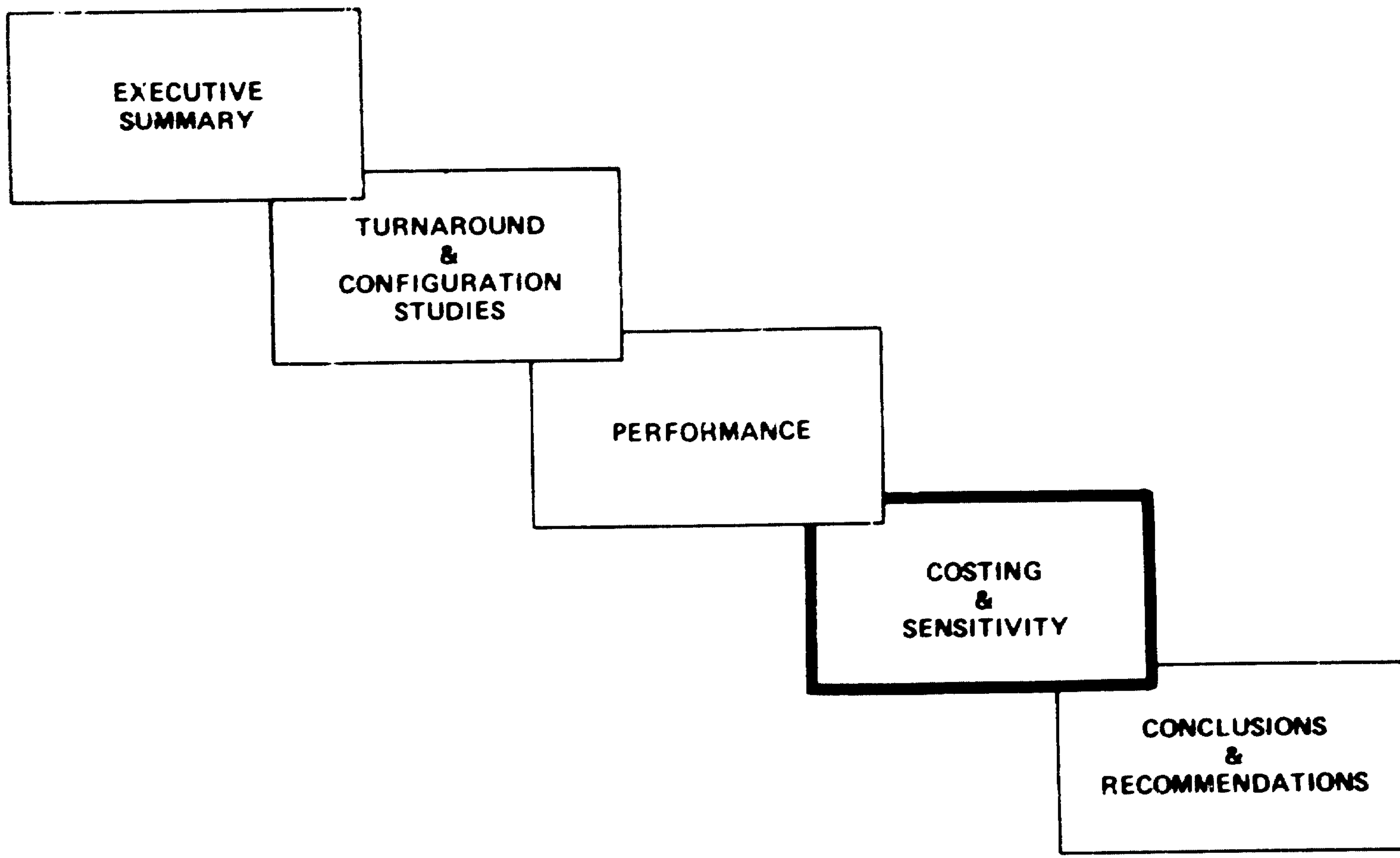
- 3-65K SHUTTLES & 2-100K SHUTTLES YIELD SIMILAR APOTV/MOTV CAPABILITIES
- 2 STAGE SPACE BASED SUFFERS PERFORMANCE DEGRADATION DUE TO PROPELLANT TRANSFER LOSSES (CONSIDER PLUG-IN TANKS)
- PROPELLANT SCAVENGING ADVANTAGEOUS IN ALL CASES
- 1½ STAGE SPACE BASED IS BEST OVERALL PERFORMER
- STS MANIFESTING A PRIME DRIVER OF OTV PERFORMANCE
- 2-75K SHUTTLE LAUNCHES REQUIRED TO SATISFY MINIMUM MOTV MISSION
- 3-65K SHUTTLE OR 2-100K SHUTTLE LAUNCHES REQUIRED TO SATISFY TYPICAL MOTV MISSION

1154-062(T)


EXECUTIVE SUMMARY
TURNAROUND & CONFIGURATION STUDIES
PERFORMANCE
COSTING & SENSITIVITY
CONCLUSIONS & RECOMMENDATIONS

MOTV COSTING CONTENTS

GRUMMAN

- GROUND RULES & ASSUMPTIONS
  - OBJECTIVE
  - COSTING ASSUMPTIONS
  - GROWTH SHUTTLES
- MOTV COST WORK SHEETS
- OTV GROSS GEO PAYLOAD COSTS VS SHUTTLE PAYLOAD CAPABILITY
- MOTV NET GEO PAYLOAD COSTS VS SHUTTLE PAYLOAD CAPABILITY
- MOTV NET GEO PAYLOAD COSTS VS DELIVERED GEO PAYLOAD
  - 3-65K SHUTTLES
  - 2-85K SHUTTLES
  - 2-100K SHUTTLES
- OPTION 1 & 2 SPACEPORT COSTS
- SPACEPORT PAYBACK
- EXTERNAL TANK SCAVENGING COST SAVINGS VS GEO PAYLOAD
- 100K SHUTTLE COST SAVINGS VS GEO PAYLOAD
- CONCLUSIONS

MOTV COSTING OBJECTIVES

GRUMMAN

- DETERMINE POSSIBLE COST BENEFITS OF SPACE BASED OVER GROUND BASED MOTV
- DETERMINE COST ADVANTAGE OF EXTERNAL TANK PROPELLANT SCAVENGING
- DETERMINE POSSIBLE COST BENEFITS OF LAUNCHING ON GROWTH SHUTTLES VS 3-65K SHUTTLES

1154-003(T)

MOTV COSTING GROUNDRULES & ASSUMPTIONS

- DDT&E COSTS OF 1½ STAGE & 2 STAGE = $700M
- STS LAUNCH COSTS CALCULATED @ $33M/STS & @ $61M/STS
- STS RETURN FLIGHT COSTS = $3.2M/FLIGHT (REF: JSC)
- MOTV COSTS BASED ON NET GEO PAYLOAD DELIVERED (PAYLOAD DELIVERY CAPABILITY OVER & ABOVE THE DELIVERY & RETURN OF A MINIMUM 3100 KG CREW CAPSULE)
- EVALUATE 3-65K SHUTTLE FLIGHT MOTV's AND 2 GROWTH SHUTTLE FLIGHT MOTV's
- CPF FOR GROWTH STS's SAME AS STANDARD STS

1154-004(T)

MOTV ASSOCIATED COSTS AT $33M PER SHUTTLE

This chart shows APOTV costing worksheet upon which the costing trades are based. The upper portion shows the cost factors that were used and how they were applied to the various APOTVs considered. Two cost totals were obtained one with and one without the MOTV crew capsule.

OTV gross GEO payload delivery capability was divided by the total cost without crew capsule to arrive at $/kg costs for APOTV GEO delivery only payload.

The more important parameter for this MOTV study is the delivery cost of the net GEO payload (the payload that can be delivered over and above the delivery and return of an MOTV capsule). This value was obtained by dividing the total cost by the net payload.

A similar exercise (although not included herein) was performed for the configurations shown with external tank propellant scavenging.

The calculations included here were based on $33M per shuttle launch.

MOTV ASSOCIATED COSTS @ $33M PER SHUTTLE

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	COST PER FLT, $M	3-65K SHUTTLES				2 SHUTTLE LAUNCHES															
						65K SHUTTLE				75K SHUTTLE				85K SHUTTLE				100K SHUTTLE			
		1½ G.B.	1½ S.B.	2 G.B.	2 S.B.	1½ G.B.	1½ S.B.	2 G.B.	2 S.B.	1½ G.B.	1½ S.B.	2 G.B.	2 S.B.	1½ G.B.	1½ S.B.	2 G.B.	2 S.B.	1½ G.B.	1½ S.B.	2 G.B.	2 S.B.
1½ PROP STAGE	1.87	1.87				1.87				1.87				1.87				1.87			
2 PROP STAGE	1.87			3.74	3.74			3.74	3.74			3.74	3.74			3.74	3.74			3.74	3.74
DROP TANK	2.19	4.38	6.57			2.19	4.38			2.19	4.38			2.19	[illegible]			2.19	4.38		
ASSY ON ORBIT	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29
XFER TANK	.22				.66				.44				.44				.44				.44
CREW CAPSULE	7.40	7.40	7.40	7.40	7.40	7.40	7.40	7.40	7.40	7.40	7.40	7.40	7.40	7.40	7.40	7.40	7.40	7.40	7.40	7.40	7.40
ZERO STAGE	1.50		1.50				1.50				1.50				1.50				1.50		
STS LAUNCH	33.00	99.00	99.00	82.50	99.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00
STS RETRIEVAL	3.20	3.20		6.40	3.60	3.20		6.40	6.40	3.20		6.40	6.40	3.20		6.40	6.40	3.20		6.40	6.40
TOTAL COST		117.14	115.76	101.33	121.69	81.95	80.57	84.83	85.27	81.95	80.57	84.83	85.27	81.95	80.57	84.83	85.27	81.95	80.57	84.83	85.27
COST LESS CAPSULE		109.74	108.36	93.93	114.29	74.55	73.17	77.43	77.87	74.55	73.17	77.43	77.87	74.55	73.17	77.43	77.87	74.55	73.17	77.43	77.87
DELIVERY ONLY PAYLOAD, KG		19,397	20,894	14,823	18,353	7763	8844	8910	8905	11,816	13,014	12,852	12,461	15,873	17,447	16,780	16,123	20,912	22,108	21,752	20,762
$M/MT (W/O CAPSULE)		5.658	5.186	6.337	6.227	9.603	8.273	8.690	8.745	6.309	5.622	6.025	6.249	4.697	4.194	4.614	4.830	3.565	3.310	3.560	3.751
DELIVERY PL/OVER DEL (NET OF 3100 Kg CAPSULE)		8181	9678	2900	6409			-		600	1798	855	402	4657	6231	4836	4169	9696	10,892	9833	8839
$M/MT		14.319	11.961	34.341	18.987	-	-	-		136.583	44.811	99.216	212.114	17.597	12.931	17.541	20.453	8.452	7.397	8.627	9.647

1154-006(T)

MOTV ASSOCIATED COSTS AT $61M PER SHUTTLE

This chart shows APOTV costing worksheet upon which the costing trades are based. The upper portion shows the cost factors that were used and how they were applied to the various APOTVs considered. Two cost totals were obtained one with and one without the MOTV crew capsule.

OTV gross GEO payload delivery capability was divided by the total cost without crew capsule to arrive at $/kg costs for APOTV GEO delivery only payload.

The more important parameter for this MOTV study is the delivery cost of the net GEO payload (the payload that can be delivered over the delivery and return of an MOTV capsule). This value was obtained by dividing the total cost by the net payload.

A similar exercise (although not included herein) was performed for the configurations shown with external tank propellant scavenging.

The calculations included here were based on $61M per shuttle launch.

MOTV ASSOCIATED COSTS @ $61M PER SHUTTLE

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	FLT. $M	3-65K SHUTTLES				2 SHUTTLE LAUNCHES															
						65K SHUTTLE				75K SHUTTLE				85K SHUTTLE				100K SHUTTLE			
		1½ G.B.	1½ S.B.	2 G.B.	2 S.B.	1½ G.B.	1½ S.B.	2 G.B.	2 S.B.	1½ G.B.	1½ S.B.	2 G.B.	2 S.B.	1½ G.B.	1½ S.B.	2 G.B.	2 S.B.	1½ G.B.	1½ S.B.	2 G.B.	2 S.B.
1½ PROP STAGE	1.87	1.87				1.87				1.87				1.87				1.87			
2 PROP STAGE	1.87			3.74	3.74			3.74	3.74			3.74	3.74			3.74	3.74			3.74	3.74
DROP TANK	2.19	4.38	6.57			2.19	4.38			2.19	4.38			2.19	4.38			2.19	4.38		
ASSY ON ORBIT	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29
XFER TANK	.22				.66				.44				.44				.44				.44
CREW CAPSULE	7.40	7.40	7.40	7.40	7.40	7.40	7.40	7.40	7.40	7.40	7.40	7.40	7.40	7.40	7.40	7.40	7.40	7.40	7.40	7.40	7.40
ZERO STAGE	1.50		1.50				1.50				1.50				1.50				1.50		
STS LAUNCH	61.00	183.00	183.00	152.50	183.00	122.0	122.0	122.0	122.0	122.0	122.0	122.0	122.0	122.0	122.0	122.0	122.0	122.0	122.0	122.0	122.0
STS RETRIEVAL	3.20	3.20		6.40	9.60	3.20		6.40	6.40	3.20	6.40	6.40	3.20		6.20	6.40	3.20			6.40	6.40
TOTAL COST		201.14	199.76	171.94	205.69	137.95	136.57	140.83	141.27	137.95	136.57	140.83	141.27	137.95	136.57	140.83	141.27	137.95	136.57	140.83	141.27
COST LESS CAPSULE		193.74	192.36	164.36	198.29	130.55	129.17	133.43	133.87	130.55	129.17	133.43	133.87	130.55	129.17	133.43	133.87	130.55	129.17	133.43	133.87
DELIVERY ONLY PAYLOAD, KG		19,397	20,894	14,823	18,353	7763	8844	8910	8905	11,816	13,014	12,852	12,461	15,873	17,447	16,780	16,123	20,912	22,108	21,752	20,762
$M/M T (W/O CAPSULE)		9,988	9.206	11.088	10.804	16.817	14.605	14.975	15.033	11.049	9.925	10.382	10.743	8.225	7.404	7,952	8.303	6.243	5.843	6.134	6.448
DELIVERY PL (OVER DEL & RET OF 3100 Kg CAPSULE)		8181	9678	2900	6409	–	–	–	–	600	1798	855	402	4657	6231	4836	4169	9696	10,892	9933	8839
$M/M T		24.586	20.641	59.290	32.094	–	–	–	–	229.917	75.957	164.713	351.418	29.622	21.918	29.121	33.886	14.228	12.539	14.322	15.983

1154-007(T)

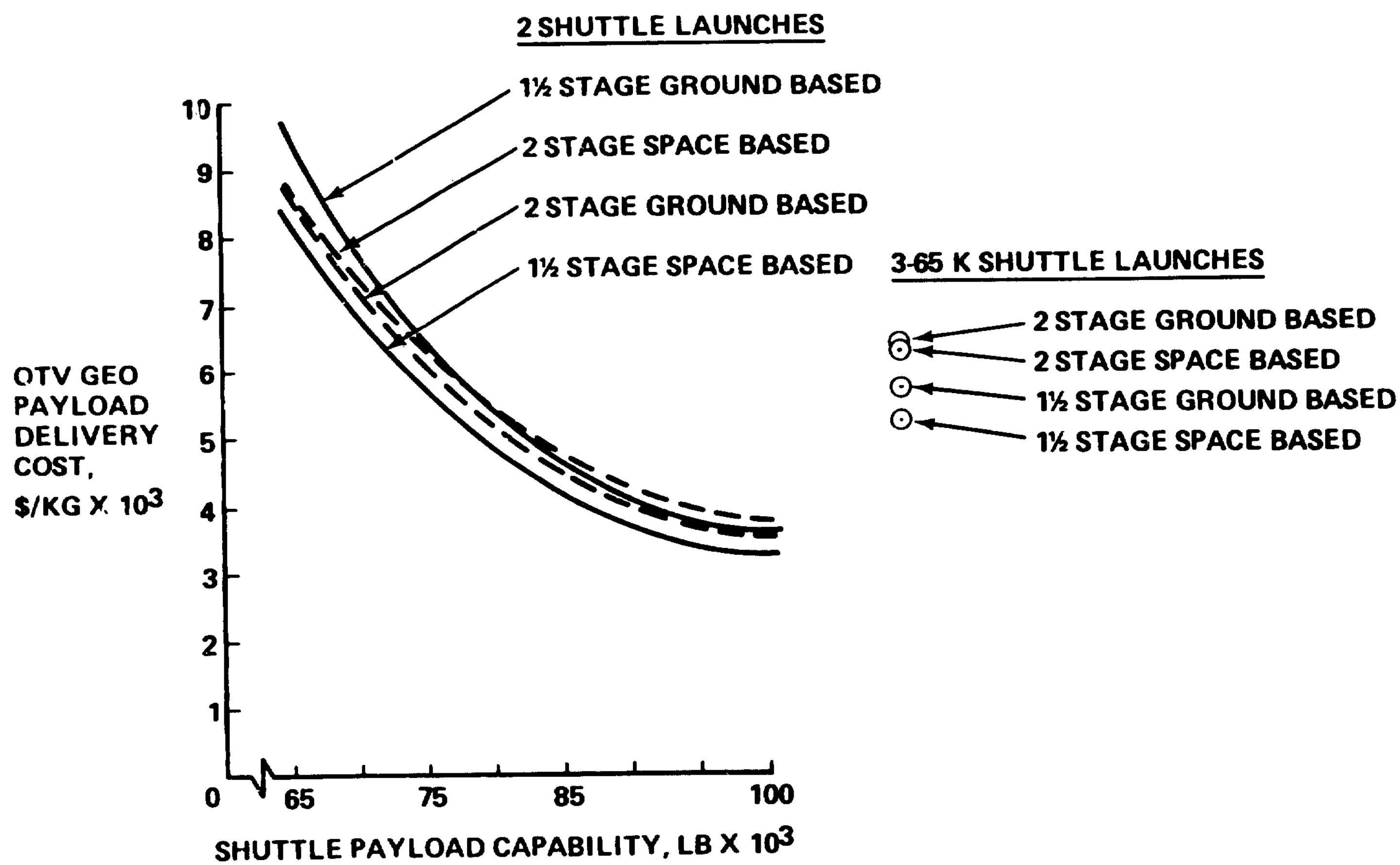
OTV GEO PAYLOAD DELIVERY COST VS SHUTTLE PAYLOAD CAPABILITY AT $33M PER SHUTTLE

This chart shows the OTV payload delivery costs for APOTVs delivering payload only. There is no MOTV crew capsule included.

The curves represent the payload delivery costs for the several APOTVs as the shuttle payload capability is increased. The costs for the same APOTVs using three 65-K shuttle launches are also shown.

These data reflect the APOTV performance and cost without external tank propellant scavenging and shuttle per launch costs of $33M.

OTV GEO PAYLOAD DELIVERY COST VS SHUTTLE PAYLOAD CAPABILITY @ $33M PER SHUTTLE



1154-009(T)

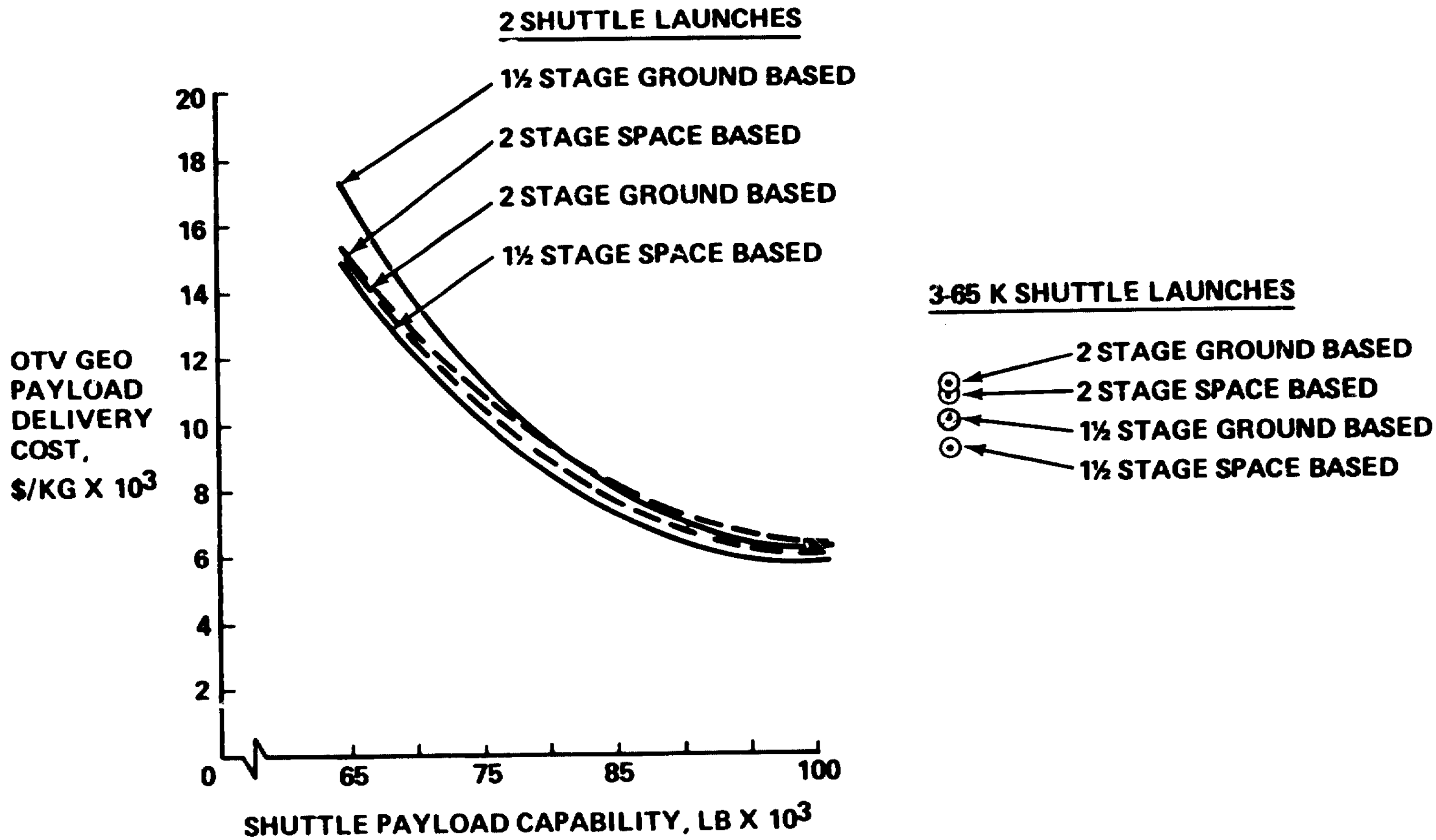
OTV GEO PAYLOAD DELIVERY COST VS SHUTTLE PAYLOAD CAPABILITY AT $61M PER SHUTTLE

This chart shows the OTV payload delivery costs for APOTVs delivering payload only. There is no MOTV crew capsule included.

The curves represent the payload delivery costs for the several APOTVs as the shuttle payload capability is increased. The costs for the same APOTVs using three 65-K shuttle launches are also shown.

These data reflect the APOTV performance and cost without external tank propellant scavenging and shuttle per launch costs of $61M.

OTV GEO PAYLOAD DELIVERY COST VS SHUTTLE PAYLOAD CAPABILITY @ $61M PER SHUTTLE



1154-006(T)

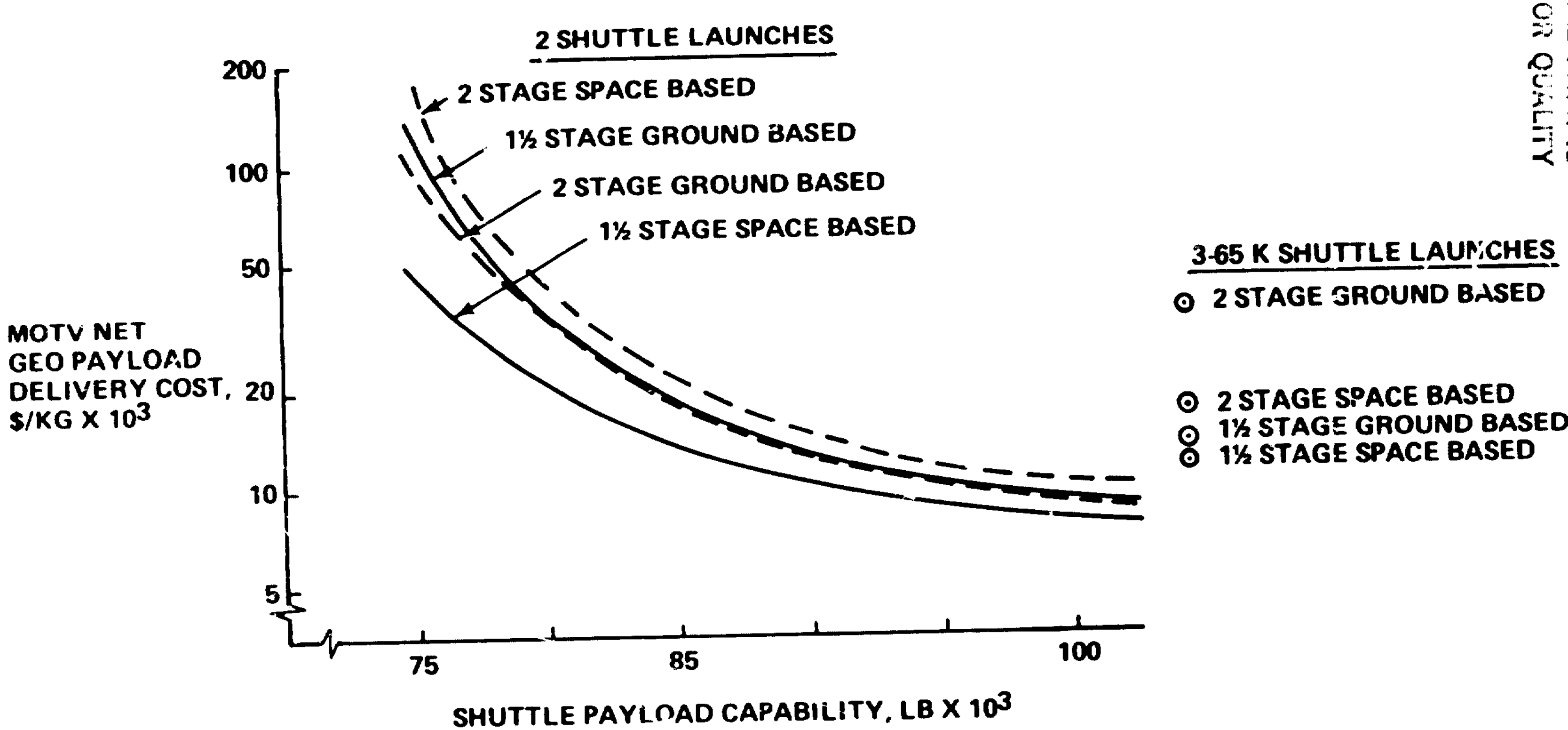
MOTV NET GEO PAYLOAD DELIVERY COST VS SHUTTLE PAYLOAD CAPABILITY: AT $33M PER SHUTTLE

This chart shows the MOTV net payload delivery costs. The cost is for delivering a Kg of payload to GEO over the delivery and return of the crew capsule.

The curves represent the costs for the several MOTVs (limited to two shuttle launches) as the shuttle payload capability is increased. The costs for the same MOTVs using three 65-K shuttle launches are also shown.

These data reflect the MOTV performance and cost without external tank propellant scavenging and shuttle per launch costs of $33M.

MOTV NET GEO PAYLOAD DELIVERY COST VS SHUTTLE PAYLOAD CAPABILITY @ $33M PER SHUTTLE



1154-010(T)

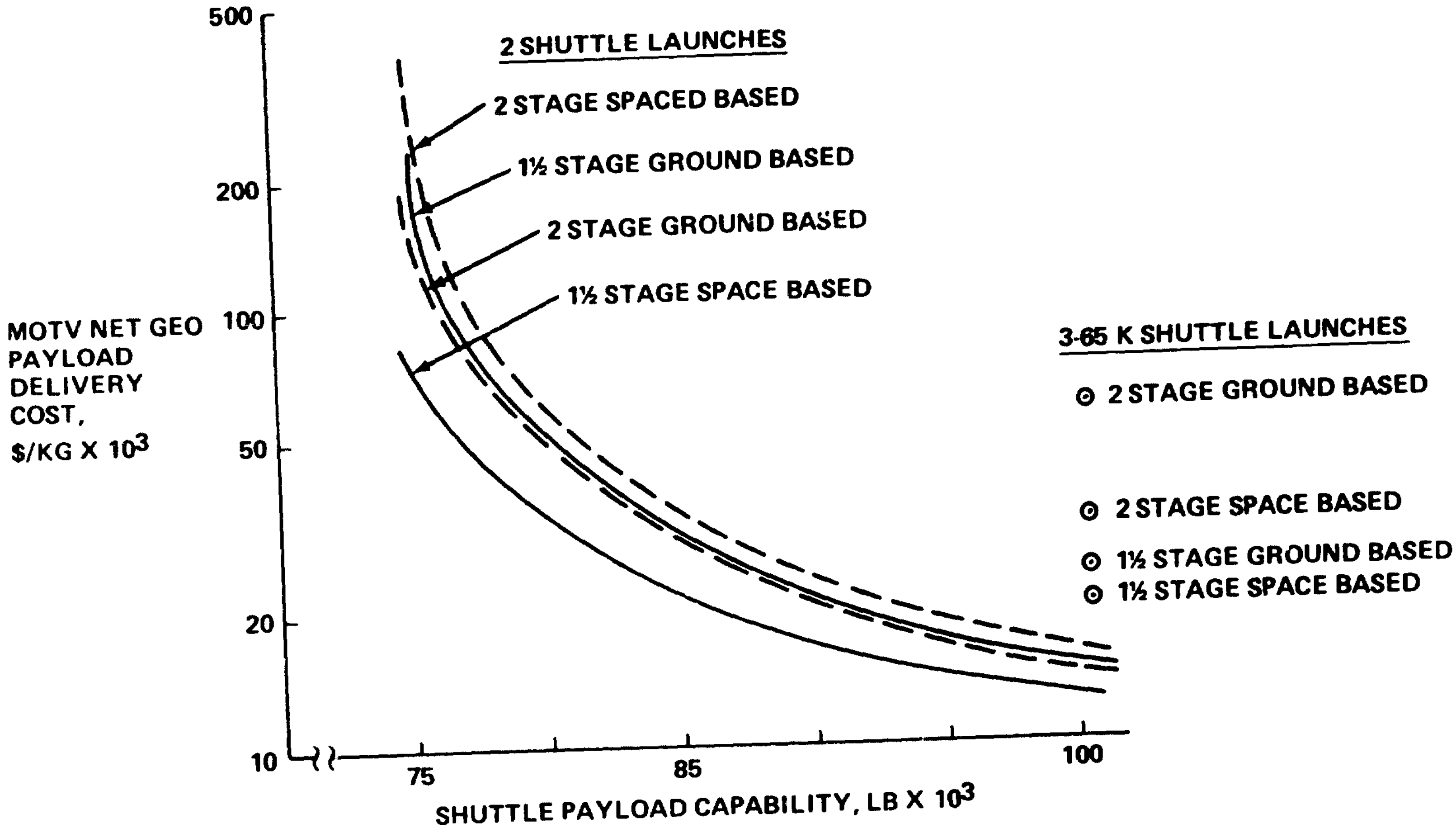
MOTV NET GEO PAYLOAD DELIVERY COST VS SHUTTLE PAYLOAD CAPABILITY: AT $61M PER SHUTTLE

This chart shows the MOTV net payload delivery costs. The cost is for delivering a Kg of payload to GEO over the delivery and return of the crew capsule.

The curves represent the costs for the several MOTVs (limited to two shuttle launches) as the shuttle payload capability is increased. The costs for the same MOTVs using three 65-K shuttle launches are also shown.

These data reflect the MOTV performance and cost without external tank propellant scavenging and shuttle per launch costs of $61M.

MOTV NET GEO PAYLOAD DELIVERY COST VS SHUTTLE PAYLOAD CAPABILITY @ $61M PER SHUTTLE



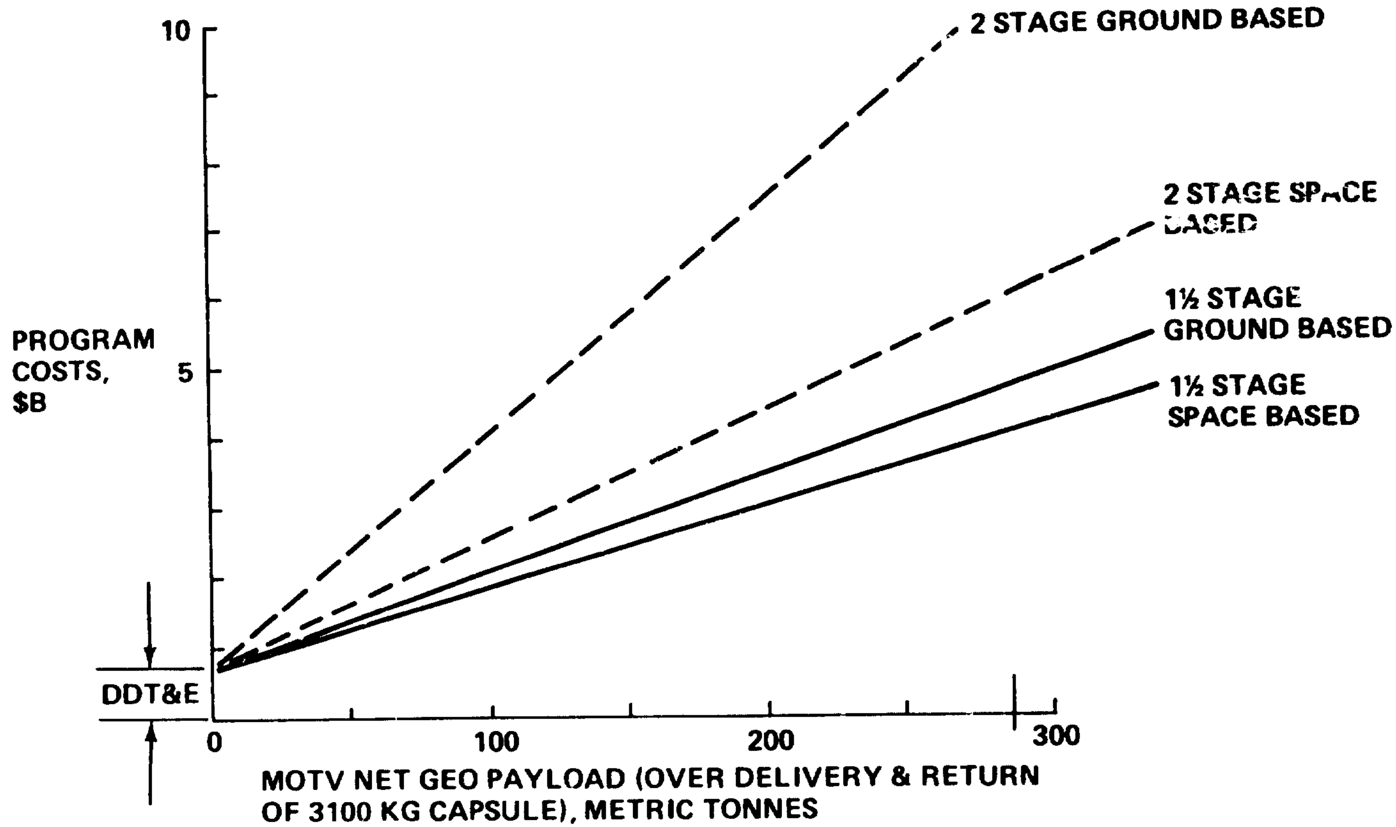
1154-011(T)

MOTV PROGRAM COSTS VS MOTV NET GEO PAYLOAD: THREE 65-K SHUTTLE LAUNCHES AT $33M/SHUTTLE

This plot shows the total program costs vs the MOTV net payload (in metric tons) for an MOTV utilizing three 65-K shuttle launches. 288 metric tons represents the net GEO payload delivered in 10 years of typical MOTV payload delivery.

These data reflect the MOTV performance and cost without external tank propellant scavenging and shuttle per launch costs of $33M.

MOTV PROGRAM COSTS VS MOTV NET GEO PAYLOAD — THREE 65K SHUTTLE LAUNCHES @ $33M/SHUTTLE



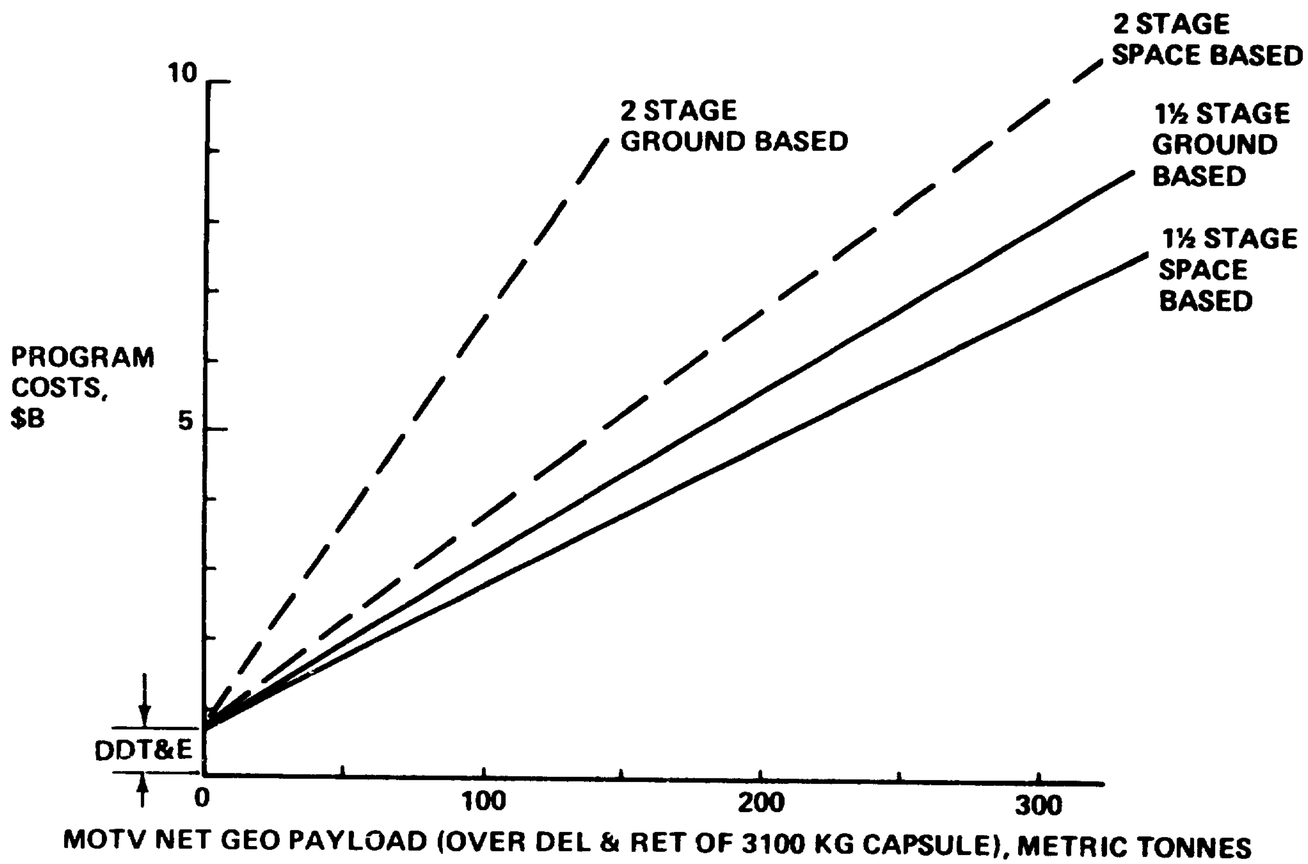
1154-012(T)

MOTV PROGRAM COSTS VS MOTV NET GEO PAYLOAD: THREE 65-K SHUTTLE LAUNCHES AT $61M/SHUTTLE

This plot shows the total program costs vs the MOTV net payload (in metric tons) for an MOTV utilizing three 65-K shuttle launches. 288 metric tons represents the net GEO payload delivered in 10 years of typical MOTV payload delivery.

These data reflect the MOTV performance and cost without external tank propellant scavenging and shuttle per launch costs of $61M.

MOTV PROGRAM COSTS VS MOTV NET GEO PAYLOAD – THREE 65K SHUTTLE LAUNCHES @ $61M/SHUTTLE



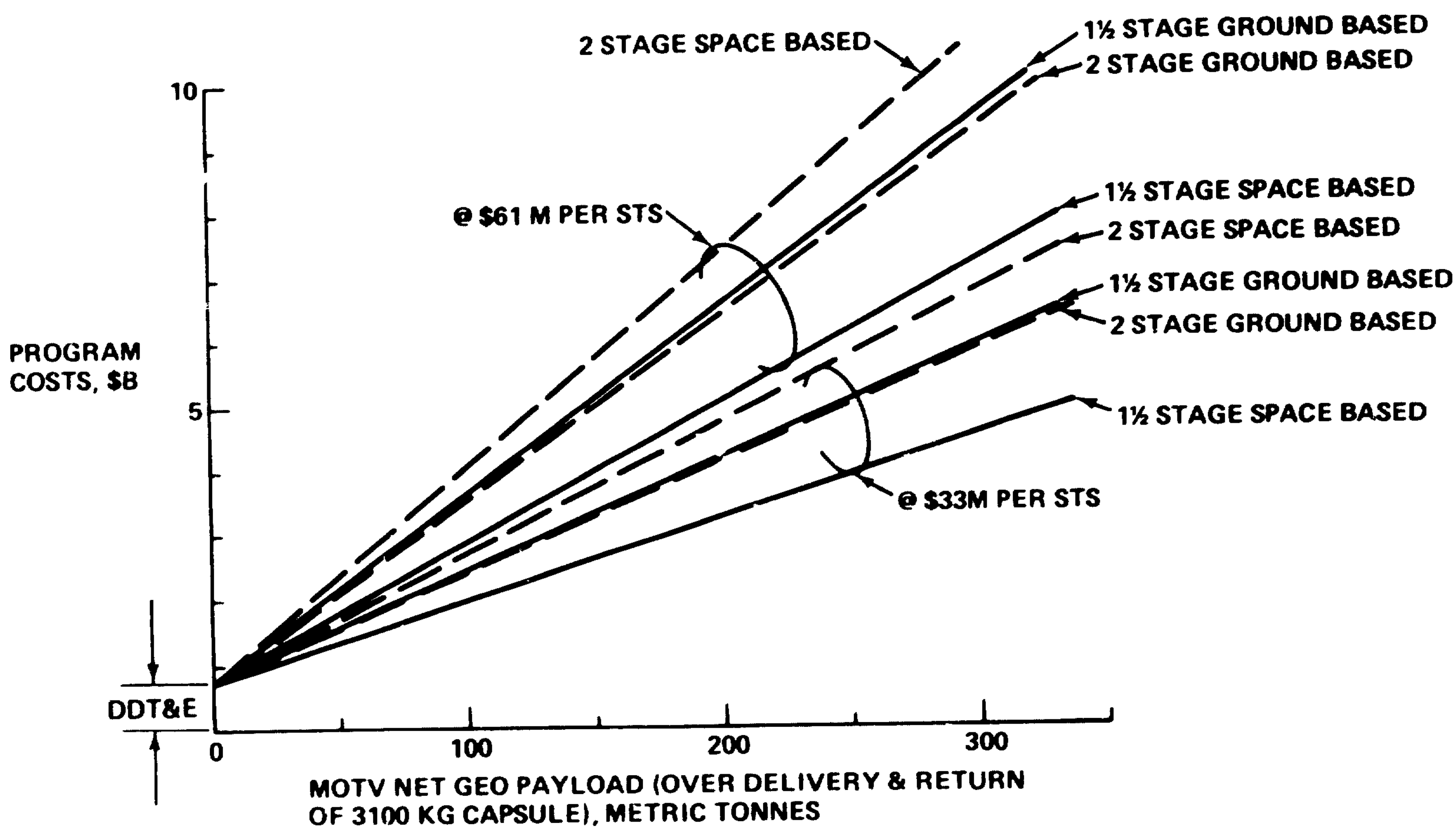
1154-013(T)

MOTV PROGRAM COSTS VS MOTV NET GEO PAYLOAD: TWO 85-K SHUTTLES

This plot shows the total program costs vs MOTV net tonnage to orbit for MOTVs using two 85-K shuttle launches. Costs for MOTVs based on shuttle per flight costs of $33M and $61M are both shown. 288 metric tons represents 10 years of typical MOTV missions.

These data reflect the MOTV performance and cost without external tank propellant scavenging.

MOTV PROGRAM COSTS VS MOTV NET GEO PAYLAOD – TWO 85K SHUTTLES



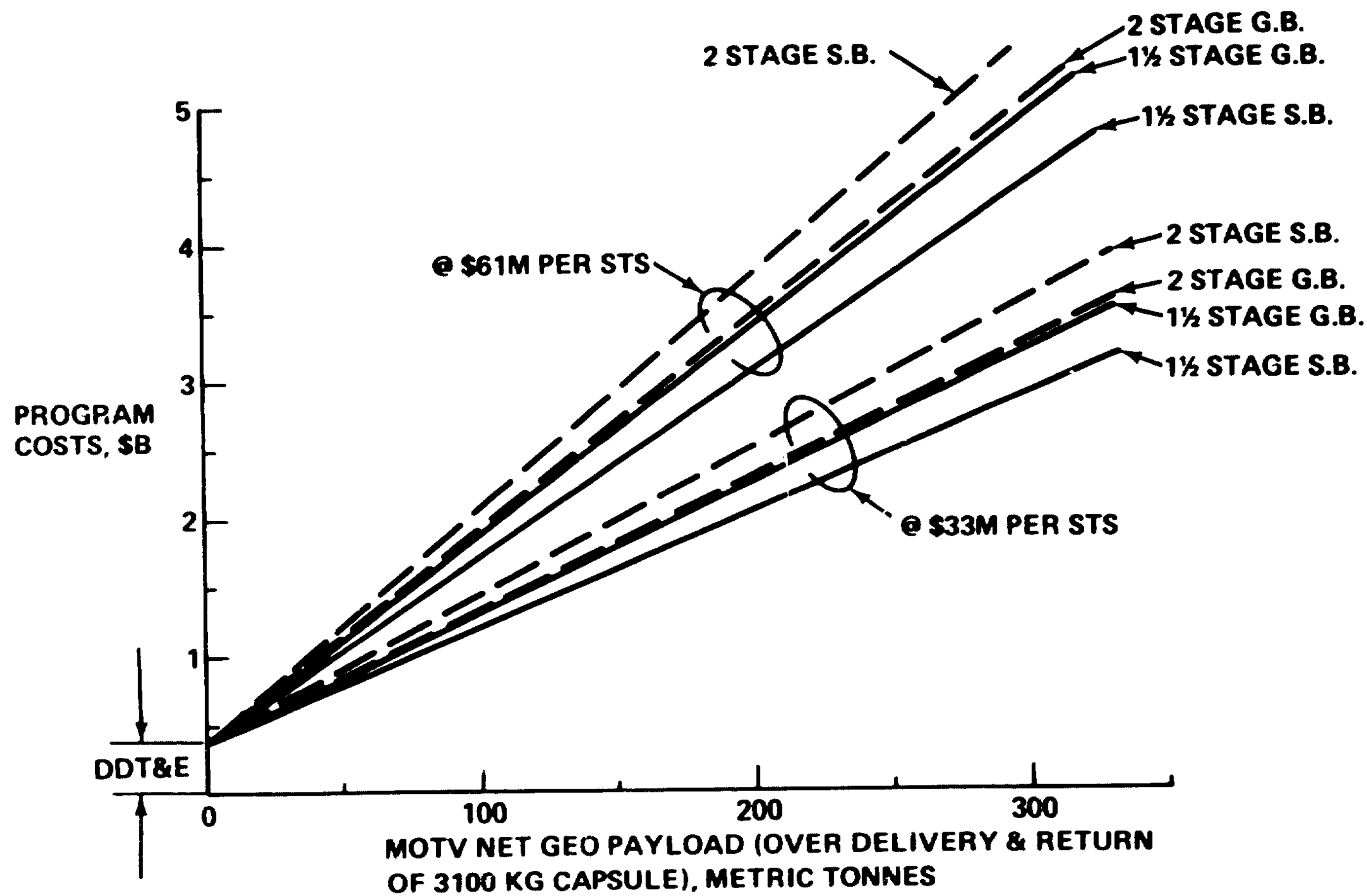
1154-014(T)

MOTV PROGRAM COSTS VS MOTV NET GEO PAYLOAD: 2-100K SHUTTLES

This plot shows the total program costs vs MOTV net tonnage to orbit for MOTVs using two 100-K shuttle launches. Costs for MOTVs based on shuttle per flight costs of $33M and $61M are both shown. 288 metric tons represents 10 years of typical MOTV missions.

These data reflect the MOTV performance and cost without external tank propellant scavenging.

MOTV PROGRAM COSTS VS MOTV NET GEO PAYLOAD – TWO 100K SHUTTLES



1154-015(T)

OPTION 1 SPACEPORT (ALL EVA) COSTS: 1982 $M

This chart presents the ROM cost estimate for the all EVA, minimum MOTV turnaround spaceport that is pictured and described in the turnaround & configuration studies portion of this report.

DDT&E and unit production costs have been totaled to arrive at the total cost of the spaceport. All monies are in 1982 dollars.

MOTV

OPTION 1 SPACEPORT (ALL EVA) COSTS, 1982 $M

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	DDT&E	PROD
STS PAYLOAD BAY SURROGATE STRUCTURE	31.41	2.88
DROP TANK SUPPORT STRUCTURE	66.09	3.66
BERTHING RINGS (2)	9.29	1.98
SPACELAB PALLET	–	3.59
SKYLAB GYROS	–	5.30
AVIONICS	27.09	24.19
FUEL CELLS	35.22	3.78
POWER DISTRIBUTION	1.85	1.15
HPA CONTROLS	–	2.37
2 ARMED HPA	–	2.05
OPEN CHERRY PICKER	–	2.79
END EFFECTOR	–	2.14
SUB TOTALS	170.95	55.88
"WRAPAROUND" (SYSTEM ENG'G, INTEGRATION, ASS'Y & CHECKOUT, INITIAL SPARES, MANAGEMENT, SYSTEM TEST & EVALUATION)	40.18	27.39
TOTALS	211.13	83.27
TOTAL DDT&E & 1 UNIT	294.40	

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1154-016(T)

OPTION 2 SPACEPORT (IVA/EVA) COSTS · 1982 $M

This chart presents the ROM cost estimate for a slightly more ambitious spaceport that utilizes a modified MOTV crew capsule as a command post and permits many tasks to be performed IVA.

The previsouly described option 1 spaceport provides the basis for this cost estimate and additional equipments are added. The total cost reflects the DD&E plus one unit's production cost. All monies are in 1982 dollars.

MOTV

OPTION 2 SPACEPORT (IVA/EVA) COSTS, 1982 $M

GRUMMAN

	DDT&E	PROD
OPTION 1 SPACEPORT (ALL EVA)	211.13	83.27
OPTION 2 SPACE PORT (IVA/EVA) DELTAS		
SURROGATE STRUCTURE DELTA	40.57	2.29
MODIFIED MOTV CREW CAPSULE	62.40	82.93
BERTHING RING TO CREW CAPSULE TUNNEL	8.88	2.22
STS RMS	—	.19
"WRAPAROUND"	26.28	42.94
SUB TOTAL OPTION 2 DELTAS	138.65	130.57
TOTAL OPTION 2	349.78	213.84
TOTAL OPTION 2 DDT&E & 1 UNIT	563.62	

SPACEPORT PAY BACK: $33M SHUTTLE

This chart plots the delta program costs between the space based and ground based 1 1/2-stage vs MOTV delivered payload tonnage. A second scale is shown representing the years anticipated to use that tonnage at the typical MOTV mission rate. The resulting cost savings curves for MOTVs using two 85-K shuttles, two 100-K shuttles, and three 65-K shuttles are shown. It should be noted that two 85-K shuttles cannot perform the typical mission.

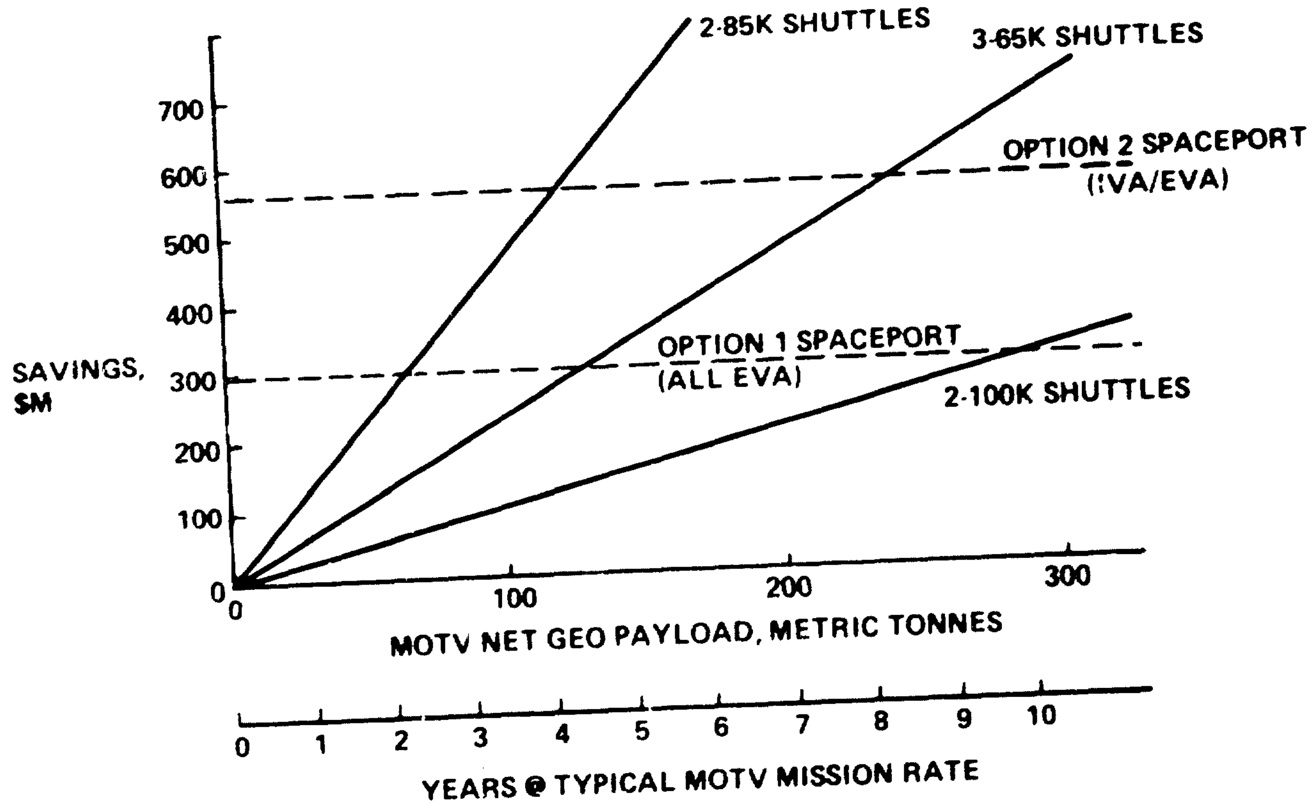
These data reflect the MOTV performance and cost without external tank propellant scavenging and shuttle costs of $33M per launch.

The time required to pay back the cost of an option 1 (All EVA) spaceport for a three 65-K shuttle MOTV is 4 1/2 years.

MOTV

SPACEPORT PAYBACK - 1½ STAGE SPACE BASED SAVINGS VS MOTV NET GEO PAYLOAD $33M SHUTTLE

GRUMMAN



1154-018(T)

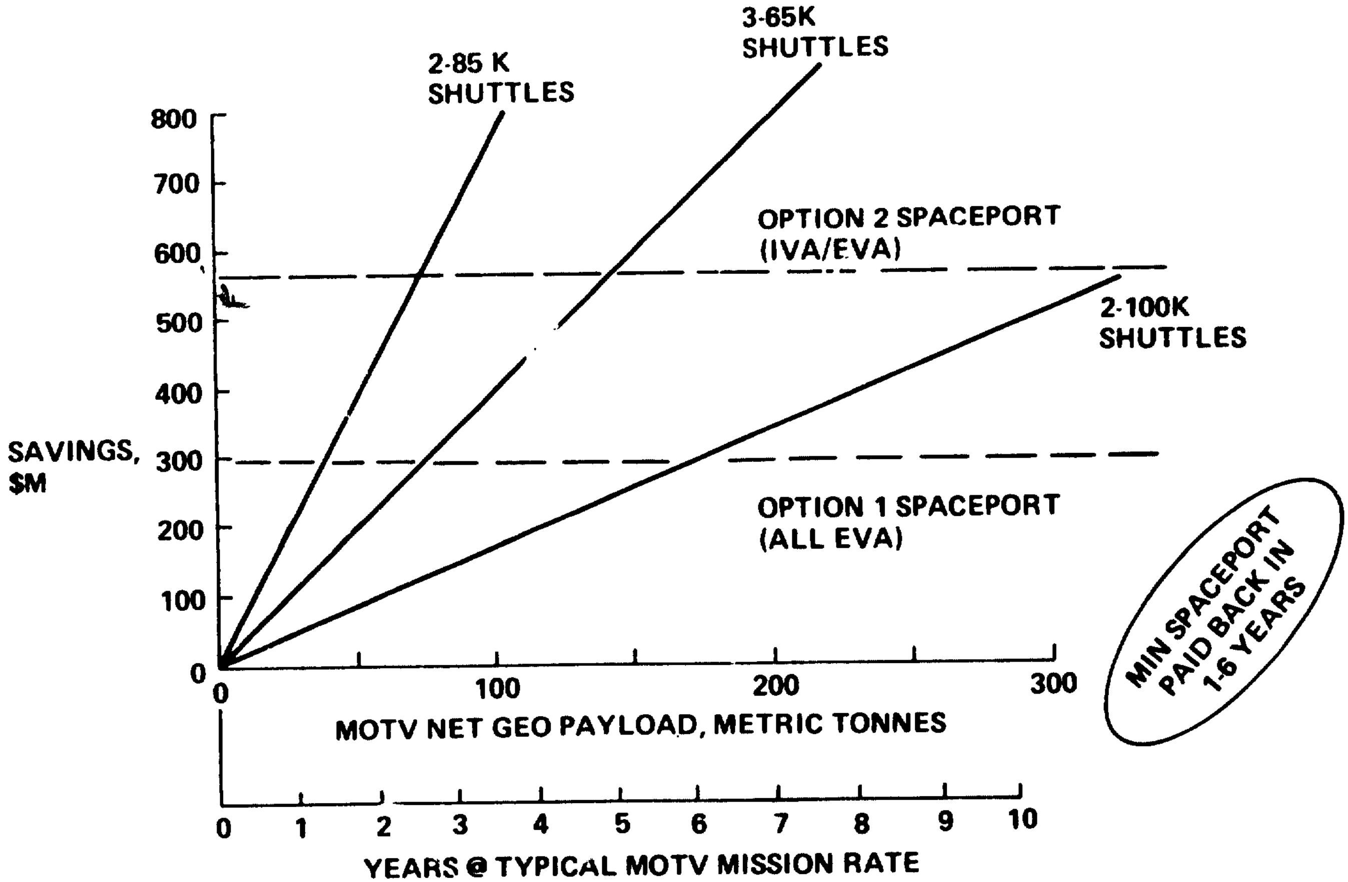
SPACE PORT PAYBACK $61M SHUTTLE

This chart plots the delta program costs between the space based and ground based 1 1/2-stage vs MOTV delivered payload tonnage. A second scale is shown representing the years anticipated to use that tonnage at the typical MOTV mission rate. The resulting cost savings curves for MOTVs using two 85-K shuttles, two 100-K shuttles, and three 65-K shuttles are shown. It should be noted that two 85-K shuttles cannot perform the typical mission.

These data reflect the MOTV performance and cost without external tank propellant scavenging and shuttle costs of $61M per launch.

The time required to pay back the cost of an option 1 (all EVA) spaceport for a three 65-K shuttle MOTV is 2 years.

SPACEPORT PAYBACK – 1½ STAGE SPACE BASED SAVINGS VS MOTV NET GEO PAYLOAD – $61M SHUTTLE



1154-019(T)

EXTERNAL TANK PROPELLANT SCAVENGING COST SAVINGS $33M SHUTTLE

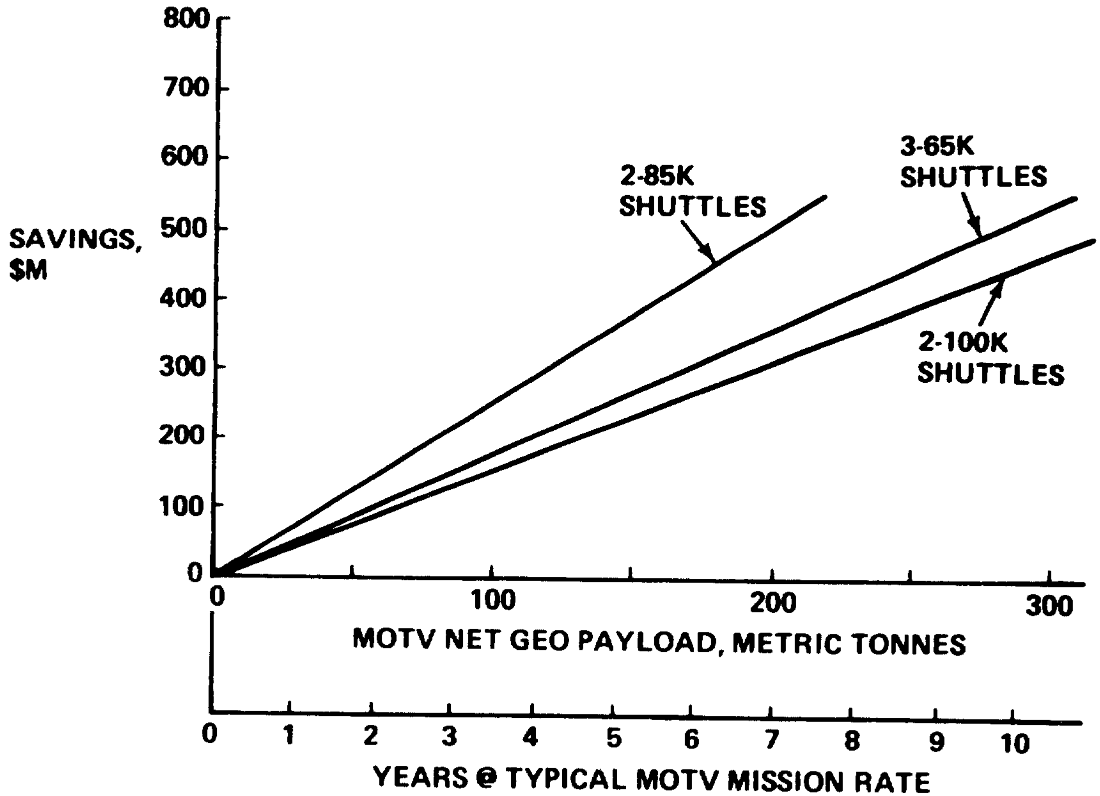
The cost savings between a 1 1/2-stage space based MOTVs with scavenging and the same vehicles without scavenging have been plotted vs MOTV payload tonnage to GEO. A second scale is shown representing the years anticipated to use that tonnage at the typical MOTV mission requirement. The resulting cost savings curves for MOTVs utilizing two 85-K shuttles, two 100-K shuttles, and three 65-K shuttles are shown. It should be noted that the two 85-K shuttle MOTV cannot perform the typical mission.

These data reflect shuttle costs of $33M per launch.

MOTV

E.T. PROPELLANT SCAVENGING — 1½ STAGE SPACE BASED SAVINGS VS MOTV NET GEO PAYLOAD $33M SHUTTLE

GRUMMAN



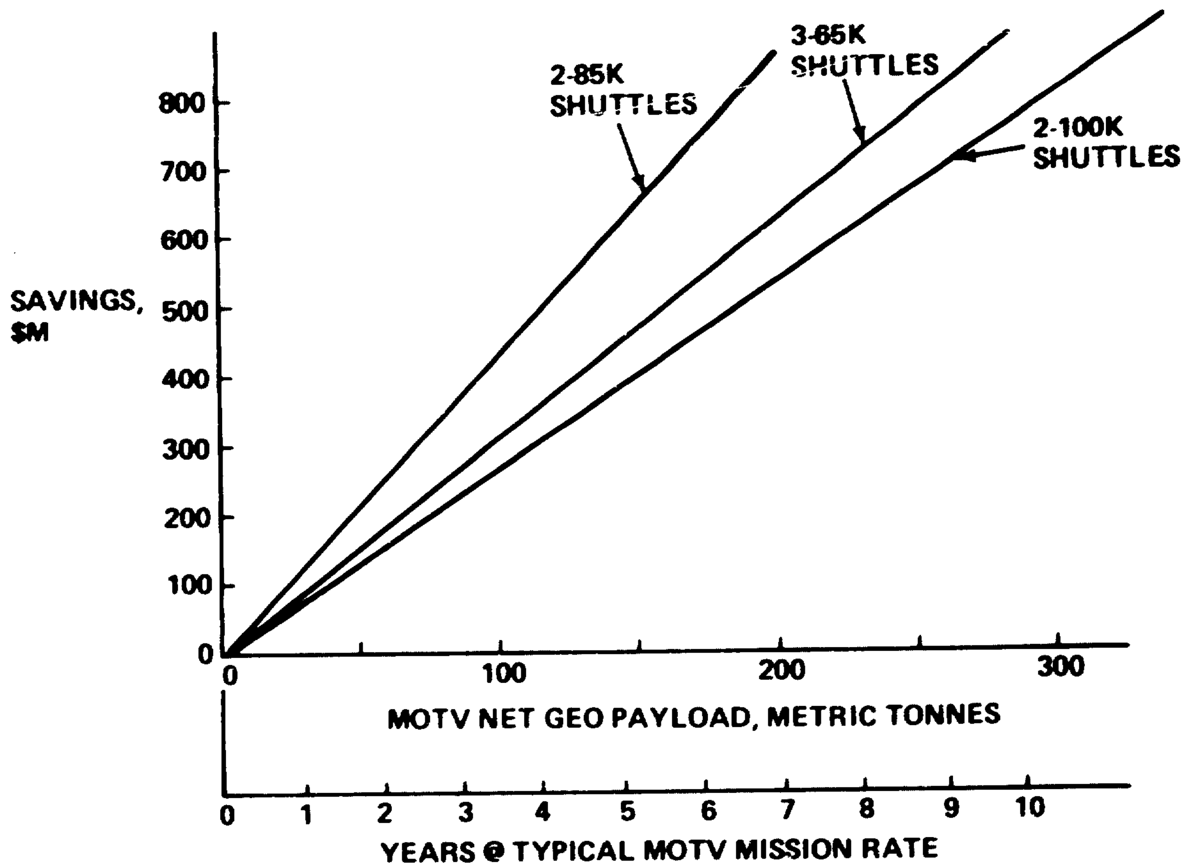
1154-020(T)

EXTERNAL TANK PROPELLANT SCAVENGING COST SAVINGS: $61M SHUTTLE

The cost savings between the 1 1/2-stage space-based MOTVs with scavenging and the same vehicles without scavenging have been plotted vs MOTV payload tonnage to GEO. A second scale is shown representing the years anticipated to use that tonnage at the typical MOTV mission requirement. The resulting cost saving curves for MOTVs utilizing two 85-K shuttles, two 100-K shuttles, and three 65-K shuttles are shown. It should be noted that the two 85-K shuttle MOTV cannot perform the typical mission.

These data reflect shuttle cost of $61M per launch.

E.T. PROPELLANT SCAVENGING SAVINGS – 1½ STAGE SPACE BASED SAVINGS VS MOTV NET GEO PAYLOAD $61M SHUTTLE

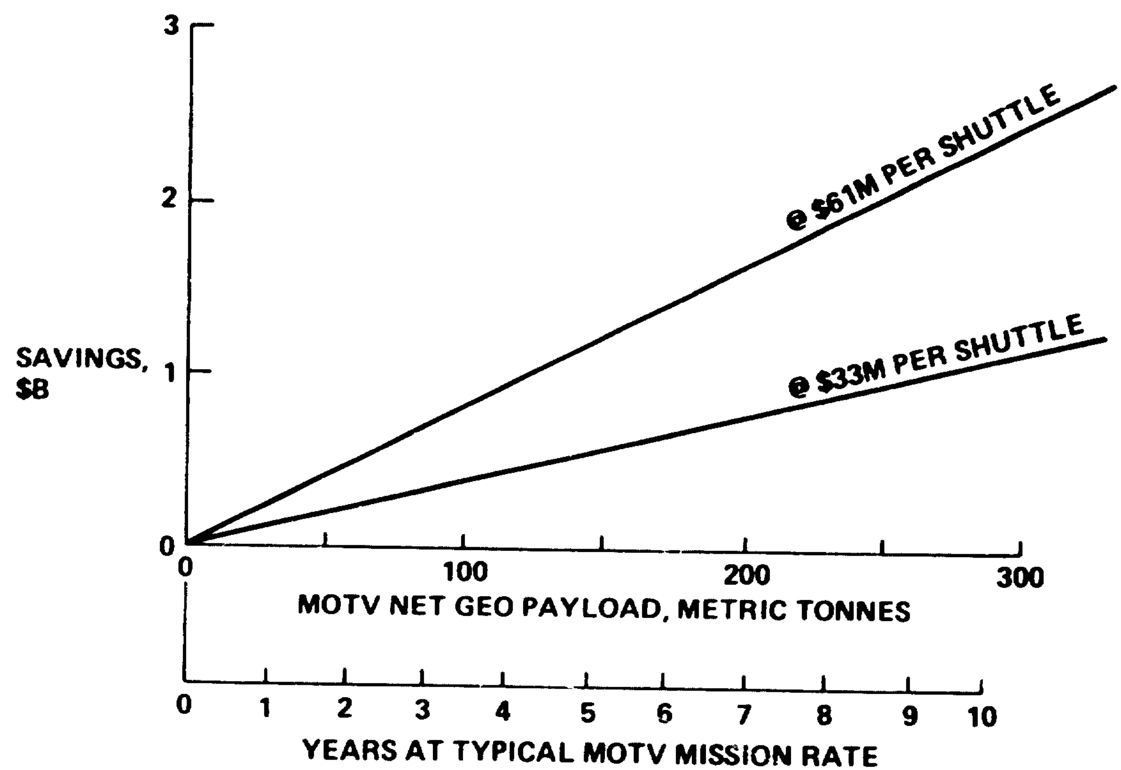


1154-021(T)

100-K SHUTTLE COST SAVINGS

The cost savings between the 1 1/2-stage space based MOTV using three 65-K shuttle launches and the same vehicle using two 100-K shuttle launches have been plotted vs MOTV payload tonnage to GEO. A second scale is shown representing the years anticipated to use that tonnage at the typical MOTV mission requirement. The resulting cost saving curves for MOTVs based on $33M and $61M per shuttle launch are shown.

100K SHUTTLE — 1½ STAGE SPACE BASED SAVINGS VS MOTV NET GEO PAYLOAD



1154-022(T)

MOTV

COSTING CONCLUSIONS

GRUMMAN

- SPACE BASED 1½ STAGE MOTV IS LOWEST COST OPTION
- SPACE BASING MORE ECONOMICAL FOR 1½ STAGE
- MINIMUM SPACEPORT CAN BE PAID BACK IN 2 TO 5 YEARS (DEPENDING ON STS LAUNCH COSTS)
- EXTERNAL TANK SCAVENGING IS ATTRACTIVE — SHORT PAYBACK TIME PROBABLE

1154-023(T)

MOTV

GRUMMAN

EXECUTIVE SUMMARY

TURNAROUND & CONFIGURATION STUDIES

PERFORMANCE

COSTING & SENSITIVITY

CCNCLUSIONS & RECOMMENDATIONS

MOTV

CONCLUSIONS

GRUMMAN

- SERVICEABLE SATELLITE SYSTEM MORE COST EFFECTIVE THAN EXPENDABLE SATELLITE SYSTEM
- MINIMUM TENDED SPACEPORT CAN HANDLE OTV/MOTV TURNAROUND AND CAN BE PAID BACK IN 2 TO 5 YEARS
- 2-65K SHUTTLES CANNOT PERFORM MINIMUM MOTV MISSION
- 2-100 K SHUTTLES OR 3-65 K SHUTTLES REQUIRED TO PERFORM TYPICAL MOTV MISSION
- PROPELLANT SCAVENGING IS ATTRACTIVE
- PROPELLANT TRANSFER LOSSES SIGNIFICANTLY REDUCE 2 STAGE SPACE BASED MOTV PAYLOAD CAPABILITY (CONSIDER PLUG IN TANKS)
- SPACE BASED 1½ STAGE IS BEST PERFORMING AND LOWEST COST MOTV

1154-118(T)

MOTV

RECOMMENDATIONS

GRUMMAN

- PERFORM SIMULATIONS TO QUANTIFY MANNED VS UNMANNED SATELLITE SERVICING CAPABILITY
- PURSUE EXTERNAL TANK PROPELLANT SCAVENGING
- CONTINUE TO DETERMINE, QUANTIFY AND EVALUATE THE DIFFERENCES BETWEEN PLUG-IN TANKS AND PROPELLANT TRANSFER
- DEFINE AND COMPARE CREW CAPSULE SUBSYSTEMS FOR GROUND BASED VS SPACE BASED OPTIONS
- DETERMINE EVOLUTIONARY PROGRAM FOR OTV/MOTV

1154-119(T)