TR–220–1370
MARCH 1975

(NASA-CR-120638) MISSION ROLES FOR THE SOLAR ELECTRIC PROPULSION STAGE (SEPS) WITH THE SPACE TRANSPORTATION SYSTEM. VOLUME 3: DESIGN REFERENCE MISSION DESCRIPTION AND PROGRAM SUPPORT (Northrop Services, Inc., G3/20 N75-18318 Unclas 13581

MISSION ROLES FOR THE SOLAR ELECTRIC PROPULSION STAGE (SEPS) WITH THE SPACE TRANSPORTATION SYSTEM

VOLUME III – DESIGN REFERENCE MISSION DESCRIPTION AND PROGRAM SUPPORT REQUIREMENTS

PREPARED FOR:

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
Program Development Directorate

Under Contract NAS8–30742

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REVIEWED AND APPROVED BY:

David M Hammock

David M. Hammock
Program Manager

FOREWORD

This volume, Volume III, presents the Northrop Services, Inc., SEPS Design Reference Mission Description and Program Support Requirements.

The complete final study report is composed of four volumes:

Volume I	Executive Summary
Volume II	System Analysis, Evolution of Design and Operational Concepts, and Requirements Definition
Volume III	Design Reference Mission Description and Program Support Requirements
Volume IV	Traffic Model and Flight Schedule Analysis Techniques and Computer Programs

The study, Mission Roles for the Solar Electric Propulsion Stage, with the Space Transportation System, was conducted under Contract NAS8-30742. Mr. Robert E. Austin of the Marshall Space Flight Center was the Contracting Officer's Representative for NASA. Mr. David M. Hammock was Northrop Services, Inc.'s, Study Program Manager.

The study was accomplished under Contract NAS8-30742 during the period from 20 May 1974 to February 1975, and was funded at $130,000.

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Section I

INTRODUCTION

This volume presents a design reference mission and a representative sortie description with resulting system requirements for the Solar Electric Propulsion Stage (SEPS) in its role as an element of the Space Transportation System (STS). The rationale for the recommended SEPS configuration and associated General Purpose Mission Equipment (GPME) is contained in Volume II of the final report of this study. Certain payload handling, transporting, servicing, and onorbit maintenance capabilities and inflight procedures are described in greater detail in Volume II. Volume II also contains conceptual designs of various elements.

Summaries of other mission applications and SEPS benefits to the Interim Upper Stage (IUS), Tug, and payloads are given in Section II of this document. Section III summarizes the SEPS role in accomplishing the NASA-supplied reference mission model in a manner that maximizes the transport effectiveness of STS with SEPS operating as a transport element. An overview of the STS with SEPS elements and the recommended SEPS configuration are presented in the following paragraphs. By NASA direction, the 25 kw power level SEPS was the baseline for operations analysis.

1.1 THE SPACE TRANSPORTATION SYSTEM WITH SEPS AS A TRANSPORT ELEMENT

The system elements are shown on Figure 1-1. No physical changes or additions to the Shuttle are required for SEPS operation in the system. A standard family of "kick stages" should not be defined until more detail exists on the character of payloads and specific mission requirements. For this study, a representative kick stage that could be fitted with different numbers of solid rocket motors was assumed. For earth orbital missions, SEPS eliminates the need for any kick stages or payload velocity addition ability in the payloads themselves for achieving initial mission position; or for retrieval of payloads after mission accomplishment. For other missions,

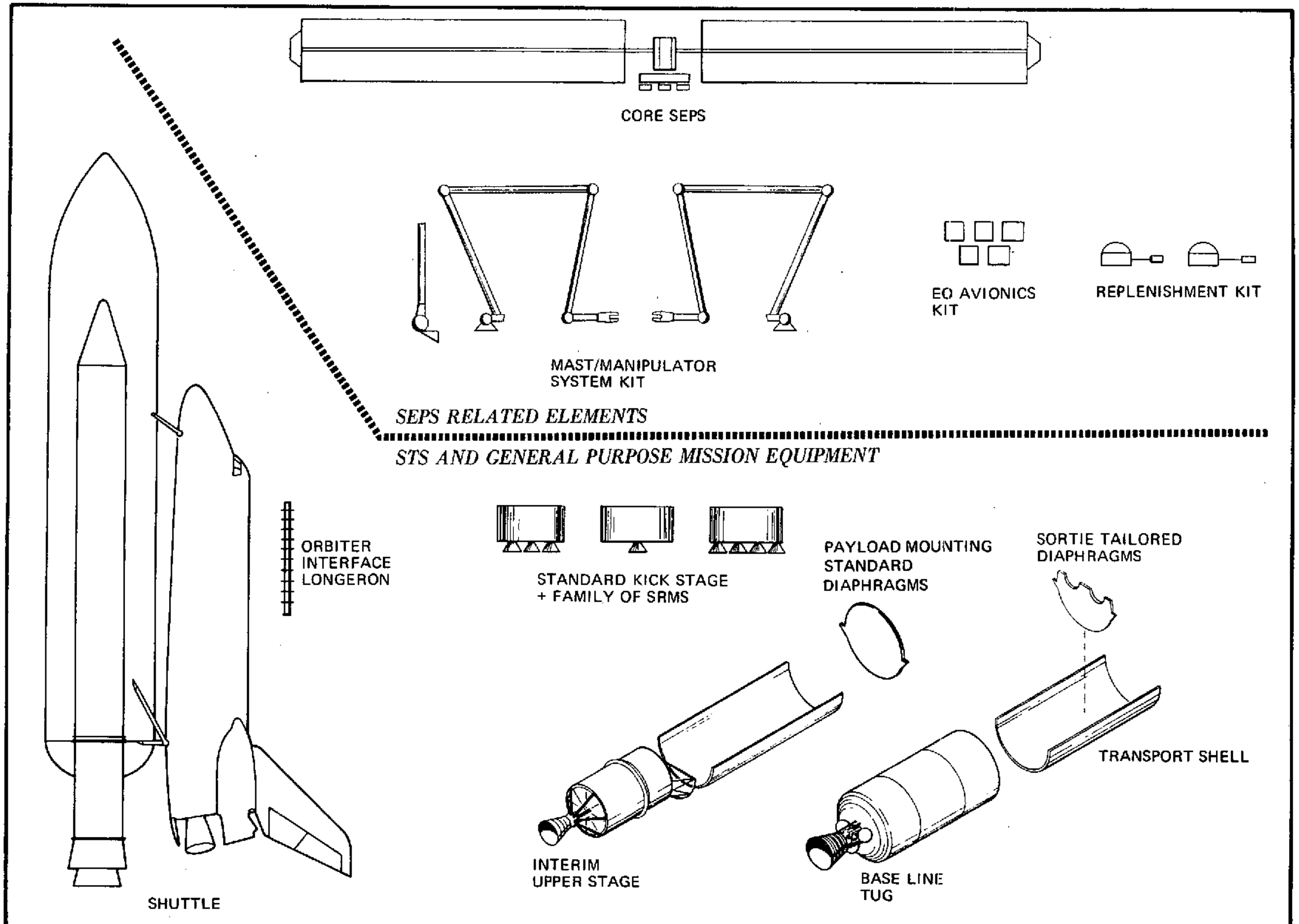

Figure 1-1. SPACE TRANSPORTATION SYSTEM ELEMENTS WITH SEPS

planetary and earth escape, SEPS reduces auxiliary propulsion performance requirements without placing any demands or constraints on the kick stages. SEPS offers the potential for recovery of Tug instead of expending it for many missions.

The study ground rules supplied by NASA defined an IUS which is a "stretched tank" transtage for use through 1983 and baseline Space Tug defined by MSFC for use from 1984 onward. SEPS does not impose requirements on these vehicles that are not needed for their missions when operated independently of SEPS. Because SEPS can always accomplish the remaining portions of any combined SEPS plus IUS or Tug missions by extensions of the required SEPS trip time, SEPS has the potential to remove the development schedule and cost risks that are associated with meeting burnout weight and propulsion performance goals from the IUS and Tug programs.

1.2 SEPS CONFIGURATION AND FUNCTIONAL CHARACTERISTICS

The foregoing discussion described the elements comprising an STS plus SEPS transport system. At the beginning of any discussion on SEPS configuration, several basic factors should be emphasized. The active elements of SEPS are very compact. Once operational in space, the greatest acceleration that SEPS is ever exposed to results from its attitude control system (ACS) thrusters. Their absolute thrust level requirement for control and docking is extremely low. The level is therefore chosen based on accelerations that make for operator convenience and reduce the time that mission control centers must be involved in SEPS operations. Peak accelerations from the ACS thrusters are in the range of 0.002 to 0.01g. Any desired deployed geometry in space can therefore be implemented at a very small penalty in structural mass increase. The only two elements of SEPS that require preferential orientation are the solar arrays and radiation cooling panels.

The decision controlling factors regarding SEPS' overall configuration, therefore, are primarily related to the functional interfaces with payloads and STS General Purpose Mission Equipment (GPME). In summary form, the decision controlling factors are:

- STS transportation efficiency is enhanced by multiple payload deliveries and multiple retrievals
- Cost effectiveness requires that GPME be usable on successive flights without modification and with few special payload adapter items
- The GPME must simplify Shuttle-Tug operations
- Multiple payload transport must place minimum constraints on payload designers
- SEPS staytime in space is limited only by wear out. Design should provide for easy replenishment of expendables
- GPME mass increase to simplify other STS operations does not reduce SEPS plus Tug net payload capability; modest trip time increases allow SEPS to make up for Tug's lower payload transfer orbit ability
- Earth orbital SEPS has no ΔV limit within mission model requirements
- SEPS' capabilities are almost directly proportional to design power levels in the range from 25 to 100 kw. Development at higher power levels causes less than 10 percent increase in development cost.

The recommended SEPS configuration is shown on Figures 1-2 through 1-4.

Each solar array wing is deployed on two spars. The spars are identical in concept to the transport mast. On Figure 1-2, the spar which deploys the solar array wing from the launch position to an inflight position is shown deployed to allow the wings to clear a 4.6-meter (15-foot diameter) payload. The spars can be extended further to clear elements of a payload that require deployment of the spar's elements outside the 4.6-meter launch envelope during the final checkout before SEPS releases the payload. The housing and extension-retraction drive of the spar is located inside SEPS body and is not visible on Figure 1-2.

The solar array wing assembly, mounted at the outboard end of the inboard spar, is an independent assembly, comprised of: The rotation mechanism that allows it to be oriented normal to the sunline, the solar blanket storage cylinder, the wiring harness and switch assembly, and the biconvex spar solar blanket deployment and retraction mechanism.

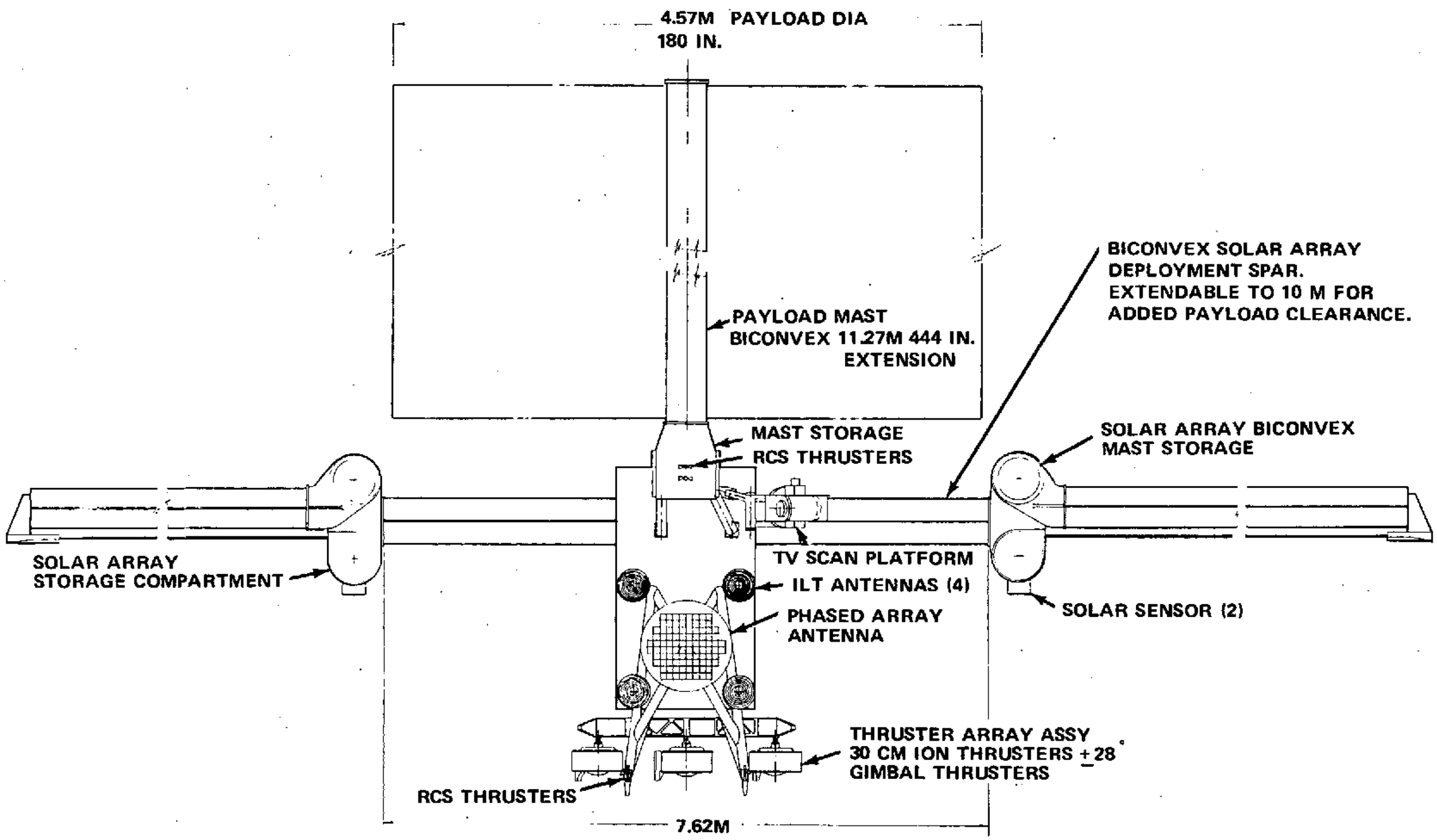

Figure 1-2. RECOMMENDED SEPS CONFIGURATION

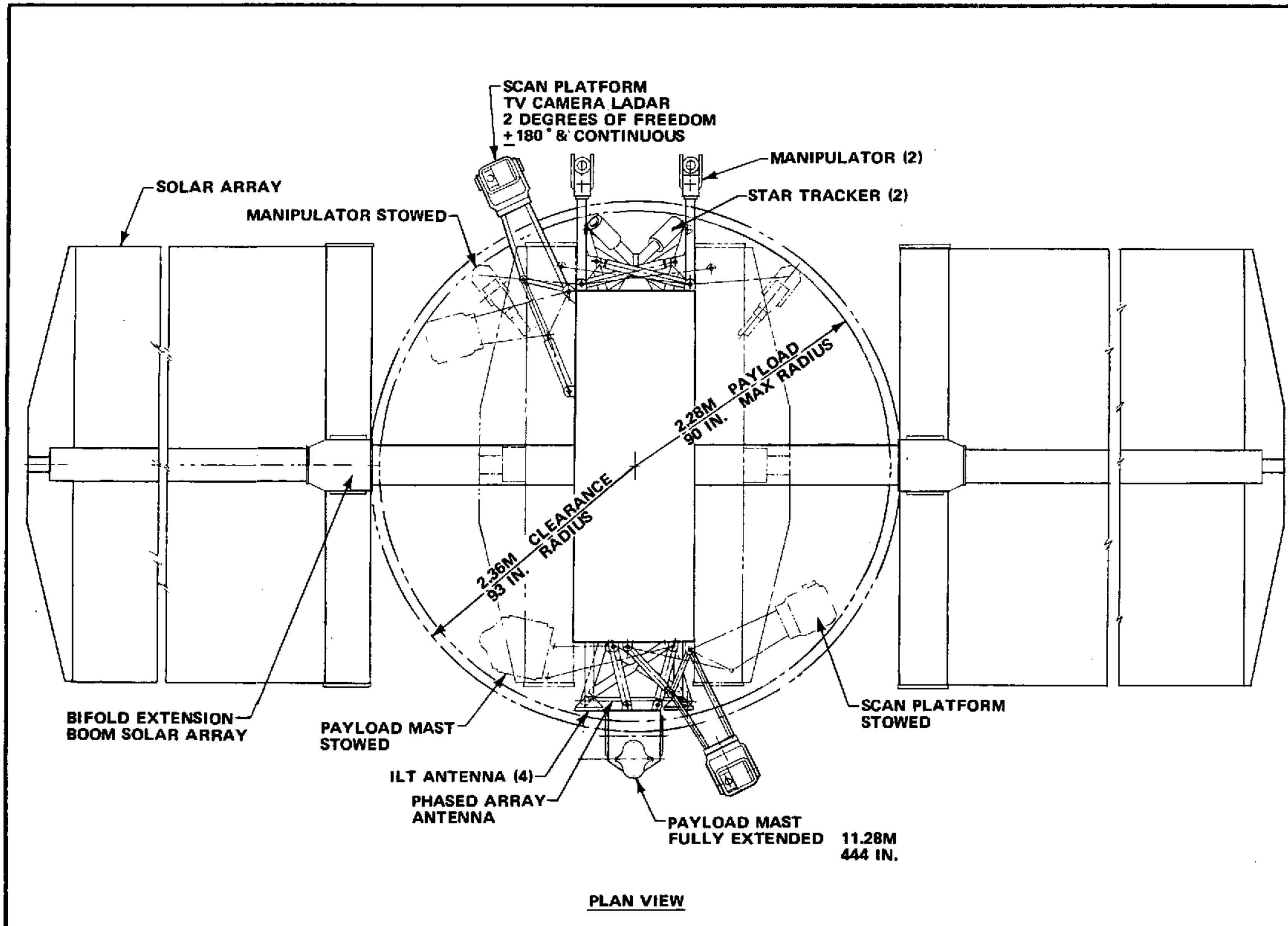

Figure 1-3. RECOMMENDED SEPS CONFIGURATION

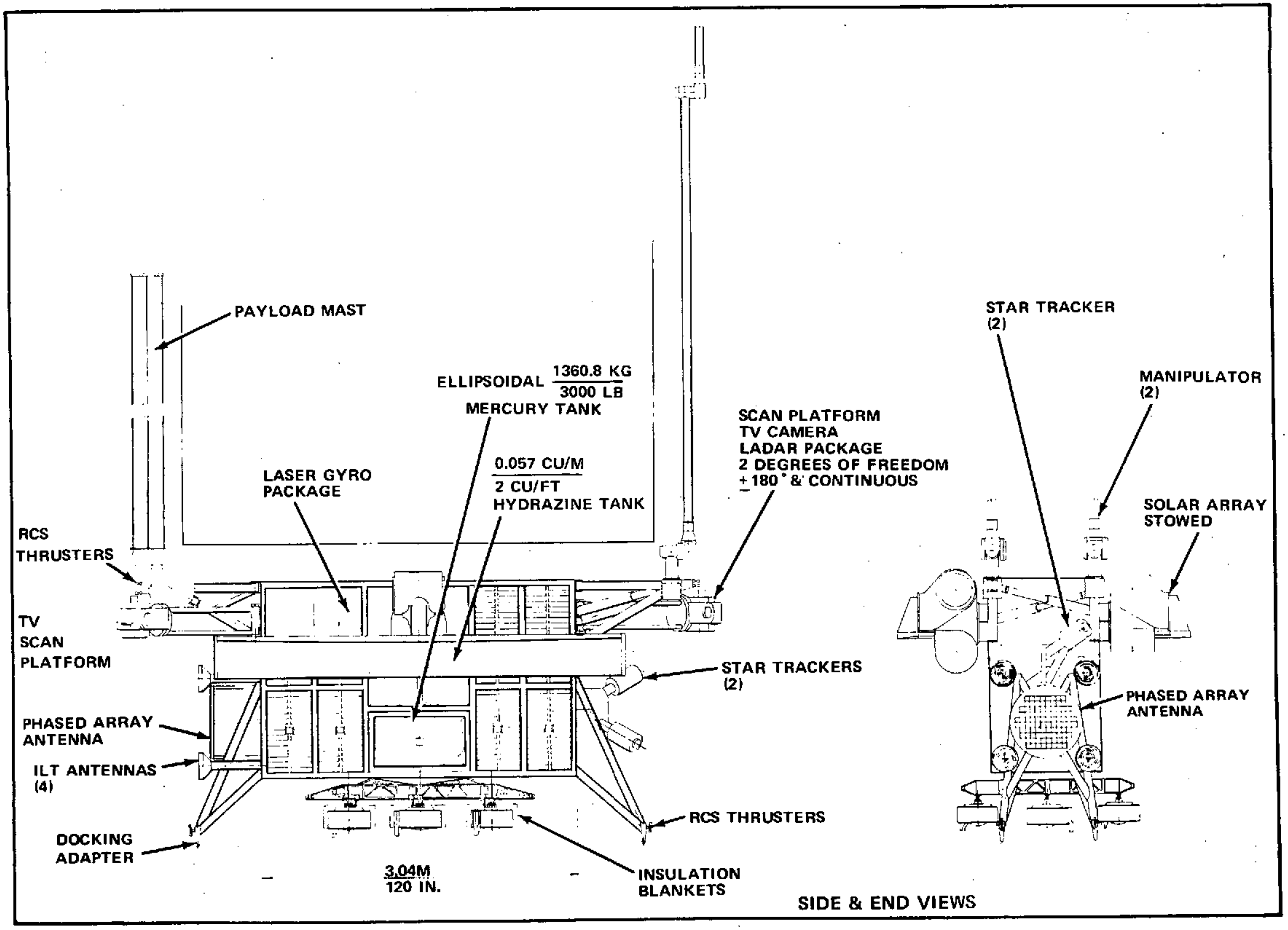

Figure 1-4. RECOMMENDED SEPS CONFIGURATION

Biconvex spars are selected for these assemblies because of their simplicity and their high rigidity in torsion, bending, and compression relative to other storable mast concepts. Northrop Services, Inc., (NSI) assessed them as having the highest potential reliability of the mast concepts examined. Considering the fact that the blanket spars do not require an EI in the direction parallel to the blanket as high as in the normal direction, data from the Rockwell International Exhibit E and previous studies show these biconvex, edge-welded spars to be essentially as low in mass as other concepts. SEPS effectiveness is not particularly sensitive to inert mass. It is very sensitive to reliability.

The high gain antenna is phased-array, and the beam is electronically steered. The phased-array antenna and the Interferometric Landmark Tracker (ILT) are located as outboard as feasible without requiring mounting on a deployable structure.

There are two scan platforms, each mounted on a deployable structure, and located on opposite ends of SEPS. They would normally be used in conjunction, but missions can be completed with only one functional platform.

The star trackers are located as far forward as clearance with the manipulator mount deployment structure permits. The second phased-array antenna is mounted just below the star trackers. Missions can be completed with only one active antenna, but some otherwise unnecessary attitude maneuvers may be required. Figure 1-3 is a top view of the earth orbital (EO) SEPS configuration.

The submodules of the thruster subsystem power conditioning and control system have no preferred orientations as long as the orientation does not interfere with such items as maintaining their proper thermal environment, test, and maintenance accessibility. The same is true of the thrusters themselves except that their installation pattern must be such that flight control torques are efficiently applied. Many suitable arrangements are possible with little, other than personal preferences, to dictate a choice between them. The best arrangement will be a function of the detail design characteristics of the submodules. The square 3 by 3 thruster array shown, with each thruster fully gimballed, was considered acceptable as a baseline for this study. Insulation around the thrusters (and other elements of the structure to which the ACS components requiring themal conditioning are attached) is not shown in the figures. The 3 by 3 thruster array was a Rockwell International concept and a characteristic of the initial study baseline designated by MSFC.

The equipment module mounted above the thruster subsystem's power processors and control electronics is an independent module. The equipment module contains all of the systems intelligence, housekeeping, and payload support subsystems. The equipment module structure is attached to the thruster subsystem structure in such a manner that the two structures, after final assembly, form an integrated airframe. Figure 1-4 shows a side view and a view looking in on the manipulator mounting end of SEPS. The manipulators described earlier are mounted on deployable structures to locate their bases outside the 4.6-meter diameter payload accommodation area. In this end view, the solar arrays are shown in the fully stowed position as they would be for launch.

Because of SEPS low acceleration, it does not use phasing orbits but is started on trajectory profiles so that continuous thrusting for the minimum length of time will bring it to the desired rendezvous or payload deployment point. The terminal phase of SEPS to a target point for deployment of a payload, or to a rendezvous, is just an extension of the cruise phase. For sunlit targets, the SEPS, with information from the ground as to target payload position, can acquire the target at distances up to 3,900 nautical miles and begin path adjustments. Generally, only the ion thrusters are used in order to conserve ACS propellants.

The flight control center would not need to be fully manned prior to about 2 hours before payload deployment or retrieval was to begin. If it is desired to compress the last hours of the terminal approach operation, ACS thrusters can be utilized. These thrusters, combined for additive thrust in the same direction as the ion system, provide about 100 times the acceleration of the ion system.

Section II

SEPS MISSION ROLES IN THE SPACE TRANSPORTATION SYSTEM

2.1 SEPS ROLES IN SUPPORT OF MISSION MODEL

A basic goal of the Northrop Services, Inc., (NSI) study was to evaluate the cost effectiveness of the Solar Electric Propulsion Stage (SEPS) as a part of the Space Transportation System (STS). A thorough analysis was performed to determine the direct transportation saving by minimizing the total number of Shuttle flights.

An analysis of the current STS mission model indicated that the Shuttle must have the ability to deploy multiple payloads. It became evident that a different handling and transportation support concept was required to remove payload configuration constraints. NSI developed a new system which provides more operational flexibility without imposing geometric or weight constraints on the payloads. This system contains:

- A payload transportation support half shell with a load bearing longeron
- Payload support diaphragms
- A manipulator system.

The systems' requirements and characteristics are discussed in Section VII.

With the constraints eliminated, new combinations of payloads were possible that could be deployed with fewer Shuttle flights. Each mission in the 1973 NASA payload model was evaluated, and placed in an optimum payload manifest. "Optimum" in this context is that set of manifests that meets launch year schedule requirements, payload compatibility requirements, and also results in the minimum number of Shuttle flights to accomplish the reference mission model. It was determined that the addition of SEPS to the STS is cost effective based on direct transportation costs alone (see Volume II). Mission roles for SEPS are predominantly in the geosynchronous orbit delivery, retrieval, and payload service areas. SEPS functions in accomplishing the mission model are summarized as follows:

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- Ninety-three percent (124 out of 133) of all geosynchronous deployment and retrieval missions are accomplished by a SEPS-Tug combination mission. Forty-seven percent of all intermediate orbit payload missions are accomplished in this manner.
- SEPS accomplishes 4 of 16 planetary missions. Because backup planetary spacecraft are flown, the 4 missions require 8 SEPS launches.
- Tug alone accomplishes only 7 percent of the geosynchronous missions and 53 percent of the intermediate orbit missions.

2.2 SEPS BENEFITS TO IUS, TUG, AND PAYLOADS

2.2.1 Benefits to the Interim Upper Stage (IUS)

- The IUS is not required to have a navigation and guidance system capable of active participation in rendezvous operations.
- Costly research and development programs to improve propulsion capability or reduce inert stage weights are not required since SEPS can make up any IUS performance deficit.
- IUS flight preparations are greatly simplified. Payloads can be individually mounted into the transport shell. The multiple payloads package can be checked for flight readiness and combined with a single mating operation.

2.2.2 Benefits to Tug

- Schedule and cost risk associated with high performance requirements of the Tug program are removed.
- Tug operations are simplifed. Multiple payloads are presented to Tug as a single package ready for flight.
- A Tug docking interface may be developed for a single payload interface.
- Fifteen to 29 fewer Tug flights are required to accomplish the mission model.
- Tug does not have to be designed for the long stay times in space necessary to perform orbital taxi missions for multiple payloads.

2.2.3 Benefits to Payloads

- Reduction in transportation cost is prorated to each payload. Average number of payloads per flight in SEPS case is approximately four and for Tug alone is less than two.
- Essentially removes weight restrictions for payloads.
- Higher initial payload weight allowances can be used to reduce development cost and improve reliability or provide capabilities not feasible in payloads delivered by Tug alone.

- SEPS can deploy various payload appendages as a backup to onboard deployment systems or relieve the payload entirely from self-deployment requirements.
- Most payload failures prior to end of design life are of the infant mortality type. SEPS can provide television coverage of the payload deployment and initial operation. SEPS can assist in correction of the malfunctions. Upon ground command SEPS can retrieve the payload for refurbishment.
- SEPS can service payloads by substituting new sensor packs or different experiments. This may extend the usefulness of large instrument platforms without requiring their recovery or replacement in space.
- SEPS can replenish consumable payloads.
- For planetary missions SEPS allows significantly greater payload mass and supplemental services such as power, communication, and thermal conditioning.
- Combination of science packages with SEPS can provide nearly ideal spacecraft for comprehensive surveys and continuous monitoring of earth's magnetosphere and near earth solar system space. "Out-of-the-ecliptic" missions are examples of the latter. New spacecraft do not need to be developed for these missions. SEPS itself may be considered a "standard" spacecraft.
- Where the scientific objectives require mission orbits so greatly separated in energy level that it is not practical to provide spacecraft propulsion to accomplish the change, SEPS can taxi the spacecraft to its new orbit thus saving a new Shuttle launch.

2.3 NEW MISSION APPLICATIONS FOR SEPS

This study was directed toward earth orbital mission roles and analyses of operations support requirements. Other potential applications of SEPS are:

- As a spacecraft host supplying power to a direct broadcast satellite for remote exploration sites. System would provide one-way TV and two-way voice communication.
- Provide space mobility for a high resolution earth observing satellite with high data rate real-time information on weather or other local phenomena. High resolution optics and other sensors could switch from locality to locality providing scan information.
- Removal of space debris from frequently used areas of near earth space.
- Transportation of very large fragile space structures from their initial assembly positions to final deployment position.
- High efficiency Space Tug to eject nuclear wastes clear of the earth's gravitational fields.

Section III

SPACE TRANSPORTATION SYSTEM WITH SEPS SYSTEM OPERATIONAL PROFILE FOR THE REFERENCE MISSION MODEL

A thorough analysis was performed to evaluate the use of SEPS in minimizing the number of Shuttle flights required to accomplish the total mission model. The analysis technique, within the certain constraints described in Section II of Volume II, schedules the payloads such that maximum use is made of the Orbiter's available cargo space. Schedules must ensure that each payload is launched in the year designated by the reference mission model. Orbiter cargo manifests will contain payloads for Shuttle parking orbit, intermediate orbits, and geosynchronous orbit in those combinations resulting in minimum flights for that year. The source of payload weight and dimensional data used in the evaluation is "The October 1973 Space Shuttle Traffic Model," NASA TMX-64751, Revision 2, dated January 1974. Study guidelines limited the years to be considered for cost effectiveness comparisons to 1981 through 1991.

A complete description of the analysis technique is given in Section II of Volume II. Table 3-1 shows all of the automated payload missions in the mission model listed by payload category and type of mission. The System Operational Profile that resulted in the minimum total number of flights to accomplish the reference mission model is shown on Figure 3-1.

A breakdown of the payload missions that required upper stages for accomplishment is given in Table 3-1. The table also shows the percent of the missions in each category that was delivered by combined SEPS-Tug sorties. Table 3-2 shows the schedule of accomplishment by individual payloads.

In the system operational profile presented on Figure 3-1, the calendar years 1981 to 1991 are laid out on the abscissa. The width of a "V" representing a SEPS sortie is proportional to the time required for the sortie including the time to taxi individual payloads to their final position and/or to

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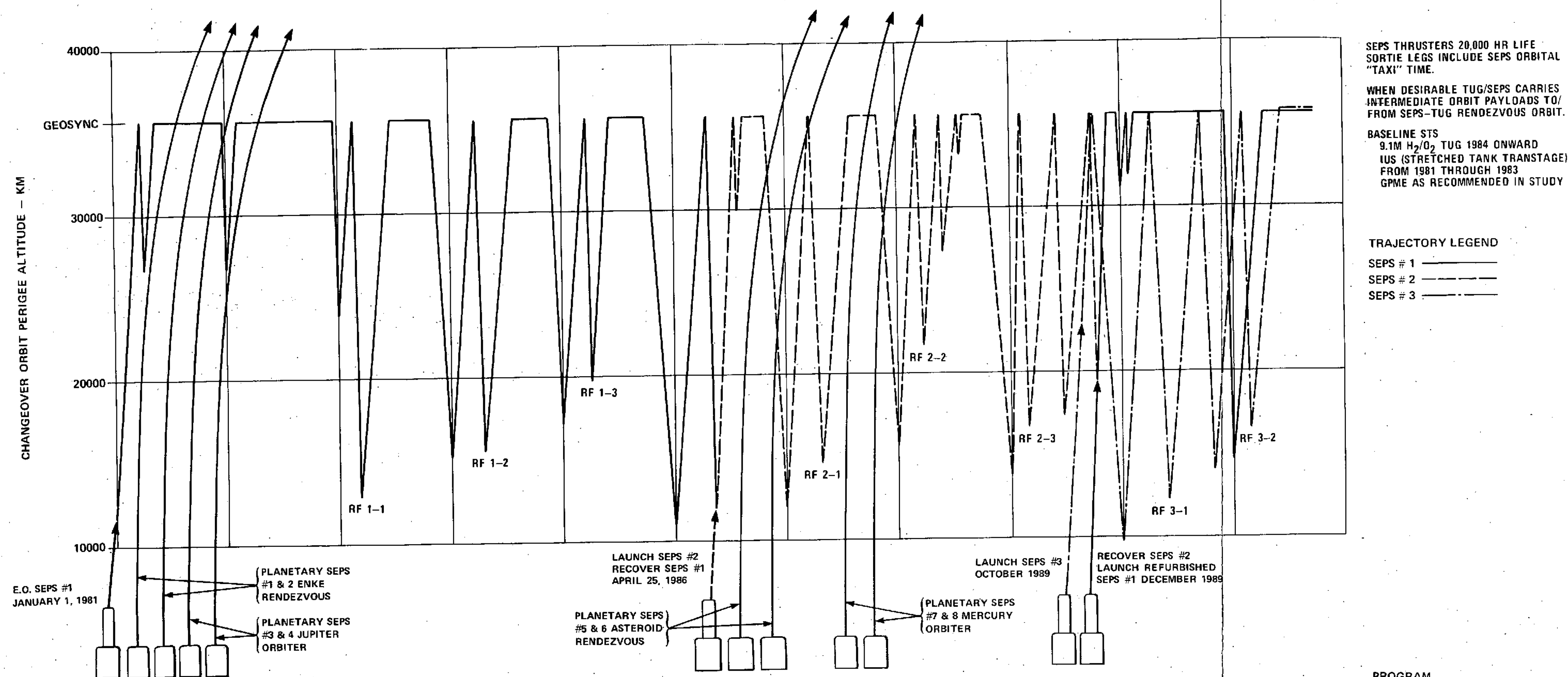
Table 3-1. ACCOMPLISHMENT OF PAYLOAD MISSIONS REQUIRING UPPER STAGES

Total Payload Missions	**879**
• **Shuttle Only**	**644**
• **Requiring Upper Stage**	**235**

MISSION CATEGORY	MISSION IN EACH CATEGORY	DIFFERENT PAYLOAD TYPES	TUG ALONE		TUG WITH SEPS RENDEZVOUS	
			No.	%	No.	%
GEOSYNCHRONOUS	133	17	9	7	124	93
ESCAPE	45	22	39	87	6	13
POLAR EO	33	5	33	91	0	0
HIGH ENERGY EO	9	3	9	100	0	0
INTERMEDIATE EO	15	2	8	53	7	47
TOTAL	235	49	95	40	137	58

collect them for retrieval. The ordinate represents the SEPS and Tug change-over orbit perigee radius in nautical miles. In 1981, five SEPS launches are indicated, one geosynchronous SEPS in January, two Encke rendezvous and two planetary SEPS (Jupiter Orbiter). Two planetary SEPS for asteroid rendezvous are launched in 1986 and two for a Mercury orbiter in 1987. SEPS No. 2 is launched in April 1986, and the first SEPS will be retrieved by Tug on the same mission. Refurbishment, flight readiness testing, and return to inventory of the first SEPS marks the end of its first mission cycle. SEPS No. 3 is launched in October 1989 because SEPS No. 2 did not have time to complete the missions scheduled for that year. SEPS No. 3 is fully employed until mid 1991. Refurbished SEPS No. 1 is launched in December 1989 and SEPS No. 2 is recovered. SEPS No. 1 completes the operational requirement of the mission model through 1991 with three additional sorties. Except for these 3 sorties SEPS No. 1 is idle in orbit.

Notice the large amount of time SEPS is idle from 1981 through 1986. The SEPS idle period is the flat portion of the graph at geosynchronous altitude. Ground processing to support the earth orbital (EO) SEPS is required only four times in 11 years. Ground support for planetary SEPS launches is required only eight times in 11 years.



												PROGRAM TOTALS
SHUTTLE	19	22	28	27	33	32	30	32	30	30	32	315
SHUTTLE/TUG	6	2	8	11	13	12	11	4	6	9	10	92
SHUTTLE/TUG/ EO SEPS	2	1	2	2	2	3	2	4	5	5	2	30
YEAR	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	437

Figure 3-1. SYSTEM OPERATIONAL PROFILE (9.1-METER BASELINE TUG + 25 KW BASELINE SEPS)

Table 3-2. SEPS MISSIONS

PAYLOAD NAME*	MISSION/YEARS											MISSIONS DELIVERED
	81	82	83	84	85	86	87	88	89	90	91	
PL-13	0	0	0	0	0	0	2	0	0	0	0	2
PL-19	2	0	0	0	0	0	0	0	0	0	0	2
PL-28	0	0	0	0	0	2	0	0	0	0	0	2
EO-4A	1	0	1	0	1	0	0	0	0	0	0	3
EO-4AR	0	0	0	0	0	1	0	0	0	0	0	1
EO-4B	0	0	0	0	0	0	2	0	2	0	2	6
EO-4BR	0	0	0	0	0	0	0	0	0	0	0	0
EO-5A	0	0	0	0	0	0	0	0	0	0	0	0
EO-5AR	0	0	0	0	0	0	0	0	0	0	0	0
EO-5E	0	0	1	0	0	1	0	0	1	0	0	3
EO-5ER	0	0	0	0	0	0	0	0	0	0	0	0
EO-7	0	0	0	0	0	0	1	0	0	0	0	1
NN/D-2C	0	0	3	0	0	0	0	3	0	0	0	6
NN/D-2CR	0	0	0	0	0	0	0	0	0	0	0	0
NN/D-1	0	0	1	3	2	2	0	0	2	3	2	15
NN/D-1R	0	0	0	0	0	0	1	1	2	3	0	7
NN/D-2A	2	2	1	0	0	0	0	0	0	0	0	5
NN/D-2B	0	0	0	1	1	2	2	3	2	1	1	13
NN/D-2BR	0	0	0	0	0	0	0	0	0	0	0	0
NN/D-3	1	1	0	0	0	0	0	0	0	1	0	3
NN/D-3R	0	0	0	0	0	1	1	0	0	0	0	2
NN/D-4	2	0	1	0	0	1	0	0	0	0	0	4
NN/D-4R	0	0	0	0	0	0	0	0	0	0	0	0
NN/D-5	1	1	1	1	1	1	1	1	1	1	1	11
NN/D-5R	0	0	0	3	1	0	0	1	1	1	1	8
NN/D-6	0	0	0	0	0	0	0	1	0	1	0	2
NN/D-9	1	1	0	1	0	1	0	1	0	1	0	6
NN/D-9R	0	0	0	1	1	1	0	1	0	1	0	5
NN/D-10	1	1	1	0	1	0	1	1	1	0	1	8
NN/D-10R	0	0	0	3	1	1	1	0	1	0	1	8
NN/D-12	0	0	0	0	0	0	0	2	0	2	0	4
NN/D-12R	0	0	0	0	0	0	0	0	0	0	0	0
NN/D-13	0	0	0	0	0	0	0	1	2	0	0	3
NN/D-13R	0	0	0	0	0	0	0	0	0	0	0	0

See legend on next page.

Table 3-2. SEPS MISSIONS (Concluded)

LEGEND

PAYLOAD NAME	PAYLOAD TITLE
PL-13	MERCURY ORBITER
PL-19	MARINER JUPITER ORBITER
PL-28	ASTEROID RENDEZVOUS (VESTA)
EO-4A	SYNCHRONOUS EARTH OBSERVATORY SATELLITE (SEOS) - R AND D
EO-4AR	SYNCHRONOUS EARTH OBSERVATORY SATELLITE (SEOS) - R AND D
EO-4B	SYNCHRONOUS EARTH OBSERVATORY SATELLITE (SEOS) - OPERATIONAL
EO-4BR	SYNCHRONOUS EARTH OBSERVATORY SATELLITE (SEOS) - OPERATIONAL
EO-5A	SPECIAL PURPOSE SATELLITE - SYNC
EO-5AR	SPECIAL PURPOSE SATELLITE - SYNC
EO-5E	SPECIAL PURPOSE SATELLITE - POLA
EO-5ER	SPECIAL PURPOSE SATELLITE - POLA
EO-7	SYNCHRONOUS METEOROLOGICAL SAT.
NN/D-2C	TRACKING AND DATA RELAY SATELLITE
NN/D-2CR	TRACKING AND DATA RELAY SATELLITE
NN/D-1	INTELSAT
NN/D-1R	INTELSAT
NN/D-2A	U.S. DOMCOMSAT (MISSION A)
NN/D-2B	U.S. DOMCOMSAT (MISSION B)
NN/D-2BR	U.S. DOMCOMSAT (MISSION B)
NN/D-3	DISASTER WARNING SATELLITE
NN/D-3R	DISASTER WARNING SATELLITE
NN/D-4	TRAFFIC MANAGEMENT
NN/D-4R	TRAFFIC MANAGEMENT
NN/D-5	FOREIGN COMSAT
NN/D-5R	FOREIGN COMSAT
NN/D-6	COMMUNICATIONS R AND D SATELLITE
NN/D-9	FOREIGN SYNCHRONOUS METEOROLOGICAL
NN/D-9R	FOREIGN SYNCHRONOUS METEOROLOGICAL
NN/D-10	GEOSYNCHRONOUS OPERATIONAL METEOROLOGICAL
NN/D-10R	GEOSYNCHRONOUS OPERATIONAL METEOROLOGICAL
NN/D-12	EARTH RESOURCES-SYNC
NN/D-12R	EARTH RESOURCES-SYNC
NN/D-13	FOREIGN SYNCHRONOUS EARTH OBSERVATORY SATELLITE (SEOS)
NN/D-13R	FOREIGN SYNCHRONOUS EARTH OBSERVATORY SATELLITE (SEOS)

Refueling is carried out on the sorties indicated by the symbols RF 1-1, RF 1-2, etc. Three refuelings per mission cycle was considered the best compromise between trip time savings and otherwise unnecessary refueling operations.

The numbers in the blocks at the bottom of Figure 3-1 are numbers of Shuttle and Tug (Interim Upper Stage (IUS) in the years 1981, 1982, and 1983) flights in the respective years. These are presented to show STS concurrent activity that is not associated with SEPS sorties. Because of this high level of STS activity, NSI developed GPME concepts that would allow decoupling of prelaunch activity of Shuttle and Tug from that associated with the multiple payload packages.

Figure 3-2 shows the frequency of occurrence of numbers of payloads in a Shuttle cargo manifest versus the number of individual payloads in the manifest. Some payloads may only go to Shuttle orbit, others go to intermediate orbits and may be delivered and retrieved by Tug enroute to and from rendezvous with SEPS. The majority are transferred to SEPS for delivery to their final mission destinations.

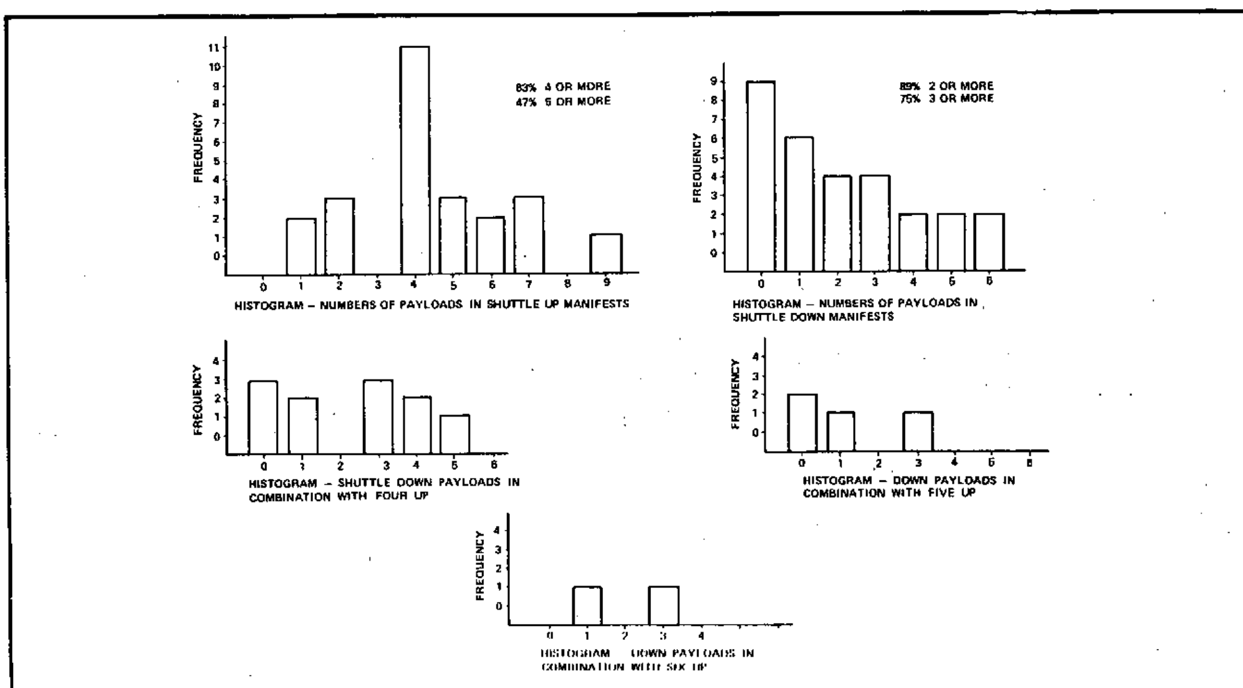


Figure 3-2. FREQUENCY OF OCCURRENCE VERSUS NUMBER OF INDIVIDUAL PAYLOADS IN CARGO MANIFESTS

Section IV

DESIGN REFERENCE MISSION

Certain operational and physical characteristics of SEPS make it possible to simplify the task of accomplishing earth orbital missions. Using these characteristics along with the latest test and flight control technology, SEPS can be made most effective by minimizing reoccurring operational costs. The design reference mission cycle presented in this section considers the following characteristics of SEPS:

- The data management system has the capacity to support flight control, ground operations, redundancy management, and fault isolation functions. SEPS will be instrumented with sufficient sensors to enable inflight evaluation of each subsystem. These same sensors will be used to evaluate SEPS flight readiness in preparation for launch.
- The computer is the Space Ultrareliable Modular Computer (SUMC) being developed by MSFC. Because of its capability it is used to automate both prelaunch testing and inflight subsystem status.
- Much SUMC operating system software, which is compatible with the IBM 360, will be available to SEPS without a development cost to this program. The system can use the HAL and GOAL compilers developed for the Shuttle program.
- The simple mechanical systems are easily instrumented with existing sensors.
- All subsystems can be evaluated through electrical testing using flight sensors as built-in test equipment (BITE).
- Flight readiness can be established with flight software. The additional stimuli required to simulate flight conditions can be inserted in the flight software using GOAL and HAL operators.
- SEPS small mass and small volume facilitate test, shipment, storage, and integration into the Tug as one element of a multiple payload (3 x 3 x 5 - 1250 kg).
- SEPS is essentially an electrical device which simplifies test operations and reduces manpower requirements.
- Flight functions requiring a "man in the loop" have a very low density. In a typical mission, sortie active control is required about 5 percent of the time. In other words, SEPS is autonomous 95 percent of the time.
- SEPS is an autonomous vehicle in its cruise mode on transfer trajectories between changeover orbits and payload mission stations. It only requires a status check with navigation and guidance updates approximately once each week.

- SEPS includes a manipulator, payload transport mast system which provides a great deal of operational flexibility. It can handle one payload at a time, several at once, or the entire payload transport shell. The manipulators can be used to maintain, service, retrieve, and deploy individual or multiple payloads. They can be used to refuel SEPS in space.
- NSI recommends a half shell payload transportation structure with diaphragms to support the payloads. This concept includes a retractable payload mast to which individual or combinations of payloads may be clamped.
- The payload support diaphragms and the half shell simplify Tug/SEPS/ multiple payload package assembly and integration into the transport shell and provide a means for substitution of individual payloads without disturbing the total package.

4.1 MISSION CYCLE TOP FUNCTIONAL FLOW

Mission preparation begins at the SEPS operational center and continues through all ground operations at the launch site. After delivery to the transfer orbit, various sorties are accomplished. After the last sortie at the end of its operating life SEPS is retrieved and returned to the SEPSOC. The cycle is terminated by refurbishment, flight readiness verification, and return to flight inventory. This mission cycle functional flow is illustrated in Figure 4-1.

The SEPS in the geosynchronous transport role is used as a third powered stage for delivery of payloads to geosynchronous orbit and taxiing to specific mission stations, deployment, and retrieval of payloads in orbit. The SEPS is used to transfer the retrieved payloads to a lower energy changeover orbit. The Tug receives the payloads for transfer to the Shuttle, subsequently the payloads are returned to earth in the Orbiter. SEPS receives a new set of payloads from the Tug for subsequent deployment and retrieval sorties. This operation is continued as long as the performance and functional capabilities of the SEPS are adequate to meet the mission requirements. For planning purposes, the thruster life has been assumed to be 20,000 hours in orbit. At the end of its thruster life, the SEPS, with its last set of payloads, descends to the changeover orbit for retrieval by Tug and return to earth. The recovered SEPS is then refurbished and put into inventory for subsequent reuse. A replacement for the first SEPS is delivered to changeover orbit on the same mission used to retrieve the recovered SEPS.

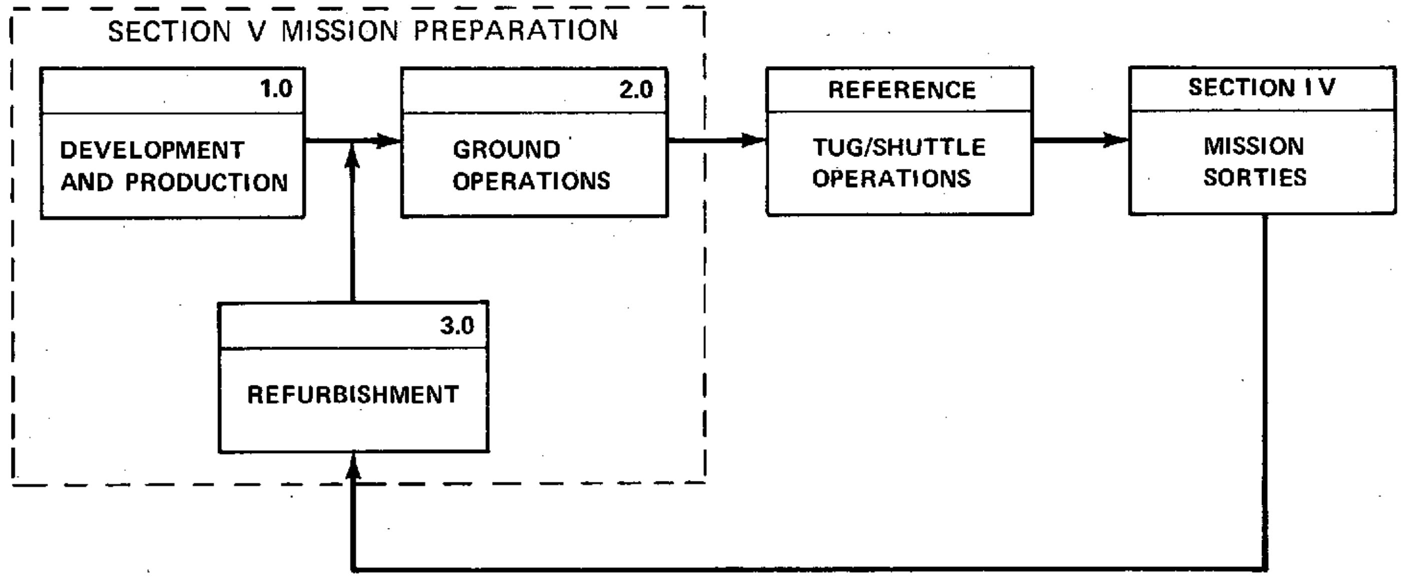


Figure 4-1. MISSION PREPARATION FLOW

4.2 DETAILED FUNCTIONAL FLOW

A more detailed functional flow of a SEPS mission cycle is presented in Figure 4-2. This figure depicts the relationship of flight mission operations and ground operations in accomplishing all of SEPS mission roles. Eight planetary and three earth orbital SEPS are required to accomplish the mission model.

4.3 SEPS REFERENCE TRAJECTORY PROFILE

In order to develop the reference trajectory profile, the following representative payload manifest for a sortie was used. This manifest does not actually occur in the traffic model. It is a composite embodying a payload delivery in each of the trajectory segments and was synthesized to illustrate the general Tug-SEPS sortie.

SORTIE PAYLOAD MANIFEST - SHUTTLE LAUNCH: MARCH 1986

Payload ID	Weight Kg	Length/ Dia.(M)	Longitude	Apogee Alt - Km	Perigee Alt - Km	Inc Deg
Intermediate Up Payloads						
EOP-9	414	3.1/1.77	--	2,000	1,000	28.0
Geosynch Up Payloads						
NN/D-1	2,039	3.7/2.5	30°W	35,785	35,785	0
NN/D-4	645	3.7/3.1	162°W	35,785	35,785	0
NN/D-9	366	3.1/1.8	135°E	35,785	35,785	0
Geosynch Down Payloads						
EO-4A	1,359	3.3/2.6	100°W	35,785	35,785	0
NN/D-10	347	3.1/1.8	80°W	35,785	35,785	0
Intermediate Down Payloads						
AST-1A	291	3.7/.8	--	550	550	28.5

The changeover orbit chosen to minimize SEPS transfer time has the following characteristics:

apogee altitude - 48,475 km
perigee altitude - 17,203 km
inclination - 4.7 deg

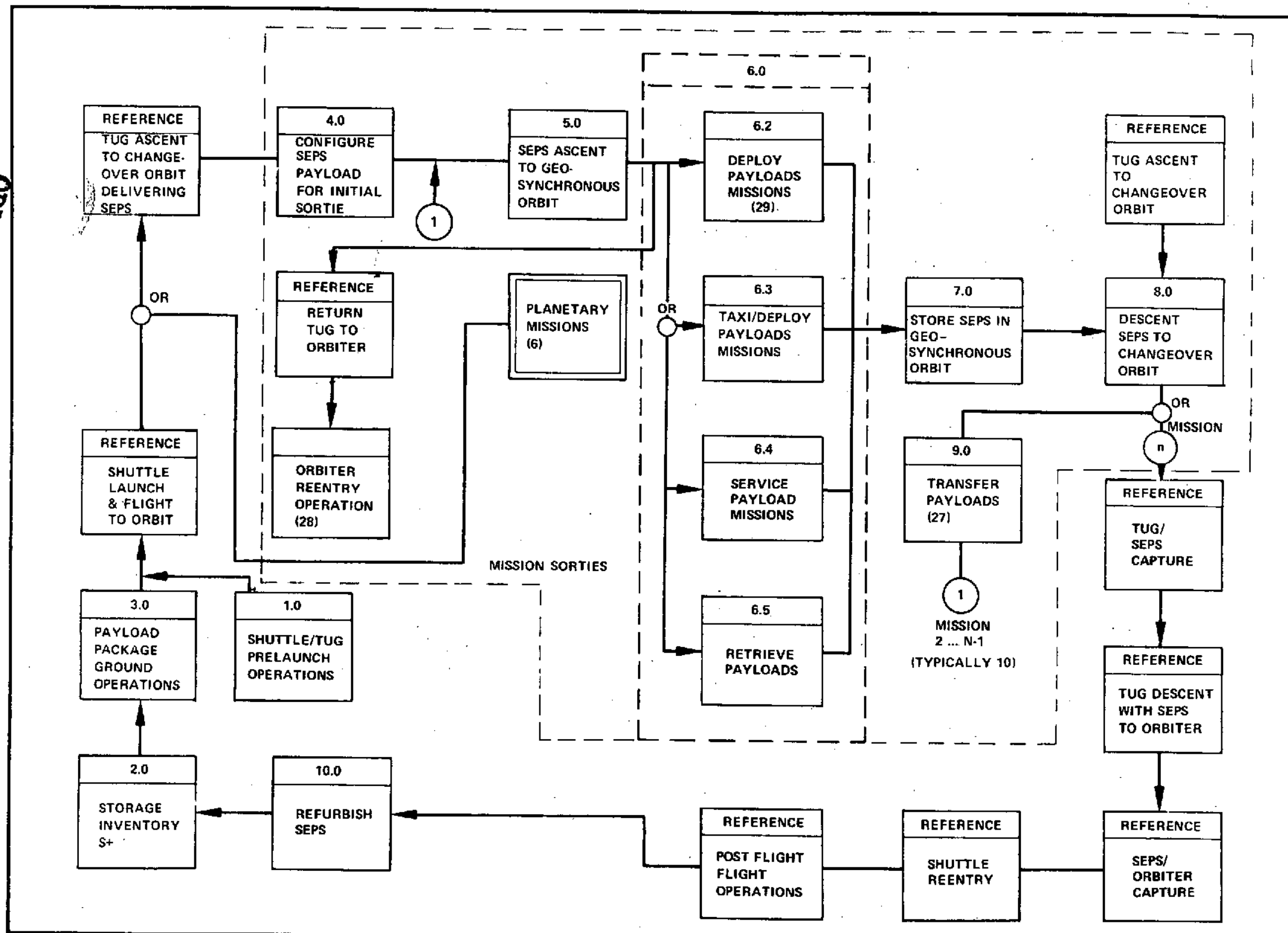


Figure 4-2. MISSION CYCLE DETAIL FLOW

The Shuttle, Tug, and SEPS characteristics were assumed to be:

Shuttle

Payload at 296 km x 28.5 degrees	- 28,616 kg
Maximum Down Payload	- 14,512 kg

Tug

Empty Weight	- 2,746 kg
Usable Propellant	- 23,000 kg
Specific Impulse	- 456.5 sec
Thrust	- 66,708 n

SEPS

Beam Power (undegraded)	- 15.67 kw
Specific Impulse	- 2,940 sec
Empty Weight	- 1,243 kg
Propellant Capacity	- 771 kg

Tug-SEPS trajectory profile on a typical sortie involves a series of maneuvers and trajectory segments as follows:

- At some time prior to Shuttle launch, SEPS gathers up payloads in geosynchronous orbit which are to be retrieved. SEPS then begins descent to changeover orbit with retrieved payloads. After from 10 to 90 days, depending upon sortie, SEPS and retrieved payloads are established in changeover orbit.
- Shuttle is launched so that the line of nodes of its parking orbit is coincident with line of nodes of changeover orbit (see Figure 4-3).
- In Shuttle orbit, Tug and payloads are checked out and deployed. Intermediate orbit payloads (defined to be payloads requiring 28.5 degree Shuttle launches with orbital altitudes less than geosynchronous) are delivered by the Tug in a series of Hohmann transfers from one intermediate orbit to the next in order of increasing altitude.
- At the ascending node of the last intermediate orbit, the Tug burns to initiate transfer to apogee of changeover orbit and accomplish 1 to 2 degrees of required plane change. Usually a phasing orbit will be necessary so that Tug can rendezvous with SEPS at apogee of changeover orbit.
- Tug burns at apogee of transfer orbit to complete plane change and inject on changeover orbit. After final closure and docking of Tug with SEPS, up payloads on Tug are exchanged with down payloads on SEPS.
- The Tug retroburns at apogee of changeover orbit to begin transfer to intermediate orbit via a phasing orbit for retrieval of intermediate

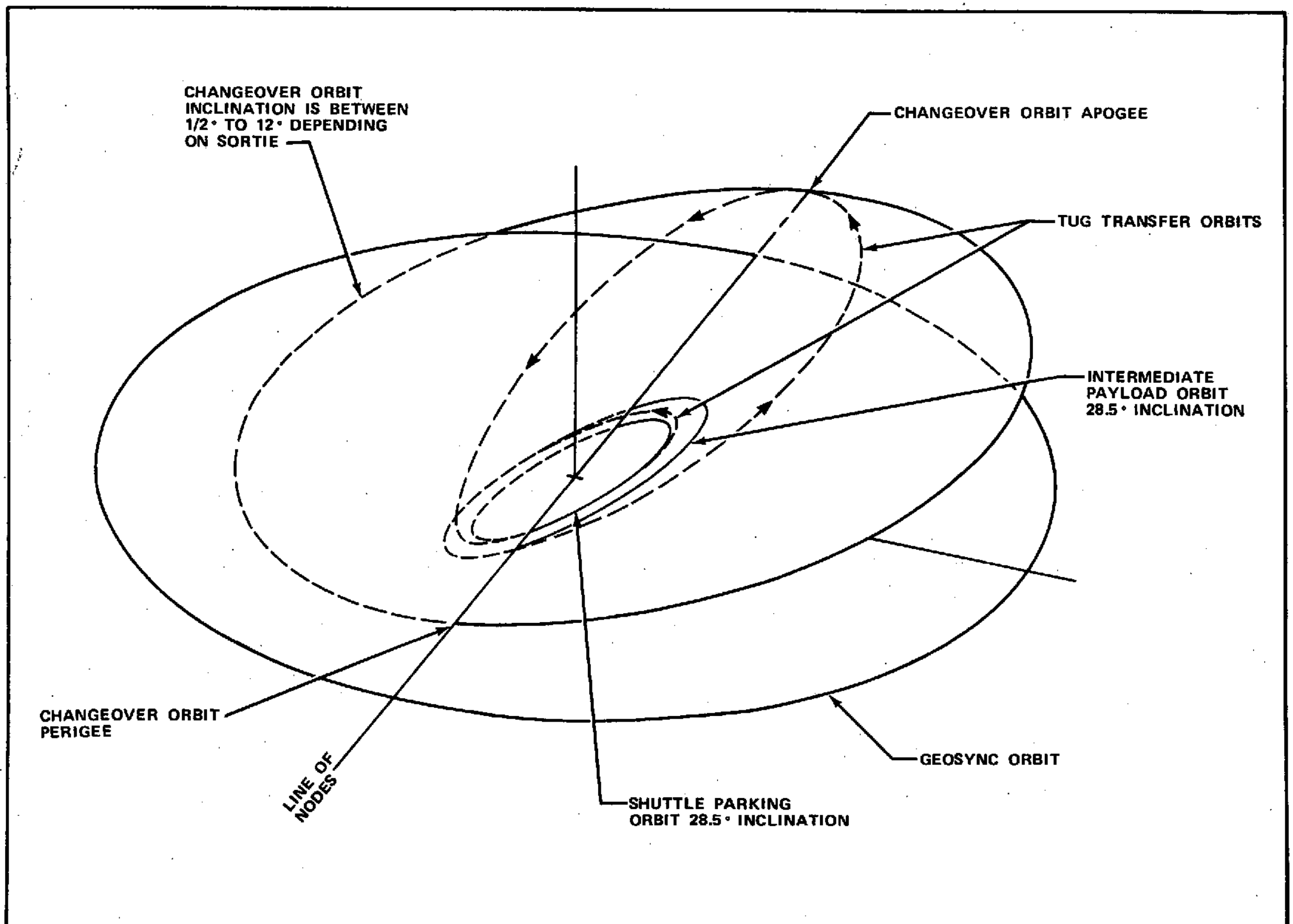


Figure 4-3. REFERENCE TRAJECTORY PROFILE

payloads. This requires that the line of nodes of the intermediate orbit be aligned with the nodal line of the changeover orbit. This can be arranged for one intermediate orbit, but in general it cannot be expected that the line of nodes of several intermediate orbits will be coincident. In the case of an elliptical intermediate orbit, it is also necessary that the major axis lie in the line of nodes; any other orientation of either the nodes or major axis requires excessive Tug ΔV. The intermediate retrieval orbit is not shown on Figure 4-4 to simplify the drawing.

- After retrieval of the intermediate payload, Tug burns to transfer by Hohmann ellipse to Shuttle parking orbit. Again, a phasing orbit will be necessary to allow Tug-Shuttle rendezvous.
- Shuttle returns to ground with Tug and retrieved payloads.
- Following exchange of payloads with Tug, SEPS begins transfer from changeover orbit to geosynchronous orbit. After a number of days (up to 90) SEPS establishes the up payloads in geosynchronous orbit.
- In geosynchronous orbit SEPS assumes its orbital taxi role and spaces the individual payloads around the orbit at their intended longitudes. SEPS is then free to begin the next sortie.

Figures 4-3 and 4-4 show the reference trajectory profile. A timeline for the various segments is presented in Table 4-1.

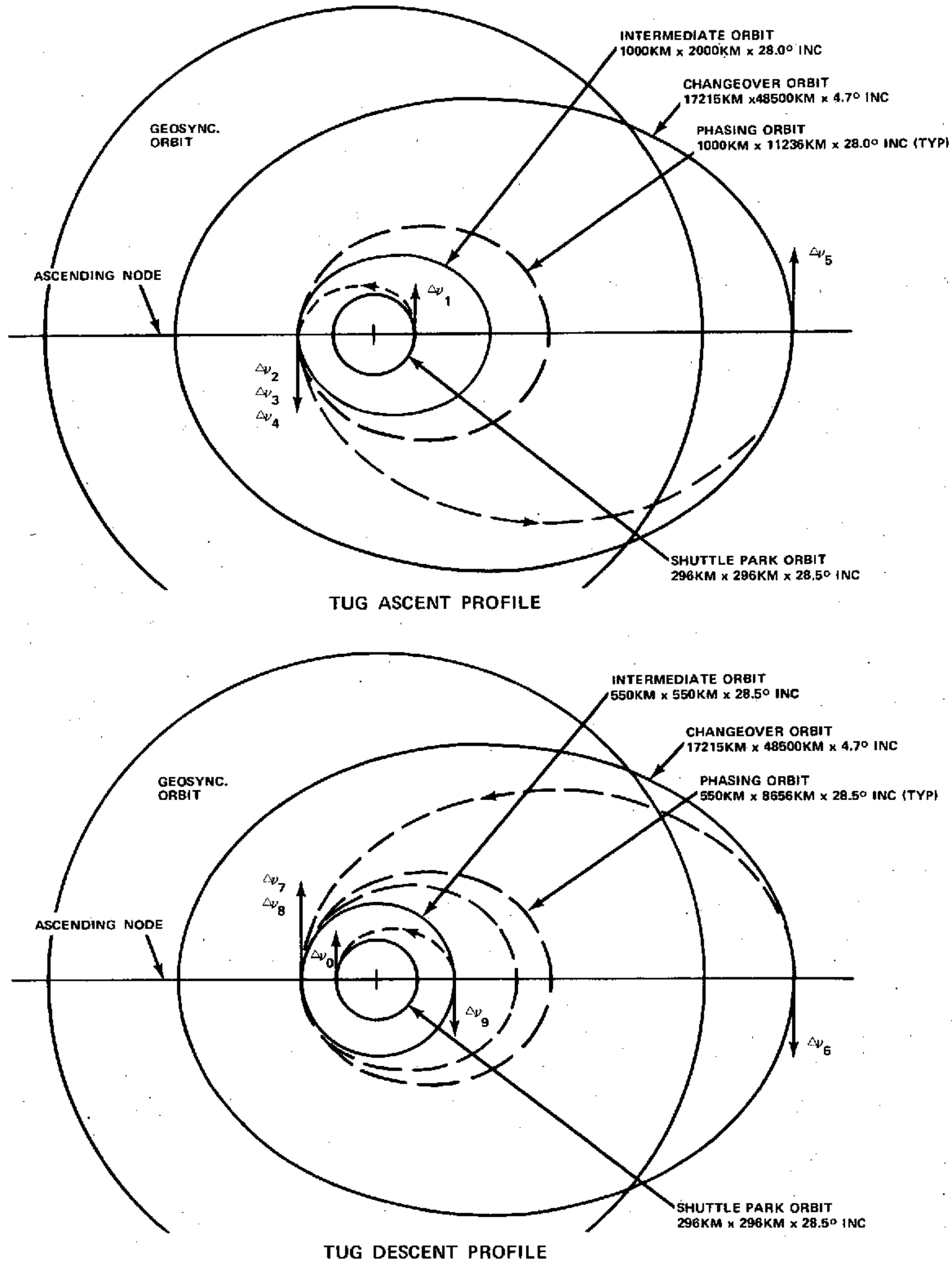


Figure 4-4. REFERENCE TRAJECTORY PROFILE

Table 4-1. EVENT TIMES ON REFERENCE TRAJECTORY PROFILE

MISSION TIME (Days)	TIME FROM SHUTTLE LAUNCH	EVENT	MASS (Kg)	PROPELLANT MASS (Kg)	BURN TIME	
SEPS DESCENT						POWER (kw)
0.00	-38.9 days	SEPS docked with payload at 80°W Longitude	2,194	604		15.3
		Longitude shift (20°W)			2.3 days	
2.30	-36.6 days	SEPS docked with payload at 100°W Longitude	3,546	597		15.3
		Descent to changeover orbit			36.6 days	
38.90	0.0 days	SEPS and payloads at changeover orbit	3,430	481		15.2
SHUTTLE ASCENT						
38.90	0.0 hours	Shuttle Launch				
39.02	2.9 hours	Orbiter injection on park orbit over 154° West Longitude				
TUG ASCENT						ΔV (m/sec)
39.02	2.9 hours	Start coast to descend node (1.32 revs)	28,622	22,409		
39.10	4.9 hours	Initiate transfer to 540 n mi (ΔV_1)	28,622	22,409	80.1 sec	191.
39.14	5.7 hours	Inject on 540 x 1080 x 28.0° orbit (ΔV_2)	24,907	18,695	165.0 sec	421.
		Drop intermediate payload and coast to ascend node (1 rev)	24,492	18,695		
39.22	7.6 hours	Inject on phasing orbit (ΔV_3)	18,568	12,770	391.0 sec	1219.
		Coast to ascend node (1 rev)				
39.39	11.8 hours	Initiate transfer to changeover apogee (ΔV_4)	18,568	12,770	240.0 sec	960.
39.70	19.3 hours	Inject on changeover orbit (ΔV_5)	11,828	6,030	204.8 sec	1026.
40.15	30.0 hours	Rendezvous with SEPS (1/2 rev)	11,828	6,030		
TUG DESCENT						
40.36	35.0 hours	Interchange Tug and SEPS payloads and coast to descend node (1/2 rev)	10,482	6,030		
40.60	40.8 hours	Initiate transfer to 297 n mi x 28.5° (ΔV_6)	10,482	6,030	147.5 sec	1056.
40.91	48.3 hours	Inject on phasing orbit (ΔV_7)	6,233	1,780	132.9 sec	1232.
		Coast to ascend node (1 rev)	6,233	1,780		
41.05	51.5 hours	Inject on 297 n mi x 28.5° orbit (ΔV_8)	4,652	200	104.4 sec	1288.
41.12	53.1 hours	Rendezvous with intermediate payload (1 rev)	4,652	200		
		Retrieve intermediate payload	4,942	200		
		Coast to phase with orbiter (10-1/2 revs)				
41.82	69.9 hours	Initiate transfer to Shuttle orbit (ΔV_9)	4,942	200	5.2 sec	71.
41.85	70.7 hours	Inject on Shuttle orbit (ΔV_{10})	4,785	42	5.2 sec	72.
SHUTTLE DESCENT						
41.91	72.2 hours	Rendezvous with Tug (1 rev)				
		Deorbit				
SEPS ASCENT						POWER (kw)
40.36	35.0 hours	Begin ascent from changeover orbit	4,776	481		15.2
		Ascent to geosynchronous orbit			50.4 days	
90.76	51.9 days	SEPS and payloads in geosynchronous orbit at 30° West Longitude	4,628	334		15.0
		Deploy payloads at 30° West Longitude	2,588	334		
		Longitude shift (132° West)			6.5 days	
97.26	58.4 days	SEPS and payloads at 162° West Longitude	2,567	313		15.0
		Deploy payload at 162° West Longitude	1,922	313		
		Longitude shift (63° West)			3.9 days	
101.16	62.3 days	SEPS and payload at 135° East Longitude	1,910	301		15.0
		Deploy payload at 135° East Longitude	1,544	301		

Section V

MISSION PREPARATION

5.1 DEVELOPMENT AND PRODUCTION

During the development phase a test article will be used in a qualification program to verify that a specific design is ready for production. Eleven SEPS will be manufactured in a single run at the most cost effective production rate. Spare or repair parts for both the flight articles and the ground support equipment (GSE) will be produced at this time.

Figure 5-1 defines the relationship between the major functions of the development and production phase. These functions are discussed in the following subsections.

5.1.1 Block 1.1 SEPS Development

Development tests and analysis will be performed to verify the feasibility of the selected design approach. This testing will evaluate hardware performance, failure modes, maintainability characteristics, and safety factors

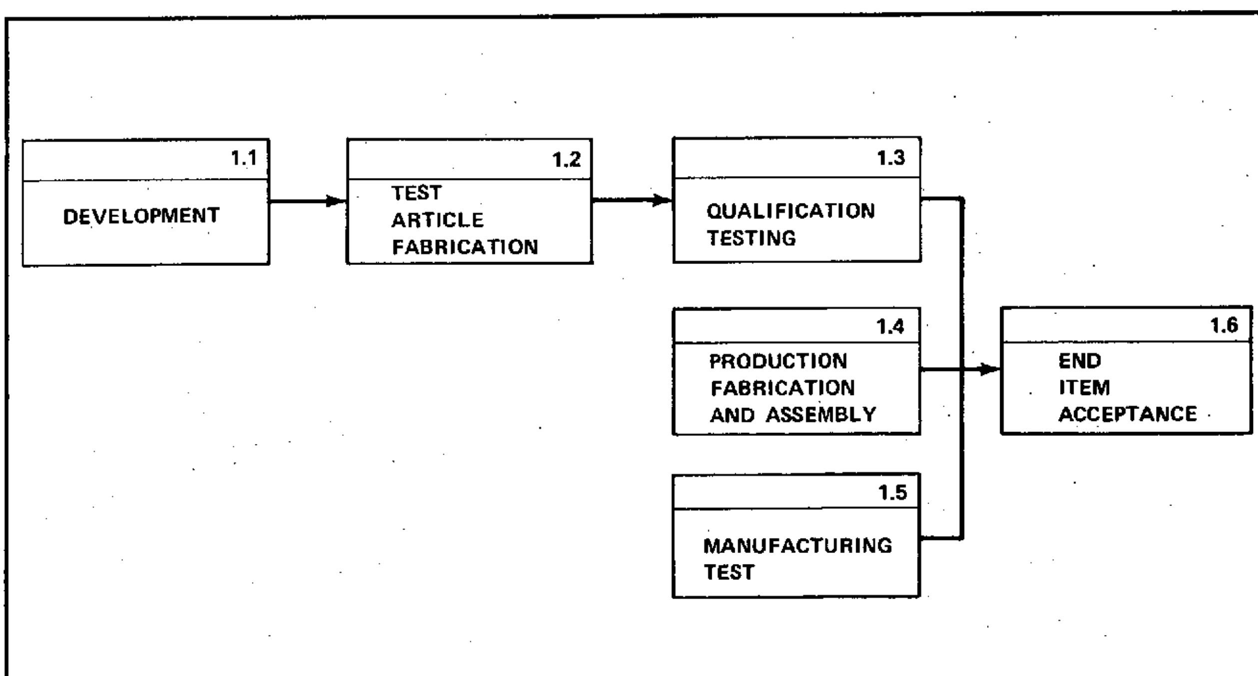


Figure 5-1. DEVELOPMENT AND PRODUCTION PHASE

required by the qualification criteria. Particular attention will be paid to (1) the performance of the ion thrusters, (2) the performance and control characteristics of the manipulator system, (3) the reliability of the solar array deployment mechanism, and (4) reliability and mission flexibility of the navigation and guidance, communications, and data systems.

In developing SEPS, first consideration will be given to the use of existing hardware whose performance meets the minimum SEPS requirements. Additional subsystem capability will be traded against realistic extensions of the mission model and evaluated against cost.

5.1.2 Block 1.2 Test Article Fabrication

A test article shall be fabricated using subsystems that have been individually qualified. The overall configuration shall match the flight configuration which is proposed for production. Each component or "black box" shall be qualified as a flight unit before inclusion in the test article. The completed unit will undergo first article inspection (FACI) and tests to verify conformance with specifications. This test article shall be subjected to the qualification test program described in the next subsection.

5.1.3 Block 1.3 Qualification Testing

Qualification tests and analyses will be performed to verify that the test article performs to its design margins. During the ground phase, each subsystem will be required to perform within specification. The ion propulsion system will be tested in a thermal vacuum chamber. Power will be provided by the airborne power processors. The solar arrays will be simulated by a ground power supply. The guidance and control system and the data management system will be functionally tested using simulated flight programs. The manipulator system will be tested without a load in a 1G environment. This qualification test article will be maintained as a sustaining engineering "hangar queen" throughout production. It will be refurbished at the end of production to become the second spare SEPS. Earth orbital tests are performed on SEPS as described in Volume II.

5.1.4 Block 1.4 Production, Fabrication, and Assembly

In concert with qualification activities, fabrication of flight articles to the production configuration will be initiated. Eleven units will be required; eight for planetary and three for earth orbital missions (including 1 spare). The refurbished qualification test article provides the second spare.

5.1.5 Block 1.5 Manufacturing Test

As part of the manufacturing process each production unit will be thoroughly tested to verify conformance with the specifications. The government inspection agency will certify each component through a test program at the vendor's plant. For example, each thruster subsystem will be checked in a thermal vacuum chamber before being assembled into a production unit.

As each subsystem is assembled, tests will be conducted to ensure that in-tolerance outputs are produced while the subsystem is operating with marginal inputs. Figure 5-2 identifies the subsystem tests to be performed at the end

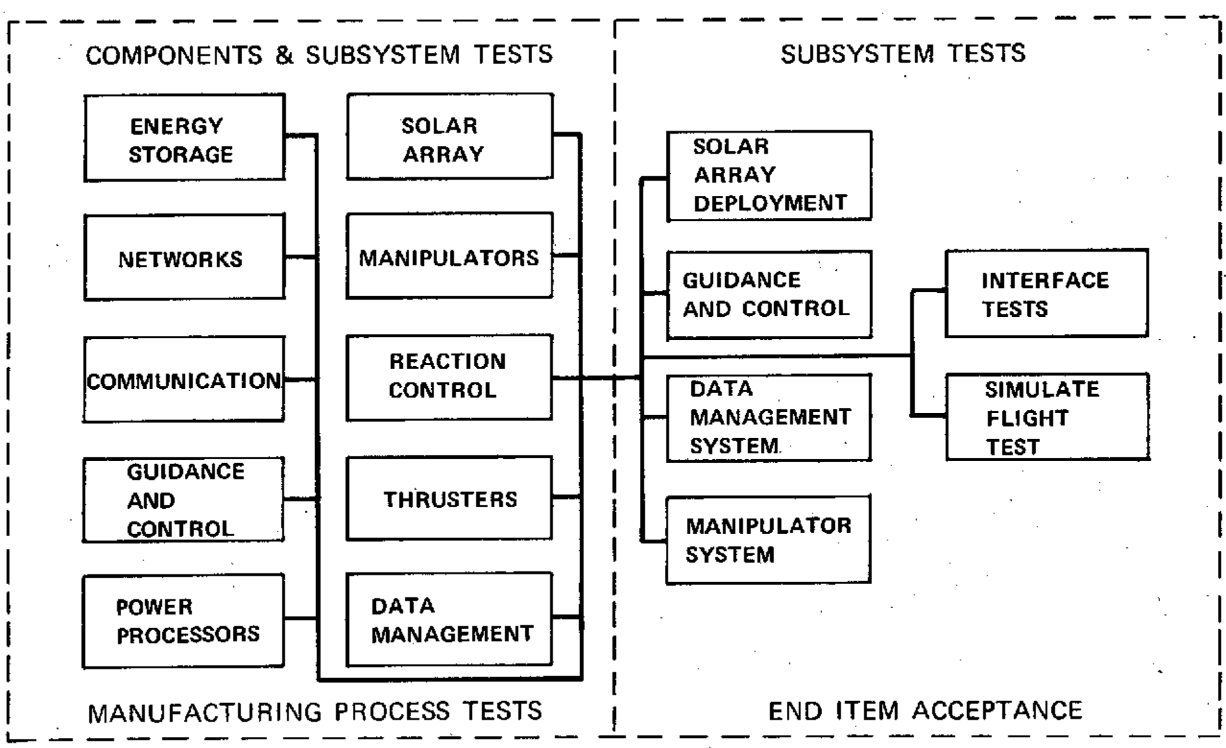


Figure 5-2. MANUFACTURING AND ACCEPTANCE TESTING

of the manufacturing process; the NASA resident shall certify that SEPS meets the design specification before each unit is presented for acceptance.

5.1.6 Block 1.6 End Item Acceptance

End item acceptance testing will be performed at the manufacturer's facility to establish flight readiness. Figure 5-2 identifies the tests required to supplement the inprocess manufacturing tests. Functional tests will be conducted by SEPS operations personnel to verify compatibility between subsystems.

The solar array deployment mechanism will be tested under simulated orbital conditions by deploying the solar blankets over an air table. The manipulator system will be operated in a 1G environment. Flight software and the flight computer will control the system. A simulated flight test will check the guidance and control system including its interaction with the data management system.

Flight readiness of the SEPS will be certified; at completion of these tests SEPS is placed in a sealed container and is ready for transport to the launch site or to the SEPSOC inventory.

5.2 SEPS GROUND OPERATIONS

SEPS ground operations are based on a "ship-and-shoot" philosophy. At the launch site, SEPS will be treated as a passive payload. It will be integrated with other payloads in a transport half shell.

All of the functions necessary to verify that SEPS is flight ready will be accomplished at the SEPS operational center prior to shipment to the launch site. The testing will be rigorous to the point that no further testing is required. The same equipment and software used in the end item acceptance testing will be used to reverify flight readiness.

The flight units will be protected from transportation damage by the original storage container. At the launch site the SEPS will be installed in a half shell along with other payloads. After the propulsion systems are serviced, SEPS will be a passive element during Shuttle/Tug launch operations.

Figures 5-3 and 5-4 depict the routing and identify the ground operations necessary to prepare for launch.

A timeline is presented in Figure 5-5.

The operations concept outlined above is based on a cost effectiveness evaluation. The factors evaluated against total operational cost for the 11-year mission model were:

- The number and skill mix of personnel required in peak flight operations activity periods. The flight control center will be in active control of SEPS about 5 percent of the lapsed time for a mission sortie.
- The ground operations must (1) prepare 12 units for launch, (2) refurbish two flight units, (3) prepare 6 refueling kits, and maintain the SEPS ground support equipment. This is also a low density function over the 11-year mission cycle.
- The cost of a central facility at a NASA host center capable of both ground and flight operations support is low in relation to the cost of personnel sustained over 11 years.

The study indicates that by using this operational concept a 45-man multi-disciplined organization can handle all functions during the operational phase. Without using the "ship-and-shoot" philosophy the personnel numbers and costs would be much higher.

5.2.1 Block 2.1 Storage (Figure 5-4)

After the completion of end item acceptance testing, SEPS will be placed in a combination storage and shipping container. The container will be sealed and pressurized with an inert gas. The SEPS will be shipped to the SEPS Operational Center (SEPSOC) and stored in the launch preparation area. Figure 5-6 shows a floor plan of this facility. During the 6-year storage period, the status will be monitored. The container must have an external interface connector to enable the monitoring without breaking the hermetic seal. The SEPSOC launch preparation area will provide storage for the repair parts and refueling kits. The repair parts will be required for refurbishment of two flight units and for maintenance of ground support equipment.

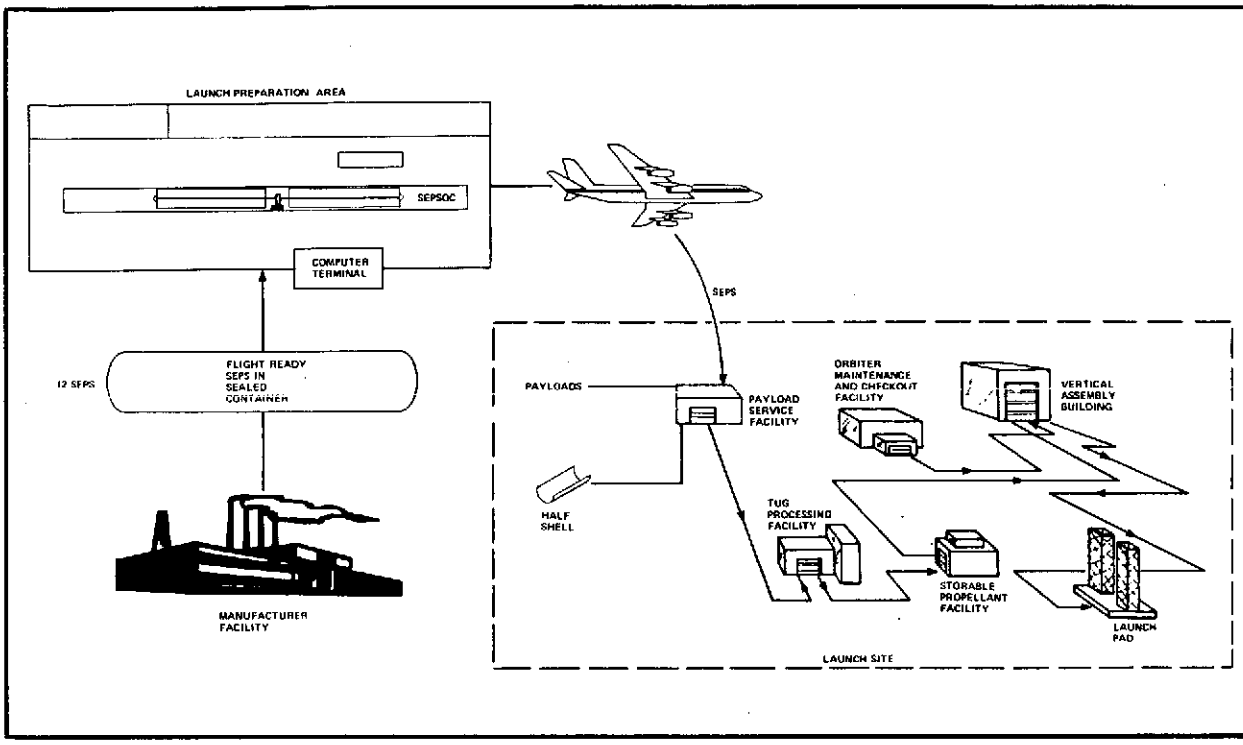


Figure 5-3. SEPS LAUNCH PREPARATION

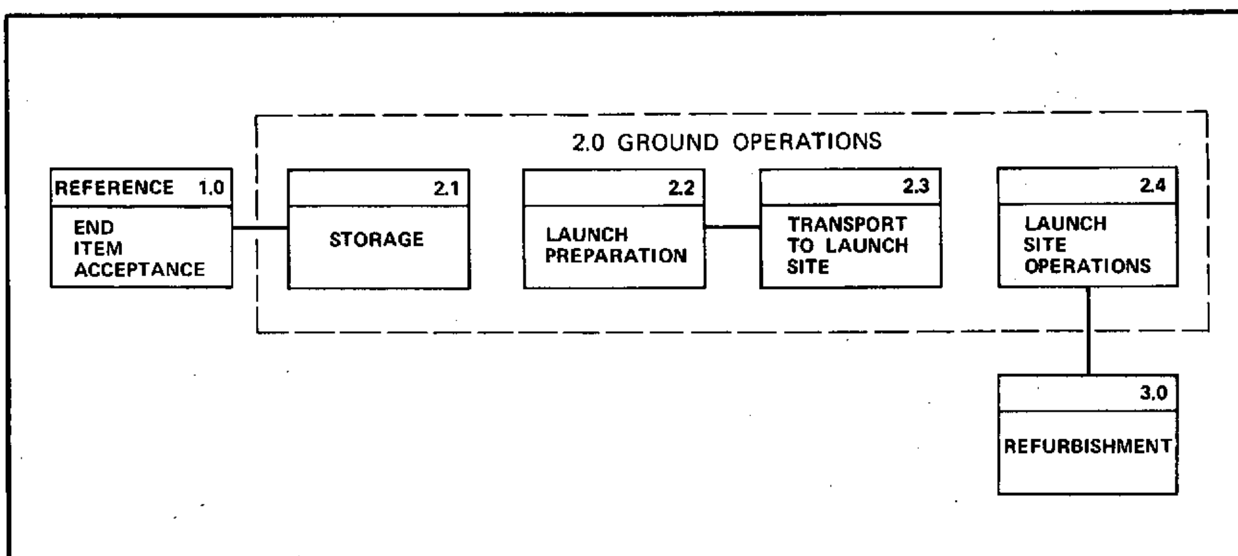


Figure 5-4. GROUND OPERATIONS FLOW

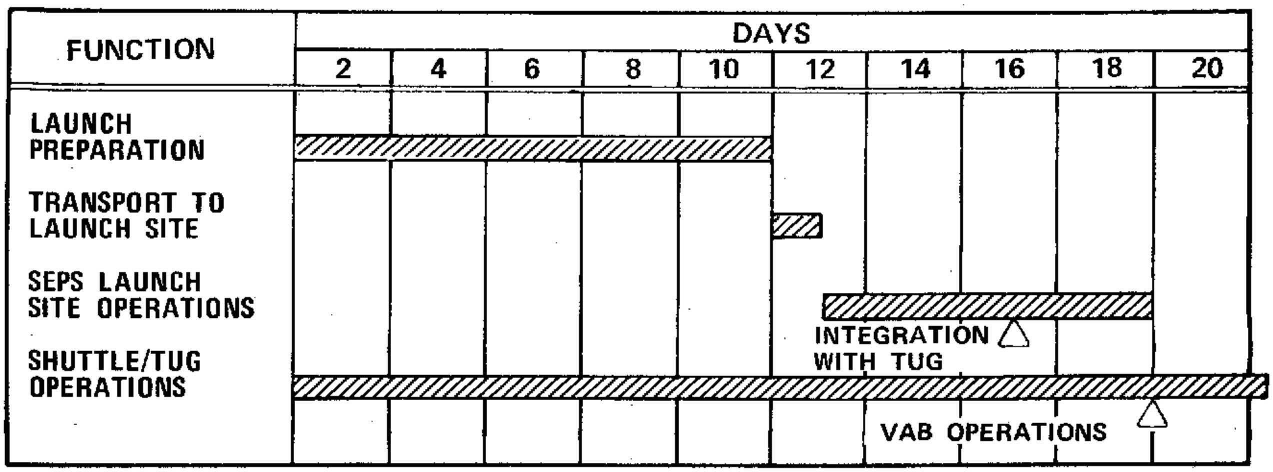


Figure 5-5. GROUND OPERATIONS TIMELINE

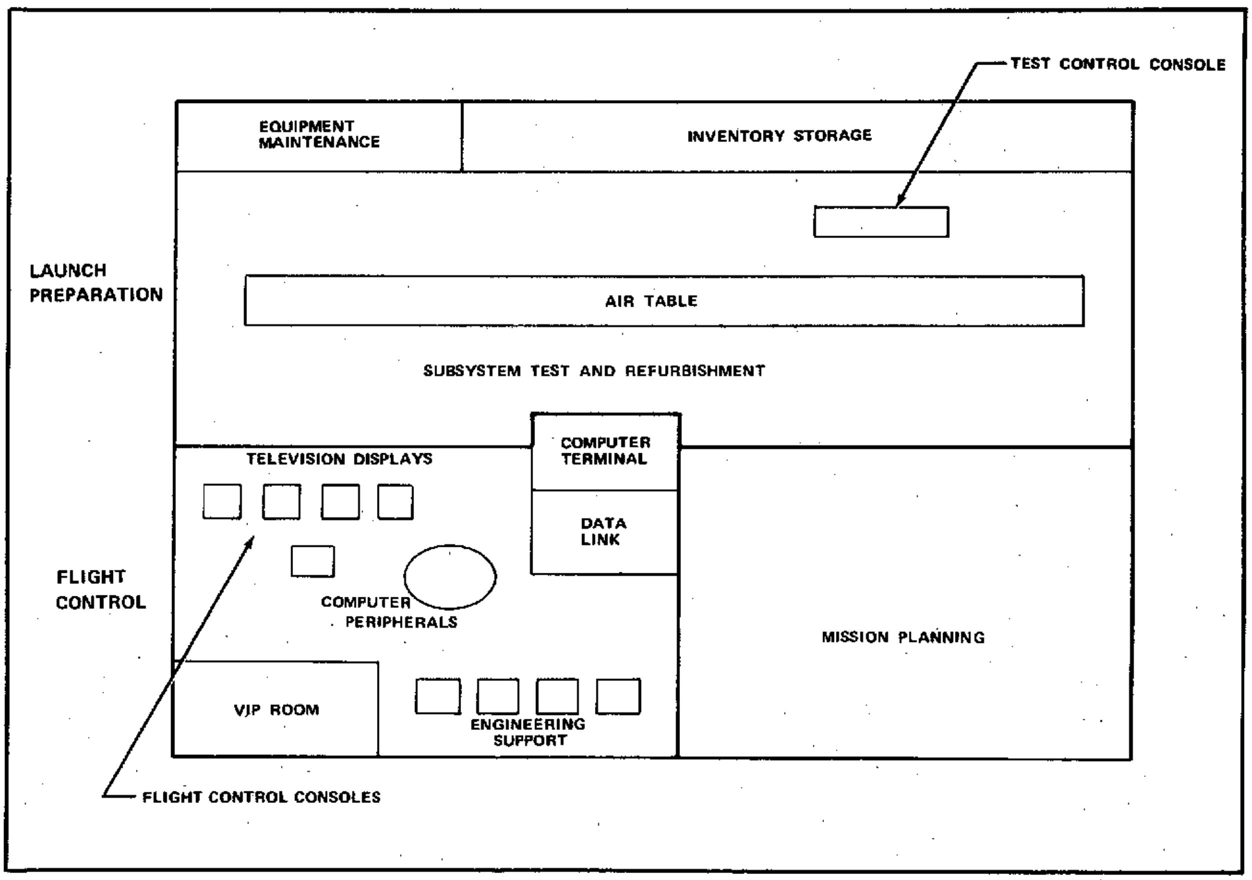


Figure 5-6. SEPS OPERATIONS CENTER (SEPSOC)

5.2.2 Block 2.2 Launch Preparation

SEPS launch preparation will begin at the SEPSOC about 30 days before launch. The unit may have been in storage for up to 6 years. A thorough checkout will be performed to reverify flight readiness. The end item acceptance tests will be rerun using identical test equipment. Subsection 5.1.6 discussed this testing. Additional tests and inspections will be performed to ensure that time in storage has not altered the unit's flight readiness status. Any required modifications determined to be absolutely essential as a result of previous SEPS operations will be accomplished by the launch preparation team. A timeline of the SEPSOC launch preparation functions is presented in Figure 5-7. The SEPSOC launch preparation area will be maintained to a reasonable cleanliness standard to prevent contamination.

5.2.3 Block 2.3 Transport to Launch Site

The original storage container will be used to protect SEPS during air transport to the launch site. The total process will take about 24 hours. A timeline is presented in Figure 5-8.

Acceleration will be monitored to ensure that SEPS is not damaged in transit. Due to the high g load design factors for orbiter crew safety, SEPS is an extremely tough flight article. Upon arrival at the launch site the unit will be taken to the payload service building for installation into the payload transport shell.

5.2.4 Block 2.4 Launch Site Operations

Upon arrival at the launch site, SEPS will be taken to the payload service facility. Here, it will be removed from the storage/transport container and assembled into a transport shell with other payloads.

The assembly will be routed to the Tug processing facility where the transport shell will be mated to the Tug. The SEPS ion propulsion system will be serviced in either the storable propellants facility or when installed in the transport shell. This is a simple operation using the inflight refueling kits. SEPS requires about 900 kg of mercury (Hg), 113 kg of hydrazine, and

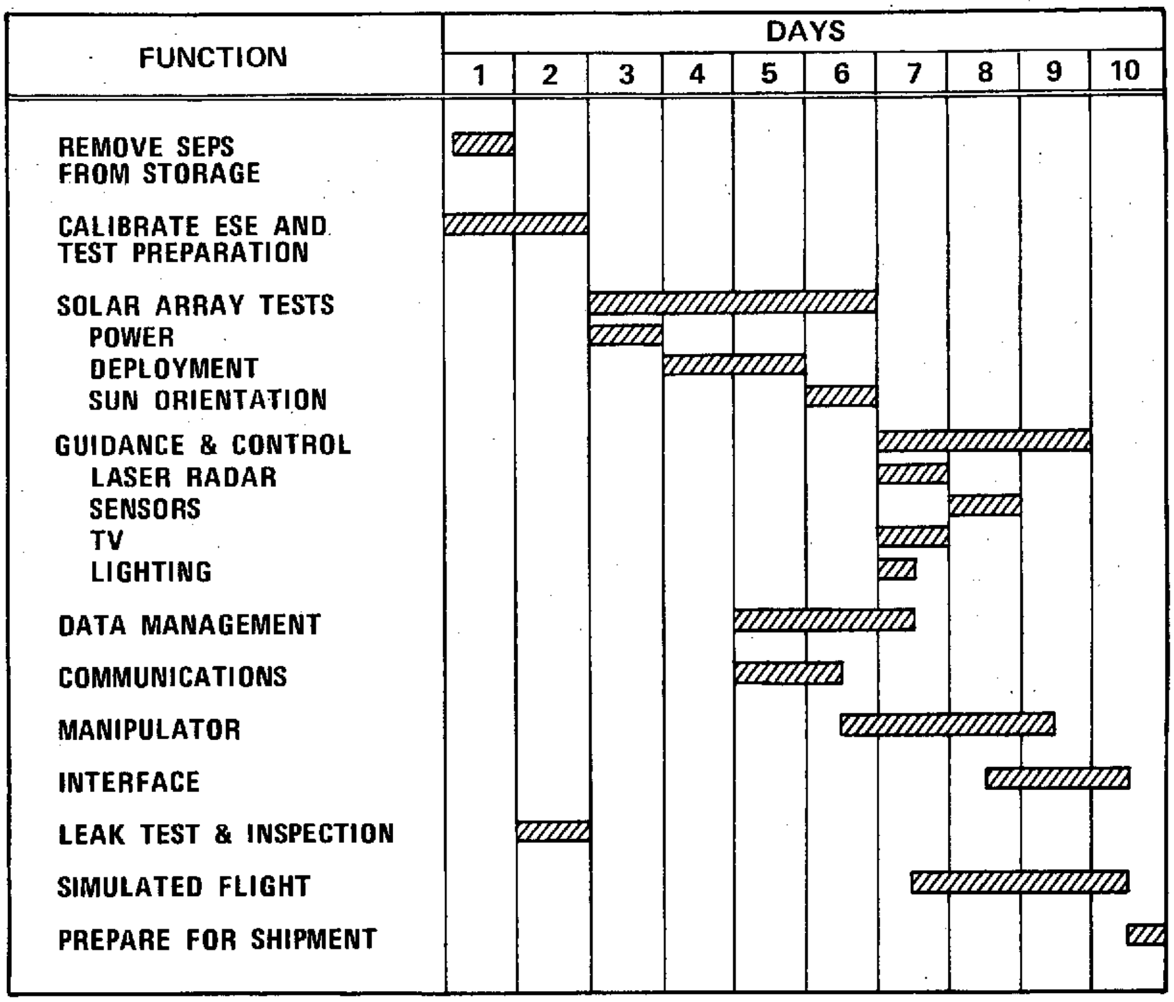


Figure 5-7. LAUNCH PREPARATION TIMELINE

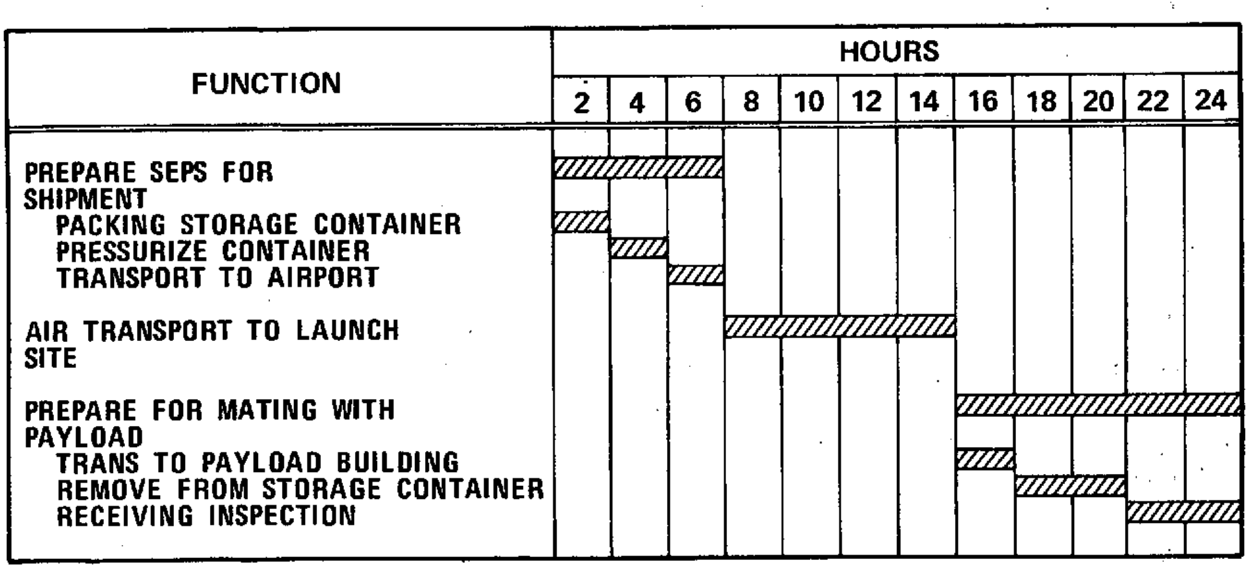


Figure 5-8. TRANSPORT TO LAUNCH SITE TIMELINE

GN2 to pressurize the propellant tanks. From this point on, SEPS becomes a passive passenger through all Tug/Shuttle operations except for a requirement of up to 200 watts of power, primarily for thermal conditioning.

It is important to note that this processing almost completely implements a "ship-and-shoot" concept.

- In-process manufacturing tests and the end item acceptance process has guaranteed that each unit is flight ready.
- The launch preparation testing at the SEPSOC reestablishes this flight readiness after storage.
- The SEPS side of all physical and functional interfaces will be verified at the SEPS operation center. These interfaces with Shuttle and Tug are minimal.
- No testing of any type except SEPS payload interface verification will be required at the launch site.
- The inert atmosphere in the storage container will prevent deterioration as a function of storage time.
- SEPS will be treated as "just another payload" in the Shuttle/Tug launch preparation cycle.

A timeline of launch site operations is presented in Figure 5-9.

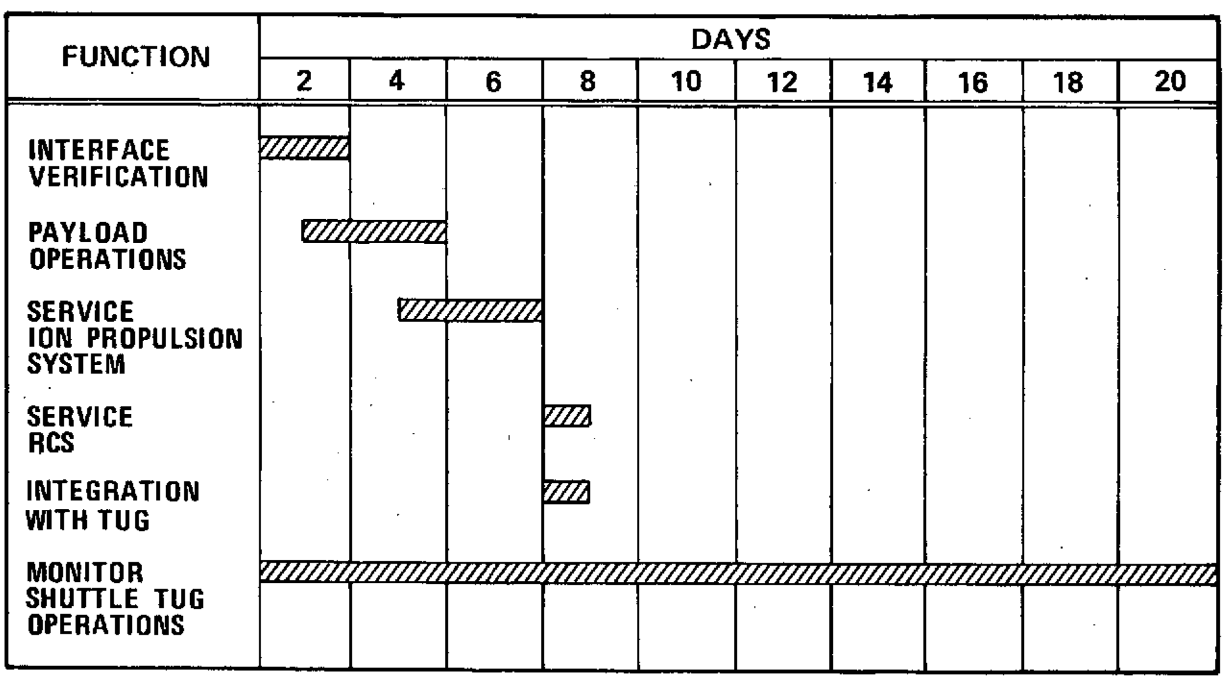


Figure 5-9. LAUNCH SITE OPERATIONS TIMELINE

5.3 REFURBISHMENT

The study analysis indicates that it will be cost effective to refurbish the development test article and the first earth orbital SEPS. This refurbishment will consist of the replacement of components designated as line replaceable units (LRU). Only those LRU's which have failed or which trend analysis indicates are about to fail will be replaced.

The magnitude of this task is expected to be small. The system is largely solid state electronics which does not degrade or become less reliable as a function of time if operation remains within specified limits. It is estimated that about 25 percent of each flight unit will be replaced. The aim will be to return each unit to "good as new" functional reliability. Original performance or peak efficiency will not be required. After the replacement is complete each unit will undergo flight readiness testing at the SEPSOC using the same equipment as used in the launch preparation function. Special production equipment, if required or desirable, for refurbishment will be transferred to SEPSOC after production is complete.

Advances in test evaluation techniques make it possible to avoid an extensive ground test program. The SEPS subsystems will be instrumented at the LRU level, a flight data recorder will be used for short term storage, and the data will be downlinked as part of the normal telemetry cycle. Fault isolation and trend analysis can be accomplished by comparing abnormal status data against analytically derived fault patterns. The SEPSOC staff will accomplish this task as an off-line function while SEPS is still in flight. Table 5-1 identifies the LRU's which may be replaced during refurbishment. An estimate of the percentage of each item that must be replaced to restore SEPS to a "good as new" condition is identified in this table.

The complete refurbishment of a single flight unit will require 60 days. The major activities are identified in Table 5-2. It will be accomplished by the operational staff in the launch preparation area of the SEPSOC.

Table 5-1. FLIGHT UNIT REFURBISHMENT COMPONENTS

ITEM	REPLACEMENT PERCENTAGE
Thrusters (9)	25
Solar Extension Mech	50
Solar Panels (98)	50
Solar Array Deploy (2)	25
Command Receivers (2)	50
Command Decoder Units (2)	50
Computer	50
Tape Recorders (2)	100
Batteries (2)	100
Heaters	50
Thermal Coatings	100
Hard Dock Mechanism	50
Umbilical Connector	100
Horizon Sensor (1)	15
Star Tracker (2)	20
Laser Radar	20
TV Camera (2)	75
Lights	100

Table 5-2. SEPS REFURBISHMENT ACTIVITIES

	MAN-HOURS
Receive and prepare for refurbishment	34
Post flight visual inspection	72
Flight data analysis	65
Develop maintenance repair schedule	24
Remove and replace thrusters	242
Remove and replace power conditioner	16
Switching matrix and cabling checkout	96
Inspect thruster array structure and gimbals	16
Remove and replace solar arrays	568
Structures and mechanisms inspection and checkout	140
Communications equipment maintenance	160
Command computer maintenance	140
Data handling system maintenance	72
Stage power and distribution system maintenance	130
GN&C sensor refurbishment	348
RCS maintenance	264
Remove and replace thermal control heaters	152
Thermal control subsystems inspection and checkout	64
Thermal coating renewal	612
Docking mechanism inspection and checkout	140
Cabling checkout	224
Mercury tank pressurization and leak check	36
ACS fluid systems leak check	30
Subsystems and integrated systems test	204
Post-test fault correction and reverification	119
Secure from maintenance and checkout	48
Prepare for storage	66
TOTAL	4082

5.4 DESIGN REQUIREMENTS

5.4.1 Flight Hardware Maintenance and Test Requirements

The mission preparation functions will impose the following requirements on the flight hardware:

- A test connector is required which makes all data management system functions and stored data available to the ground test equipment.
- Access to the test connector through the SEPS/Tug interface will be required.
- A ground power connector to the solar array is required.
- An N_2O_4 and mercury refueling system is required. The inlets must be accessible after SEPS is assembled into the half shell. Refueling will be accomplished with the flight kits.
- A GN2 inlet system is required to pressurize the mercury tank and the ACS tank.
- GN2 pressure sensors are required to measure fuel tank pressure.
- Simulated flight software will be required.
- The flight system instrumentation shall be capable of complete function status reporting and of fault isolation down to LRU levels as a minimum.
- Each subsystem shall be constructed so that LRU units can be removed in the refurbishment cycle and during launch preparation.
- The flight computer shall be compatible with a ground institutional computer such as an IBM 360.
- The flight computer operating system shall be capable of using GOAL and HAL compilers.

5.4.2 Ground Support Requirements

The mission preparation functions require the following ground support elements.

- A launch preparation area of the SEPSOC facility with storage for eleven SEPS and repair parts for refurbishment and maintenance of GSE. This facility must be approximately 300 x 50 feet. It will also contain an area for launch preparation testing. Figure 5-6 presents a floor plan of this facility.
- Two sets of dual purpose test equipment for (1) end item acceptance and (2) launch preparation. The major items are a test control console (Figure 5-10), an air table to support the solar arrays during test of the deployment mechanism, a ground power supply, and a computer terminal.

- Special tools to remove and replace Line Replaceable Units (LRU's) during refurbishment.
- LRU designated as repair parts for refurbishment and launch preparation potential use.
- Two refueling kits.
- Nine storage and transport containers.
- Transport half shells (Tug program).
- Test type applications software.

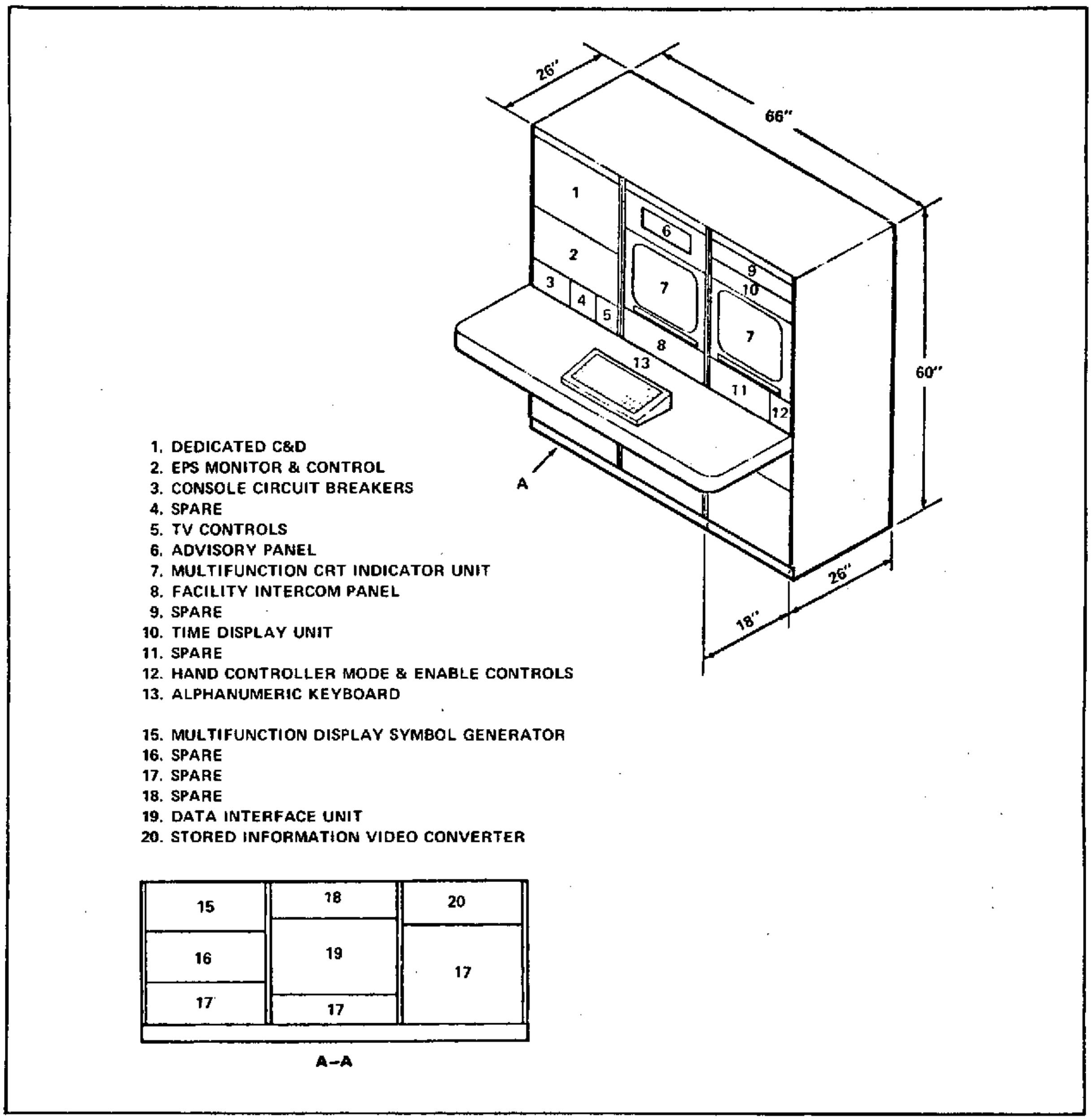


Figure 5-10. TEST CONTROL CONSOLE

Section VI

TYPICAL MISSION SORTIE

Table 4-1 presented a timeline of the flight segments flow by SEPS, Tug, and the Shuttle orbiter in a representative sortie. The SEPS activities in a representative sortie are presented in the functional flow of Figure 6-1. Each activity will be discussed in the subsections with a matching number.

A sortie may be characterized as a long flight cruise period when SEPS is autonomous, interspersed by infrequent activities which require a "man-in-the-loop." Rendezvous and payload handling functions justify manned monitoring or control, or both. These functions are low density, consuming only about five percent of the total sortie time.

This NSI study recommends a baseline SEPS with a manipulator system with the operational flexibility to handle all payloads without imposing configuration constraints. The baseline SEPS will have an avionics system capable of autonomous operation during the cruise mode. Tracking and navigation updates from the ground will be required about once a week. The baseline computer is the Space Ultra-Reliable Modular computer being developed by MSFC. The computer will come with a software operating system compatible with the HAL and GOAL compilers used by the Tug and Shuttle. The baseline SEPS includes laser radar and TV to assist the operator in the "man-in-the-loop" activities.

These baseline characteristics will enable a small group of multi-disciplined technical people to accomplish all of the direct mission sortie and operation support functions. The support functions include mission planning, interface configuration management, logistics, procedure and software modifications, flight data evaluation, equipment maintenance, and all launch preparation activities.

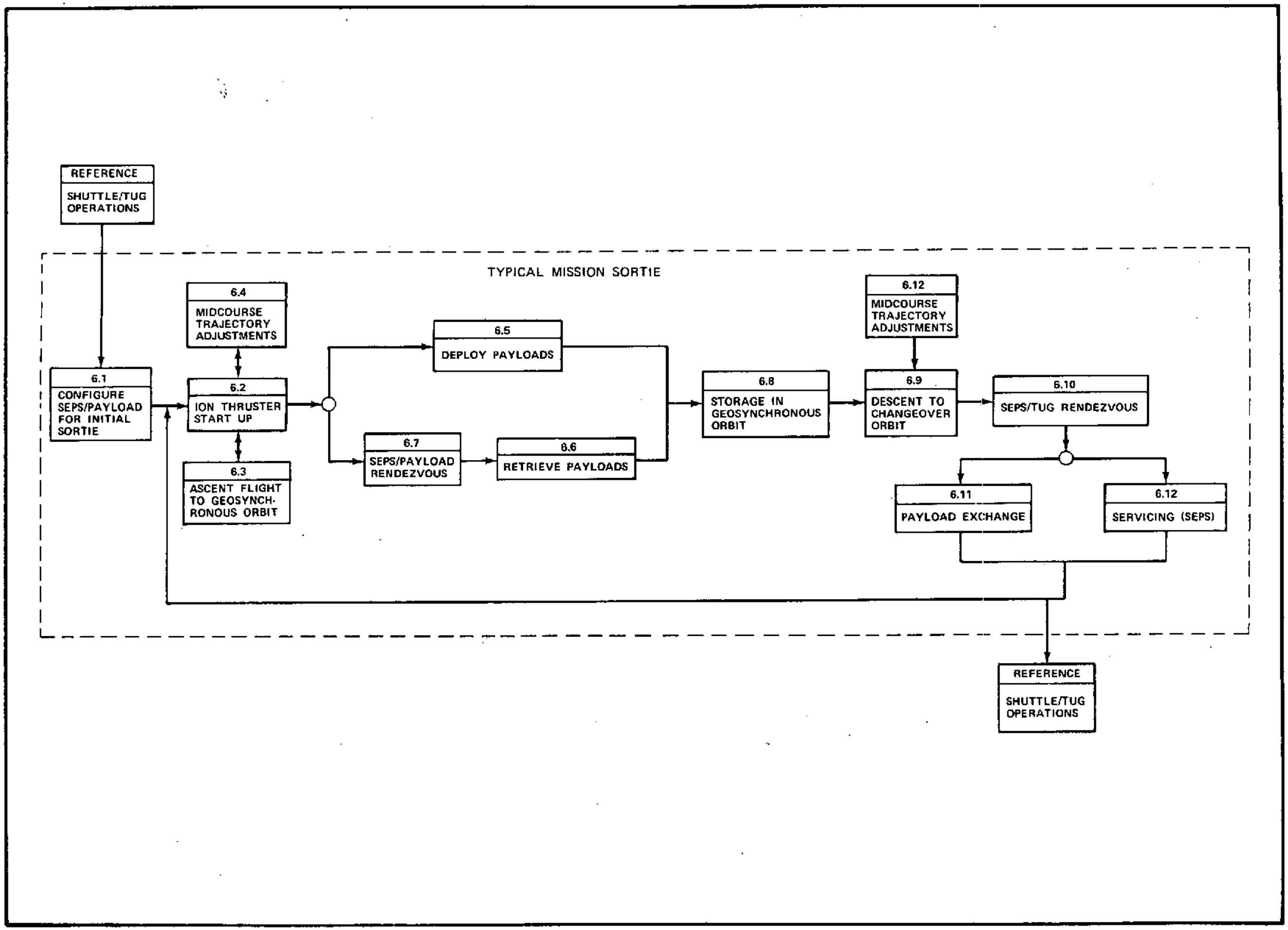


Figure 6-1. MISSION SORTIE FUNCTIONAL FLOW

A timeline showing the relationship between man-in-the-loop activities and autonomous flight functions is presented on Figure 6-2. It is evident that (1) SEPS is autonomous 95 percent of the time, (2) the payload handling system has a wide variety of tasks to perform, and (3) rendezvous and payload handling are low density functions.

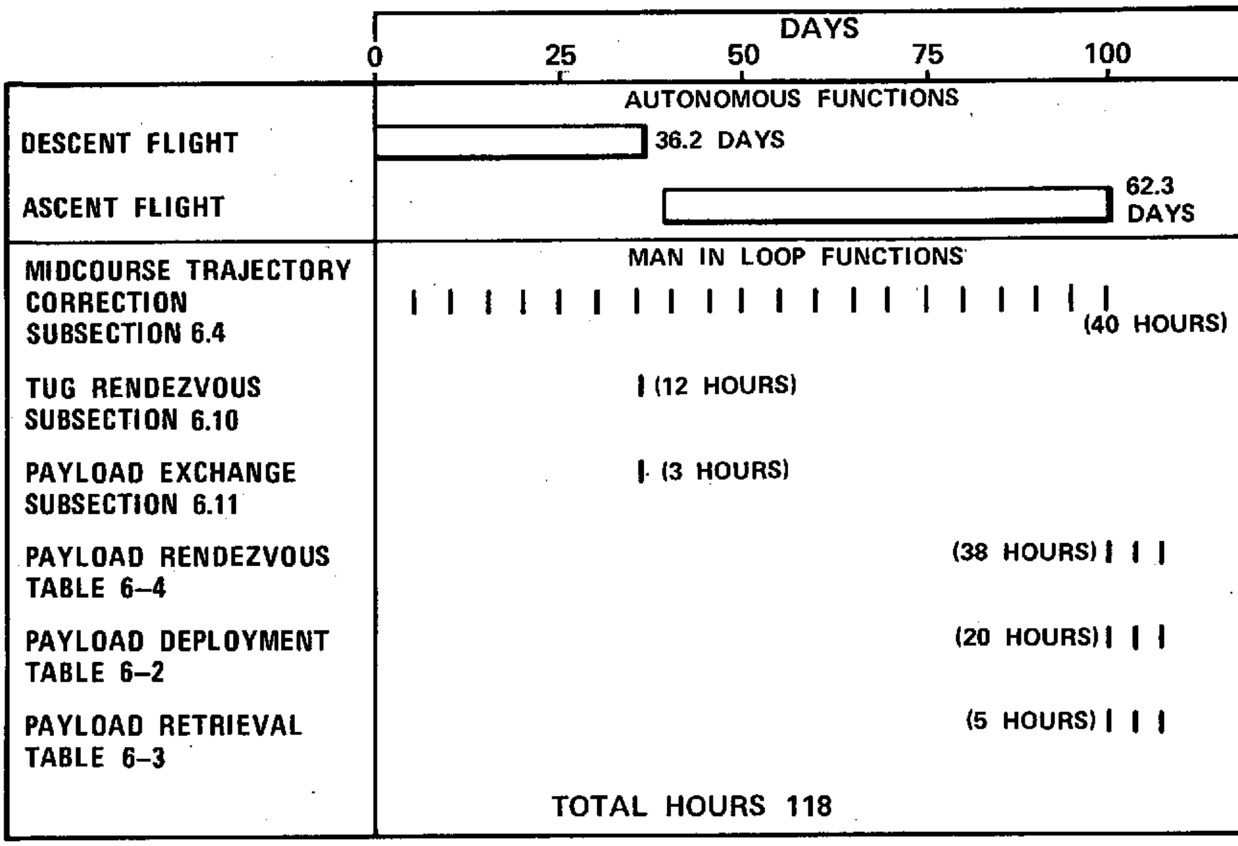
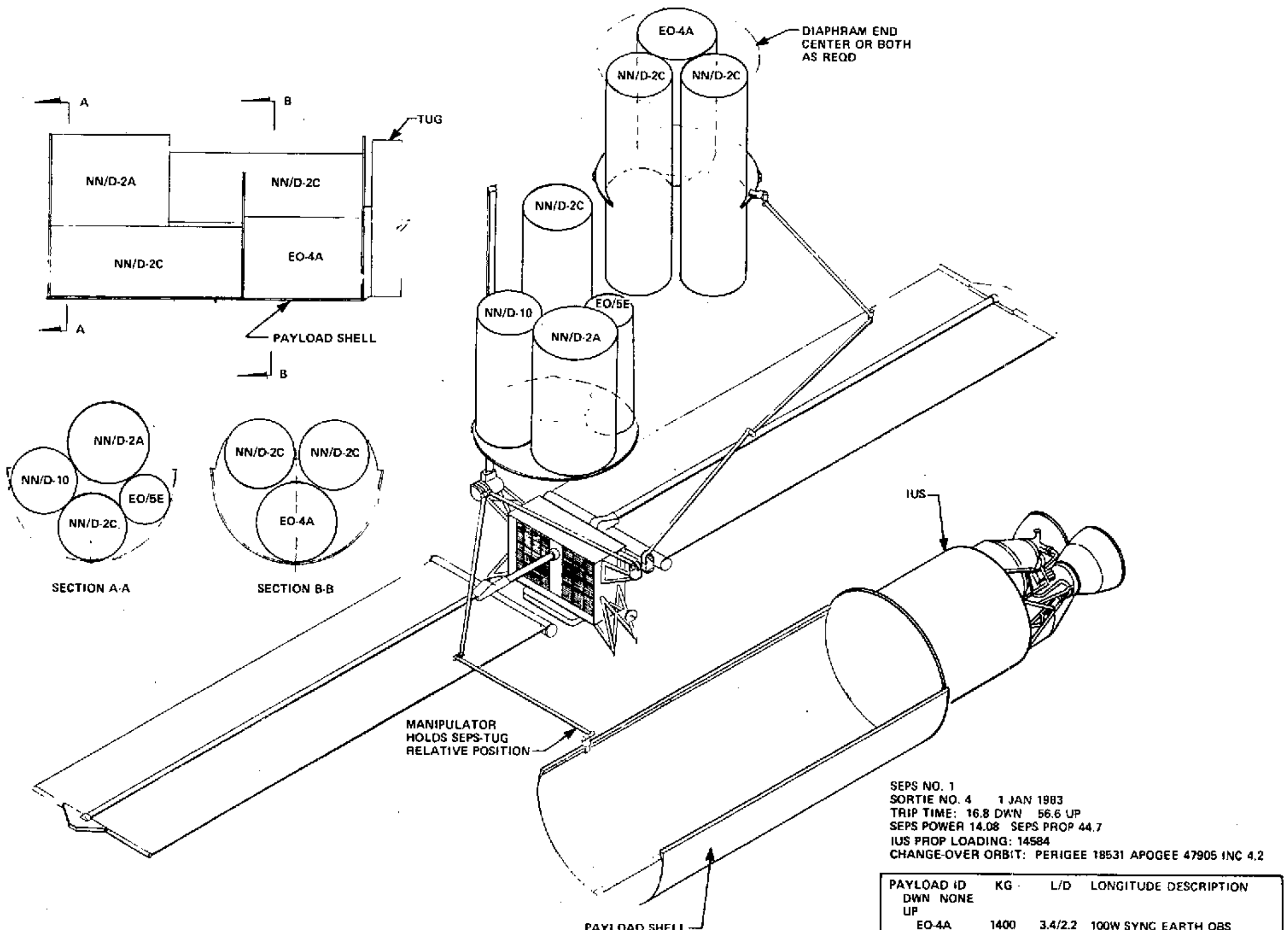


Figure 6-2. TYPICAL MISSION SORTIE TIMELINE

6.1 CONFIGURE SEPS/PAYLOADS FOR THE INITIAL SORTIE

Tug will arrive at its maximum energy orbit with SEPS and several payloads in the transfer shell.

Three options exist in the way payloads are handled in accomplishing the remaining transport functions of the sortie. In option #1, which is depicted on Figure 6-3, the payloads still mounted on the diaphragms are removed and clamped to SEPS' transport mast. In option #2, the Tug separates from the transport shell while SEPS is holding it with one manipulator, SEPS using the



SEPS NO. 1
SORTIE NO. 4 1 JAN 1983
TRIP TIME: 16.8 DWN 56.6 UP
SEPS POWER 14.08 SEPS PROP 44.7
IUS PROP LOADING: 14584
CHANGE-OVER ORBIT: PERIGEE 18531 APOGEE 47905 INC 4.2

PAYLOAD ID	KG	L/D	LONGITUDE	DESCRIPTION
DWN NONE				
UP				
EO-4A	1400	3.4/2.2	100W	SYNC EARTH OBS
EO-5E	306	2.9/1.4	–	APPLICATION EXP.
NN/D-2C	441	5.5/1.9	N/A	US DOM SAT C
NN/D-2C	441	5.5/1.9	N/A	US DOM SAT C
NN/D-2C	441	5.5/1.9	N/A	US DOM SAT C
NN/D-2A	493	3.4/2.3	N/A	US DOM SAT A
NN/D-10	366	3.1/1.8	140E	GEOSYNC OPER MET SAT

Figure 6-3. PAYLOAD EXCHANGE SORTIE NO. 4

other manipulator, then transfers the shell to its transport mast. SEPS would then transport the payloads in the half shell to geosynchronous orbit.

In option #3, individual payloads can be removed from the half shell and clamped to the SEPS transport mast.

Which option is used depends upon the series of related sorties following and whether or not availability of the transport shell or diaphragms with SEPS will simplify subsequent operations. The SEPS requirements for the GPME and supporting functions are presented in subsection 6.1.3.

6.1.1 Event Description

Figure 6-4 shows one of the handling options in configuring the SEPS/payload assembly for the initial sortie. The event timeline in subsection 6.1.2 indicates the time allocated to accomplish the payload transfer on the initial sortie. As SEPSOC operators become more proficient, the time for this operation will decrease.

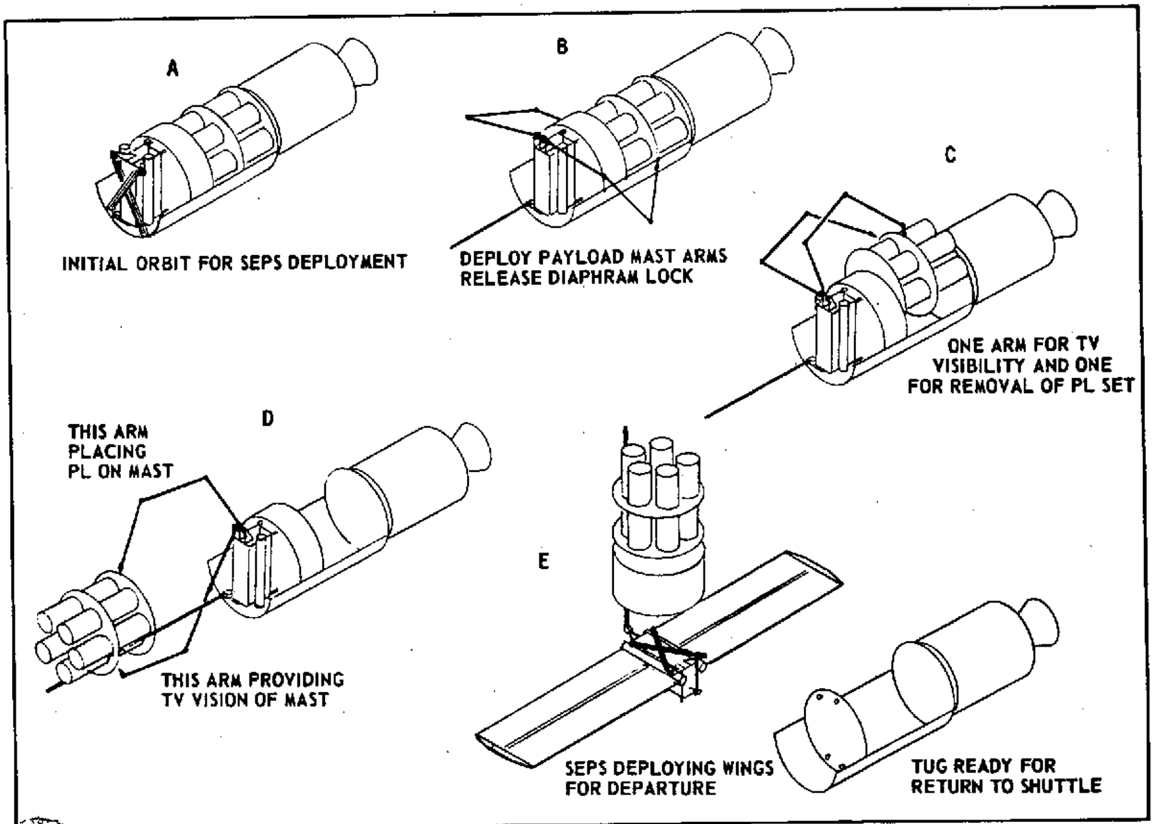


Figure 6-4. TRANSFER METHOD (OPTION #1)

6.1.2 Event Timeline

Event	ΔT (Min)	Time Completed
Arrive at transfer orbit		0
Activate all SEPS stage-keeping systems and data links	20	
Activate manipulator and check safety	10	30
Extend transport mast	5	30
Deploy solar array 25 percent	5	30
Activate TV system	5	35
Disable Tug RCS		35
Use manipulator to release diaphragm locks	5	35
Remove payload assembly #1 and clamp to transport mast	15	50
Remove payload assembly #2 and clamp to transport mast	15	65
Attach payload support umbilicals	15	80
Use manipulator to release SEPS to diaphragm locks	30	110
SEPS removes itself from half shell with manipulator	20	130
Manipulator pushes Tug away	5	135
Extend solar arrays 100 percent and check performance	20	2 hr. 35 min.

The manipulator system is commanded directly by the computer. The man's control task is simplified so that he only commands desired translation and rotation positions and rates of the manipulator end effectors. The computer's software is used to limit motion rates and to simplify the manned control problem. Approximately 8K bits of computer memory will be required to handle real-time control and monitor functions. The manipulator software controls each motor-driven joint separately. The software controls combination motions involving several joints.

6.1.3 Design Requirements

- The handling (manipulator) system shall have the ability to release and secure required latches and all locks.
- The manipulator system shall have the capacity to produce the torques necessary to allow it to be tested unloaded in a 1-g field, and the control precision to accomplish all functions indicated here and in Volume II.
- The manipulators shall be man controlled from the ground. The control software shall contain those restrictions necessary to prevent damage to either SEPS or the payloads.
- A visual monitor of payload handling shall be provided. TV cameras shall be located as necessary to enhance operator performance of all functions.
- The power supply shall provide average power of 96 watts. The peak power to the manipulators is 960 watts.

6.2 ION THRUSTER STARTUP

Figure 6-5 is an event timeline for startup of the ion thrusters that has been used in earlier phases of the ion thruster technology program. High voltage start techniques allow thrust to be established within minutes. The limiting factors in quick startup from cold soak conditions depend upon the peak power to be allocated to heaters and how nearly thermal equilibrium would be achieved. It is desirable that startup be achieved after earth shadow transit within 10 minutes.

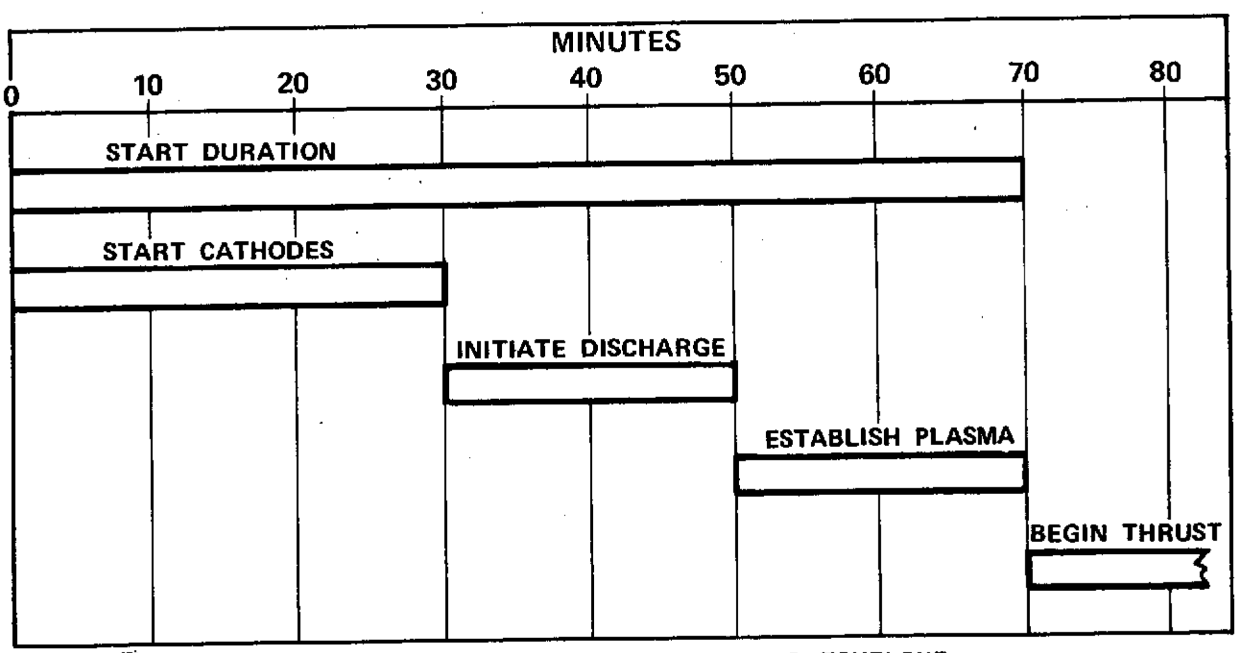


Figure 6-5. THRUSTER STARTUP TIMELINE

Active ground control is not required to start the thrusters, as the events are sequenced automatically.

The SEPS thruster startup periods impose trip time penalties proportional to the times required. Penalties occur during and subsequent to each shadow period. The worst cases are for the lowest changeover orbit perigee altitude of 5586 nautical miles and 8.2 degrees inclination. The maximum shadow period would be 1.8 hours (12 percent of an orbital period); depending on the nodal position of the orbit, it will normally be significantly less. Average shadow periods for this same changeover orbit are 40 minutes or less. These shadow data are shown on Figures 6-6 and 6-7. Thrust delay can be reduced following shadow period by initiating the preheat sequence prior to entering sunlight.

6.3 ASCENT FLIGHT TO GEOSYNCHRONOUS ORBIT

Prior to the start of this event, SEPS has received payloads from the Tug. The payloads have been clamped to the transport mast. SEPS and Tug have separated to positions where Tug RCS startup will not contaminate payloads.

During the typical flight to geosynchronous orbit, SEPS will be periodically tracked; and the trajectory errors will be calculated by a ground computer. Updates to the state guidance vectors will be uplinked to the SUM-C computer so that SEPS can initiate autonomous N&G operations. These tracking and update cycles will occur approximately once per week, that is, about 9 updates for a typical cycle.

6.3.1 Event Timeline

SEPS ASCENT			WT (Kg)	PROP WT (Kg)	BURN TIME	POWER (kw)
40.36	35.0 hr	Begin ascent from changeover orbit	23216.	2342.		15.0
		Ascent to geosynchronous orbit			50.4 days	
90.76	51.9 dys	SEPS and payloads in geosynchronous at 30° West Longitude	22093.	1623.		15.0

SEPS ASCENT			WT (kg)	PROP WT (kg)	BURN TIME	POWER (kw)
		Deploy payload at 30° West Longitude	12580.	1623.		
		Longitude shift (132° West)			6.5 days	
97.26	58.4 dys	SEPS and payload at 162° West Longitude	12480.3	1524.		15.0
		Deploy payload at 162° West Longitude	9345.	1524.		
		Longitude shift (63° West)			3.9 days	
101.16	62.3 dys	SEPS and payload at 135° East Longitude	9285.	1464.		15.0
		Deploy payload at 135° East Longitude	9506.	1464.		

6.3.2 Event Description

The Tug is in orbit approximately 3 hours after the payload exchange awaiting nodal crossing. This will occur at 48.7 hours after lift-off. The Tug executes a retroburn for descent to 170 nautical miles orbit. There it will rendezvous and be retrieved by the orbiter. The Tug in the orbiter descends to a landing approximately 84 hours after lift-off.

During the Tug phasing, tracking of both SEPS and Tug is accomplished. Their N&G status is updated and the SEPS and Tug are ready for their next maneuvers.

As soon as the payload transfer is completed and Tug is clear, the SEPS solar arrays are extended to full span and SEPS begins a 50.4 day ascent to geosynchronous orbit.

6.3.3 Requirements

- Standard Tracking Data Network (STDN) will track the SEPS vehicle (angle, range, and range rate) and transmit the data to the SEPS Operations Center (SEPSOC).
- STDN will receive telemetry data from the SEPS vehicle and transmit to the SEPSOC.
- STDN will transmit data from SEPSOC to the SEPS vehicle for the ascent to geosynchronous orbit.

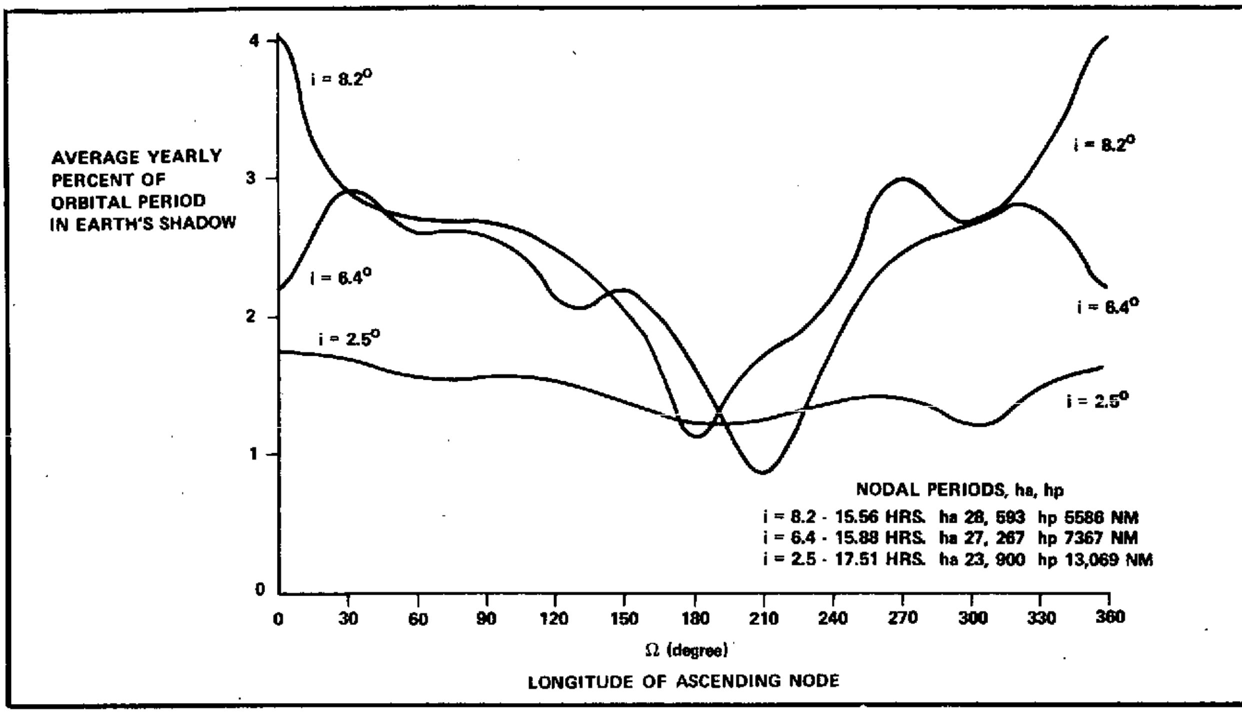


Figure 6-6. AVERAGE SHADOW PERIODS

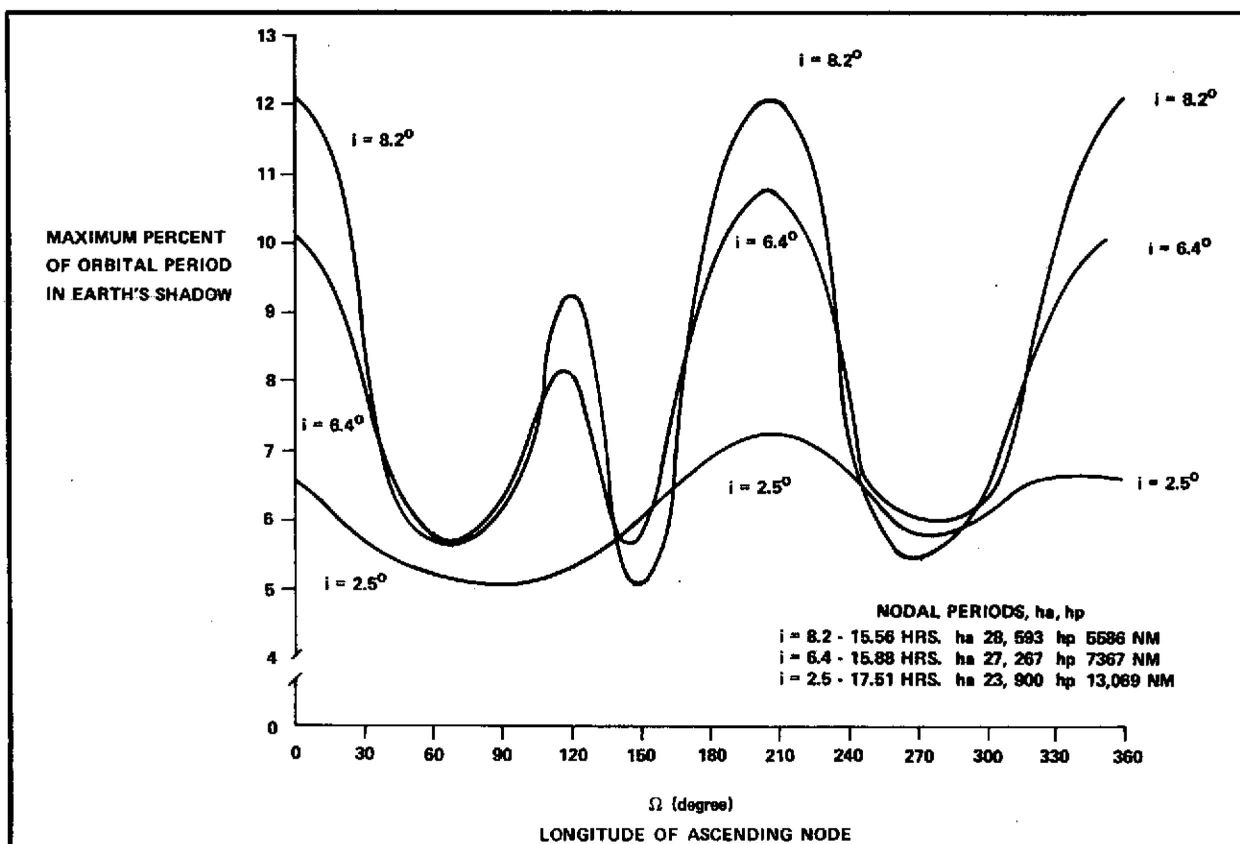


Figure 6-7. MAXIMUM SHADOW PERIODS

- Status data from each airborne subsystem shall be recorded and transmitted to the ground at least once a week. Discrete change of state shall be time tagged. Data shall be limit checked and "out of tolerance" conditions recorded with a time tag. Only out of tolerance or unacceptable trend data will be transmitted.
- The data flow requirements are shown in Table 6-1.
- SEPS shall be capable of autonomous ascent. Status along the trajectory will be monitored.

Table 6-1. DATA FLOW REQUIREMENTS

INFORMATION	SEPSOC/GSFC	GSFC/EACH STDN SITE
Telemetry	12,600 bits/sec	12,600 bits/sec
Tracking	60 bits/sec	60 bits/sec
Command	720 bits/sec	720 bits/sec
Teletype	4-100 wpm lines full duplex (180 bits/sec)	1-100 wpm line full duplex (60 bits/sec)

NOTES:

1. *The tracking data flow requirements between GSFC and the SEPSOC are based upon three-site concurrent coverage.*
2. *SEPS is in view of at least one STDN station at all times.*

6.4 MIDCOURSE TRAJECTORY MONITORING

In order to achieve a rendezvous with a payload in geosynchronous orbit, payload location must be supplied to SEPS. For rendezvous with Tug, SEPS' computers must be loaded with the appropriate data. SEPS' progress in these maneuvers will be monitored to ensure that the navigation and guidance system is not malfunctioning. The STDN will track SEPS once a day using the onboard beacon transponder as a signal source. The data will be filtered, reduced, and transmitted to the SEPSOC. Once each week this data will be used to compute the actual SEPS trajectory. The actual trajectory is compared with the required trajectory. New navigation data are calculated and a new ascent/descent program given to SEPS only if SEPS autonomous performance has been unsatisfactory. The transmission software will contain provisions for message validation. After validation, the use of the new data will be enabled by a command from the SEPSOC. Each trajectory check will require about one hour.

Requirements

- An airborne tracking signal must be provided by a beacon transponder
- SEPS navigation software must provide for insertion of all required data during flight
- The onboard computer must accept real-time commands from the SEPSOC
- Operational interfaces must be established with STDN.

6.5 DEPLOY PAYLOADS

SEPS payload deployment activity begins with arrival at a specified longitude in geosynchronous orbit. After the payload is released, SEPS translates to a stationkeeping position where it remains during payload orbital readiness testing. SEPS' TV system transmits pictures of the payloads initial deployment of solar arrays and antennas and confirms for the payload operators that the initial deployed geometry has been achieved. SEPS may assist in some functions.

6.5.1 Event Timeline

An event timeline beginning with arrival on station for deploy and terminating at thrust initiation for curise to a new longitude is given in Table 6-2.

6.5.2 Event Description

SEPS arrives at the required longitude in geosynchronous orbit at the end of a powered flight phase. The powered flight may have been ascent from the intermediate Tug/SEPS changeover orbit or phasing from one longitude to another in geosynchronous orbit.

SEPS autonomously determines arrival at the deployment longitude, terminates ion thrusting, and uses the reaction control system to null any residual velocity. The SEPS navigation status will be checked approximately 12 hours prior to arrival at the deployment station. SEPS location at the desired payload mission station is verified.

After SEPS thruster subsystem is deactivated, manned control is activated. The manipulator and television systems are activated. One manipulator with a TV camera is aimed to provide a view of the payload grasp points. The second manipulator is then maneuvered to grasp the payload. The first manipulator

Table 6-2. PAYLOAD DEPLOYMENT

TIME	ΔT	
0:00		SEPS arrives at deployment station
0:00	0:02	Terminate ion thrust; begin power-down thruster subsystem
0:02	0:10	Retract solar arrays to 1/4 spans, stationkeep
0:02	0:03	Activate manipulator system
0:15	0:03	Activate TV system
0:18	0:05	Extend payload mast (as required)
0:23	0:05	Orient one manipulator and TV camera to provide view of payload grasp point as an aid in guiding the other manipulator
0:28	0:10	Grasp payload with other manipulator
0:38	0:20	Release payload from mast using other manipulator
0:58	0:20	Using manipulator place payload in deployment attitude
1:18	0:20	Activate payload subsystems
1:38	0:15	Deploy payload appendages (solar arrays, antennas, etc.)
1:53	0:05	Update SEPS N&G data
1:58	0:10	Align payload IMU to SEPS IMU
2:08	0:05	Load payload computer if required
2:13	0:30	Payload system checkout/calibration
2:43	0:01	Release payload, begin orbital readiness test
2:44	0:07	Translate to 100 meters, begin stationkeep
2:51	0:07	Orient attitude for cruise
2:58	3:05	Stand by for payload operations
5:03	0:20	Extend solar arrays
5:23	0:10	Deactivate manipulator and TV systems
5:33	0:70	Begin thruster start up
6:43		Begin thrust on cruise mode

arm is used to release the payload clamps from the SEPS payload transport mast. Then the payload can be placed and held in deployment attitude using one manipulator. The payload is held in this position while the payload control center activates the payload systems. This includes deployment of solar arrays and antennas. The payload attitude reference is initialized by aligning it with the SEPS reference, and the payload computer is loaded with the same state vector as SEPS (if this is necessary).

The payload is evaluated through a series of checkout and calibration procedures. After satisfactory operation is established the payload is released from the SEPS manipulator. SEPS is manually maneuvered to a safe distance (100 meters) from the payload, and autonomous control is resumed. SEPS begins a standby period. During this standby period the payload is tested to ensure orbital readiness. SEPS has no assigned role in the testing, but is available to provide television observation and assistance in correcting payload malfunctions. In case of partial antenna or solar array deployment, the manipulator system can be used to correct the malfunction.

Thruster preheat and startup sequence can be initiated prior to completion of the payload testing. This permits SEPS to begin cruise to another longitude immediately upon release by the payload control center. The solar arrays are deployed to full span, the manipulators are stowed and deactivated. The TV system is deactivated before initiating thrust.

If this deployment is the last one for a sortie, SEPS may be stored in orbit until needed for the next sortie (subsection 6.8).

6.5.3 Operational Interfaces

The SEPS control center will have operational interfaces with the tracking networks and with the payload control center for transferring attitude reference and navigation information, television downlink signals, and for coordinating the man-in-the-loop control of the deployment and checkout activation.

6.5.4 Requirements

Requirements of SEPS for performing payload deployment activities are similar to those for payload retrieval and are given in subsection 6.6.

6.6 RETRIEVE PAYLOADS

The SEPS activity associated with retrieval of payloads begins with SEPS at a stationkeeping position 100 meters from the payload and terminates with SEPS in a cruise attitude with computer loaded with data necessary to begin cruise mode.

6.6.1 Event Timeline

An event timeline for a nominal payload retrieval is given in Table 6-3.

6.6.2 Event Description

At the beginning of this function the ion thrusters have been deactivated and the residual velocity autonomously nulled. Once stationkeeping is established, the SEPS is commanded to a manned control mode, the TV is activated, and the solar arrays are retracted to 1/4 span. SEPS is then translated to a position 3 to 10 meters from the payload. A manipulator is deployed with the end effector that is necessary to perform a given special or unique task associated with the payload. SEPS will be required to retrieve payloads having features requiring the use of several end effectors. The manipulator payload handling system with a variety of end effectors will provide the operational flexibility to handle various payload configurations. Payload lighting (if required) is then turned on. One manipulator arm is maneuvered by ground control to provide visibility of the payload. The other manipulator is then maneuvered and grasps the payload with its end effector. Reaction control systems are inhibited to avoid unnecessary expenditure of propellants. While the payload is held by SEPS, its attitude control and other subsystems (if active) are deactivated from the payload control center. The SEPS transport mast is extended. The free manipulator is positioned to provide television viewing of the positioning function. The arm holding the payload positions it to clamp the payload to the mast. The payload mast can then be retracted to improve the center of gravity location. The manipulator arms are stowed,

Table 6-3. RETRIEVE PAYLOAD

TIME	Δ TIME	
0:00		Arrive at 100-meter stationkeeping position
0:00	0:02	Switch from autonomous to man-in-the-loop operational mode (TV to visual mode and TV downlink)
0:02	0:10	Retract solar arrays 1/4 span
0:12	0:07	Translate to 3 meter station
0:19	0:05	Deploy second manipulator
0:23	0:03	Activate TV camera on second manipulator arm
0:26	0:20	Fit different end effector (as required)
0:46		Turn on payload illumination
0:46	0:06	Acquire payload grasp point with No. 1 TV
0:52	0:12	Grasp payload with manipulator No. 2
1:04	0:02	Inhibit SEPS and payload RCS
1:06	0:30	Passivate payload (deactivate RCS, attitude control, power-down payload systems)
1:36	0:05	Extend payload transport mast
1:41	0:05	Begin ion thruster preheat
1:46	0:20	Place payload on mast and attach
2:06	0:10	Retract transport mast
2:16	0:02	Enable RCS
2:18	0:02	Stow manipulator arms and deactivate
2:20	0:06	Deactivate TV system and payload illumination
2:26	0:01	Acquire cruise attitude
2:27	0:10	Extend solar panels to full span
2:37	0:05	Update state vector, load target vectors
2:42		Begin thrust in cruise mode

latched, and deactivated. The television and payload lighting is deactivated. After cruise attitude is acquired for the SEPS, the solar panels are extended to full span.

If SEPS is to phase to a new longitude for retrieval of another payload its state vectors would be updated from the ground. The target payload vector will be changed and thrusting will be initiated.

If this were the final retrieval operation for a given sortie, SEPS may be placed in a geosynchronous storage mode of operation (subsection 6.8).

6.6.3 Operational Interfaces

Remote control from the SEPS control center requires an interface with the STDN for uplinking commands and for viewing downlinked television images and systems status during retrieval operations.

An interface between the SEPS and payload control centers is necessary to coordinate payload operations associated with the retrieval.

6.6.4 Requirements

Control of maneuvering during the final closure from 100 meters to 3 meters and retrieval of payloads using manipulators impose visual monitoring and real-time control requirements. Commands generated in the SEPS control center must be coupled directly to the uplink with time delay compensation through applications software.

Commands. The driving requirements occur during the payload handling operations. This estimate is based on a preliminary manipulator design and experience with the Shuttle manipulator simulator. Requirements are itemized below:

Commands to end effector; one arm maneuvered at a time.

9 command words, 8 bits each, 10 updates/sec (3 angular rates, 3 translation rates, 1 end effector control)	720 bits/sec

Additional command capability is required:

- Selection of autonomous/man-in-the-loop mode
- Selection of the onboard high resolution TV output
- Payload illumination on/off
- Payload transport mast extend/retract
- RCS inhibit/enable
- Thruster preheat initiate.

Television. During payload retrieval and handling four simultaneous real-time television views of the operations will be required. To minimize bandwidth requirements, three views with 4 frames per second and one high resolution view at 16 frames per second are more than adequate. Cameras for each may be identical. A switching function is required to obtain the high resolution output from any of the four cameras. Bandwidth requirements are itemized below.

One high resolution analog link (512 x 512 lines) x 16 frames/sec	= 4.2 MHz
Three low resolution analog links (128 x 128 lines) x 4 frames/sec x 3	= 0.2 MHz
TOTAL	4.4 MHz

Telemetry. Real-time data downlink during payload handling is the driving data rate (12.6 Kbps) for the telemetry system. The telemetry rate requirements are itemized below.

Attitude Control Gyros	
6 rates and 4 status words (4 bit words sampled 30 times per second)	1,200 bits/sec
Manipulators (only if ground computers monitor the onboard computer action)	
9 elbow angles per arm, 9 torques per arm, 9 motor temperatures per arm (7 bit words sampled 30 times/sec)	11,340 bits/sec
TOTAL	12,540 bits/sec

6.7 SEPS/PAYLOAD RENDEZVOUS

The rendezvous phase begins with laser radar acquisition of the target and continues until SEPS achieves a stationary position 100 meters from the target. The closure from this station is treated in the payload deployment activity. SEPS is the active partner during rendezvous with a target payload upon attaining geosynchronous orbit. The payload for this description is inactive and noncooperative but assumed to be in a stable attitude. SEPS with the manipulator system can retrieve tumbling satellites if rates are within certain limits established by their moment of inertia and motion.

6.7.1 Rendezvous Event Timeline

Activities during the nominal rendezvous phase are identified in Table 6-4.

6.7.2 Event Description

Significant events occurring during SEPS' rendezvous with a target payload are identified in Table 6-4. The rendezvous occurs as an extension of the orbit raising mode and utilizes ion thrusting to within 460 meters (1500 feet) of the target payload.

Table 6-4. RENDEZVOUS TIMELINE

TIME (hr)	
0	Begin active ranging on target payload with laser radar
	Onboard computer (SUM-C) begins processing laser output to determine required thrust vector
6.7	Activate manipulator system
	Activate scan platform mounted TV system, acquire target on TV
	Compute range, range rate, line-of-sight angle from TV output
	Compare to laser data until correlatable
7.7	Option to begin man control
	TV tracks target
11.7	Terminate ion thrust (460 meters (1500 foot) range)
12.35	Null residual velocity with ACS
12.7	Arrive at 100 meter (300 feet) stationkeeping position

At time zero the SEPS is within active laser radar range. Once active ranging has begun, the range, range rate, and line-of-sight angle parameters are obtained as outputs of the laser radar. The SUM-C computer calculates the continually changing ion thrust vector required to accomplish closure with the payload. Approximately 6.7 hours after active ranging has begun, the SEPS manipulator and television systems are activated. One scan platform-mounted TV camera is used to acquire and track the target payload. The SUM-C computer begins processing the range, range rate, line-of-sight data from the

TV and compares it to that obtained from the laser radar sensor. Once satisfactory agreement is obtained between data from the two sensors, man control can begin at any time desired. SEPS will be in position to terminate thrust approximately 11.7 hours after active ranging has begun. At this time the SEPS ACS is used to null the residual velocity. This results in SEPS attaining a stationkeeping position approximately 100 meters from the target payload 12.7 hours after laser radar active ranging is begun. The closing maneuver on the payload can be manually controlled from the Payload/Docking console in the SEPS Control Center.

6.7.3 Rendezvous Trajectory

In order to conserve SEPS ACS propellant, the ion thrusters should be used to accomplish the rendezvous maneuver to the maximum extent possible. Factors affecting the time for switch-over from ion to ACS thrusting are:

- Requirements for rapid thrust vector direction changes
- Operational desirability of shortening rendezvous time
- Ion thruster plume impingement on payload.

An approach trajectory in rectilinear coordinates is shown on Figures 6-8 and 6-9. At a large distance from the target, the vehicle angle of attack (pitch angle from the horizontal) is zero, and the SEPS is operating in an orbit-raising mode. Beginning about ten orbits (9 days) from rendezvous, the angle of attack begins to increase reaching a maximum of about 62 degrees at six hours before rendezvous (6.7 hours after acquisition). In the last few hours, the SEPS begins to pitch down again, and has an angle of attack of -90 degrees at rendezvous.

Note that, for most of the trajectory, the direction of the thrust vector is very near to the line of sight direction. This is advantageous, since it permits laser radar ranging with a single, forward-looking instrument and SEPS could accomplish rendezvous with one scan platform inoperative.

The pitch motion called for within five hours of rendezvous presents no difficulty to the attitude control system. LADAR or optical tracking using the scan-platform-mounted TV cameras can be used. The SEPS main engines are used as long as possible, to within 1 hour (460 meters) of rendezvous. ACS thrusting is then used to null the residual velocity.

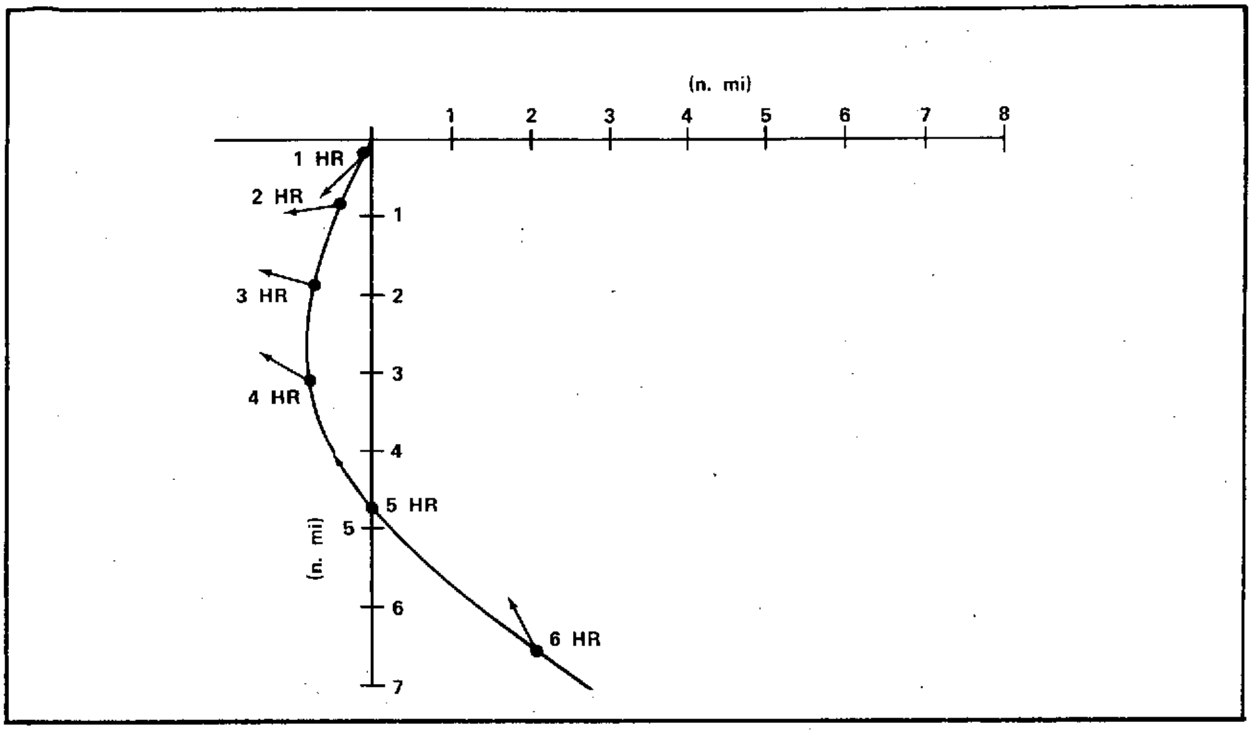


Figure 6-8. SEPS RENDEZVOUS PROFILE

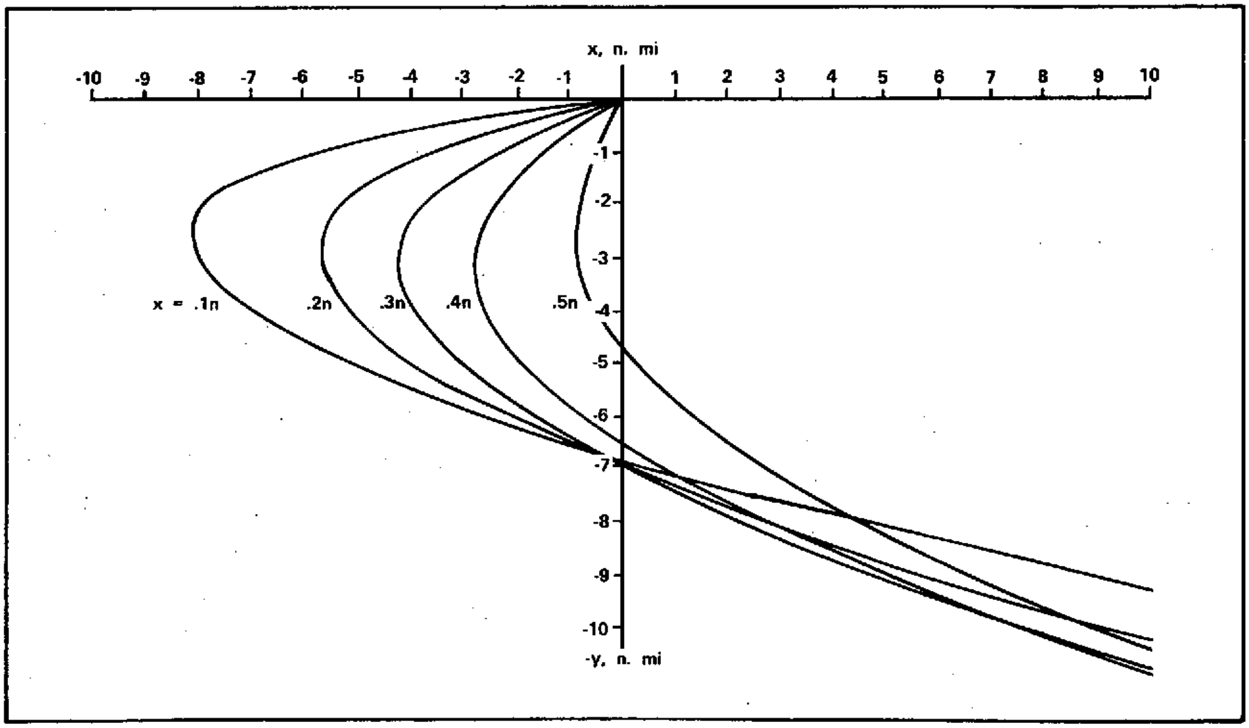


Figure 6-9. SEPS RENDEZVOUS PROFILE

6.7.4 Flight Control Activity

The SEPS operation is autonomous until the activation of the manipulator and TV system. The manipulator system is activated by command issued from the Payload/Docking console in the SEPS control center via the STDN to the SEPS command receiver. Control may remain autonomous until the stationkeeping position is reached at the option of the controller.

6.7.5 Requirements

Requirements derived from the SEPS rendezvous with a payload are a scan-platform-mounted laser radar and a steerable TV camera for controller monitoring of action and assuming of control. Line-of-sight angle information for thrust vector control by the onboard SUM-C computer is from the LADAR in normal operation. Software for the TV image processing and autonomous tracking of the target by the TV are required only if it is desired to provide an operational mode when both LADARS have failed.

SEPS RCS propellants required are 1 kilogram or less for each rendezvous which uses ion thrusters to within 460 meters of the target; about 9 kilograms for each rendezvous terminating ion thrusting at 10 kilometers from the target.

Man-in-the-loop control and TV downlink are desirable for backup or override capability, but not required.

Thrust vector requirements as depicted in the trajectory profiles in Figures 6-8 and 6-9 are not design driving requirements, but are within the capability of the SEPS system.

6.8 STORAGE IN GEOSYNCHRONOUS ORBIT

After having completed all delivery and retrieval operations in a year for which SEPS is not utilized full time, SEPS is stored in geosynchronous orbit until needed for the next sortie. This situation is common for at least one SEPS throughout the mission model.

The duration of the storage on orbit is indicated on the systems operational profile.

6.8.1 Event Identification

The events necessary to configure SEPS for the storage mode are:

- Place SEPS in a gravity gradient attitude stable position
- Retract solar arrays partially
- Put array control on sunline hold
- Command storage mode for all subsystems
- Begin storage mode
- Reactivate to cruise mode as desired.

The time required for this function is 2 hours.

6.8.2 Storage Activity Description

The storage mode will be initiated after completion of a delivery or retrieval operation. SEPS will be in cruise attitude with the thruster subsystem deactivated and solar arrays partially extended to 1/4 span.

The SEPS subsystem storage configuration would be ground commanded from the SEPS control center. The ground command would initiate an operation sequence controlled by the onboard SUM-C computer resulting in the desired subsystem configuration.

In this storage mode, SEPS attitude control and solar panel pointing systems would be active, for thermal control and to provide power necessary to maintain the batteries at adequate charge. The solar arrays would be retracted to a position compatible with power and thermal requirements. The data handling system tape recorders would continue to operate at a reduced data rate to dump status data when requested. The command receivers and tracking transponder will operate as in the cruise mode. The navigation function will be deactivated until the next cruise period. ACS operates system only if solar wing tracking of the sunline disturbs the gravity gradient stabilization attitude.

Monitoring of the SEPS from the ground control center would remain at the normal once-weekly interval. Navigation updates during the storage period would not be required. Tracking requirements will be reduced to a level required for ephemeris maintenance.

The subsystem operational configuration may be different if payloads are on the transport mast during this period. The differences would be in attitude control requirements to avoid thermal stresses to the payload.

6.8.3 Requirements

Unique requirements resulting from orbital storage are software to sequence the operations and monitor lock on to gravity gradient mode.

6.9 DESCENT TO CHANGEOVER ORBIT – BEGINNING OF NEXT SORTIE

On one of the sorties (as described in subsection 6.7) prior to the start of this event, SEPS may have completed the retrieval of two payloads. The descent time is a function of power and weight. With these two payloads, it is estimated to be 36.6 days. During the flight to the changeover orbit SEPS will be periodically tracked by STDN. The trajectory errors will be calculated by a ground computer and SEPS autonomous N&G functions monitored. If required N&G data are uplinked to the airborne SUM-C computer so that corrections can be made in its operational modes. This tracking and update cycle will be required approximately once a week or about 4 times for a typical descent. This process is described in subsection 6.4.

6.9.1 Event Timeline

MISSION TIME (days)	TIME FROM SHUTTLE LAUNCH	EVENT	WEIGHT (kg)	PROPELLANT WEIGHT (kg)	BURN TIME	
	SEPS DESCENT					POWER (kw)
0.00	-38.9 days	SEPS docked with payload at 80° West Longitude	2194.	604.		15.3
		Longitude shift (20° West)			2.3 days	
2.30	-36.6 days	SEPS docked with payload at 100° West Longitude	3545.	597.		15.3
		Descent to changeover orbit			36.6 days	
38.90	0.0 days	SEPS and payloads at changeover orbit	3430.	481.		15.2

6.9.2 Event Description

At the time to begin descent, the SEPS computer is loaded with all data and programs necessary for descent. Functions required to initiate the descent cruise mode are completed. The SEPS will use continuous thrusting for the duration of the descent period except when in the shadow of the earth.

Monitoring through STDN downlink will be required once a week. During the SEPS descent, the payloads arrive at the launch site, and are launched so that they will arrive approximately 24 hours after SEPS has reached the changeover orbit. Figure 6-10 shows a Tug and SEPS trajectory profile. SEPS position in the changeover orbit will have been established to simplify the Shuttle/Tug nominal sortie profile.

6.9.3 Requirements

The requirements for this function are included in subsections 6.3 and 6.4.

6.10 SEPS/TUG RENDEZVOUS

In this scheme, Tug will be the active element making all trajectory adjustments necessary to effect rendezvous. SEPS will be a passive, but co-operative partner if necessary. Figure 6-11 describes the Tug ascent and descent profiles.

SEPS will arrive at a changeover orbit approximately two orbit periods before the Tug injection burn. Its orbit will be calculated from tracking data provided through STDN. The Tug will be injected into an orbit which has a natural phasing capability. The Tug will be inserted below and behind SEPS. The phasing orbit would be planned for a shorter period than the SEPS orbit in order to provide for a Tug overtaking rate relative to SEPS.

When the separation distance is equal to the active range of the LADAR, velocity corrections will be made to complete the terminal phases of rendezvous. SEPS will accomplish the final stationkeeping and attach maneuvers as previously described.

In evaluating the rendezvous guidance problem, the following conditions were established:

- A state "near" that of the target is achieved following injection into an approach trajectory
- The above state is such that the SEPS will appear to the Tug with a distance of less than 30 km at some time (active range of LADAR)

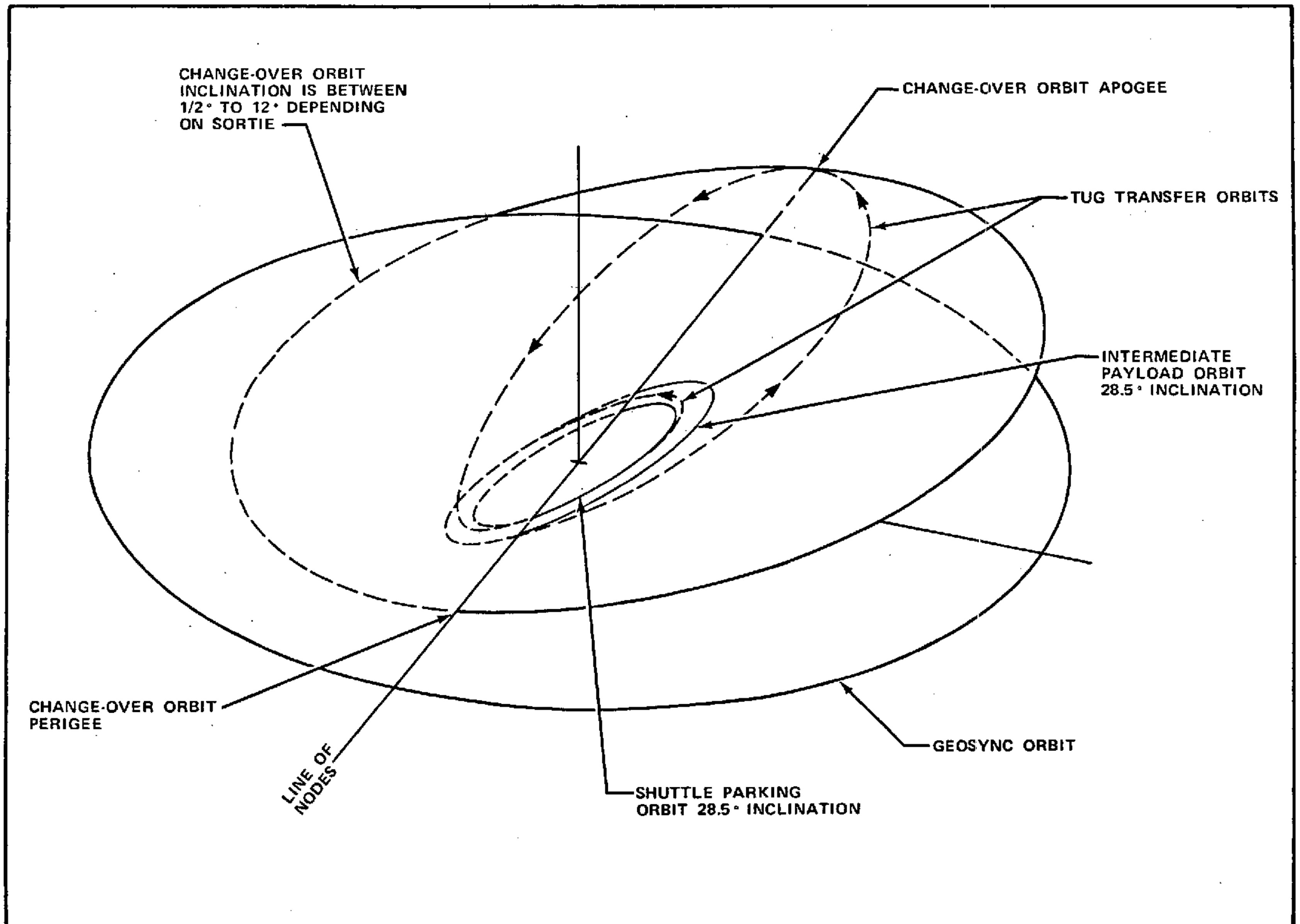
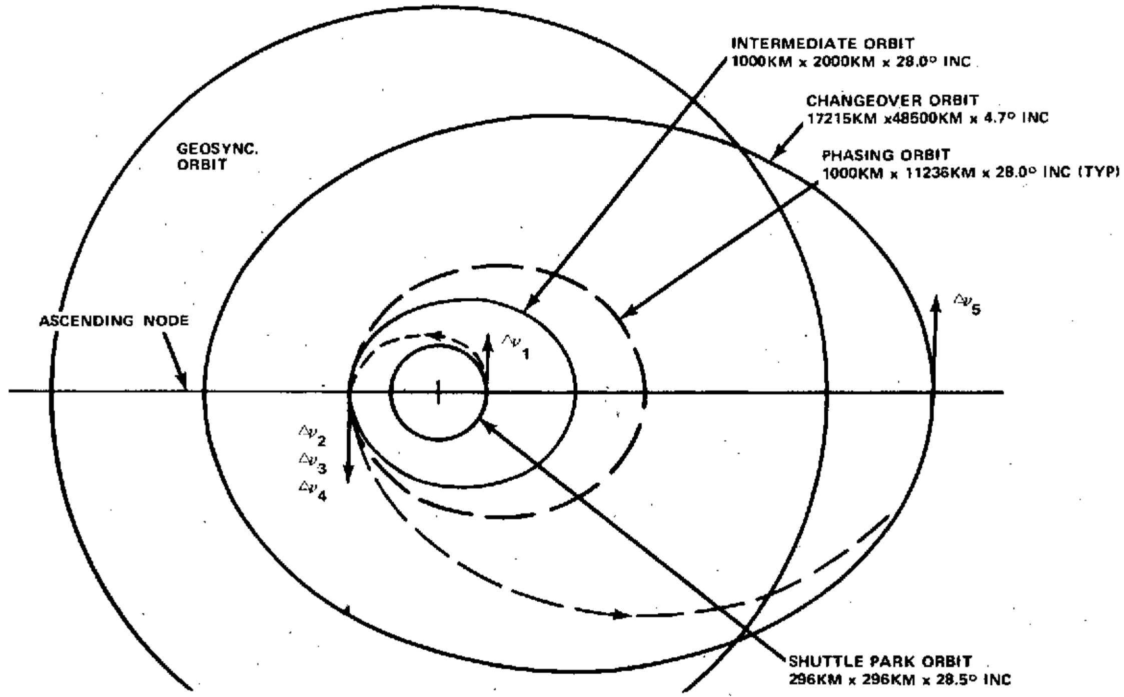
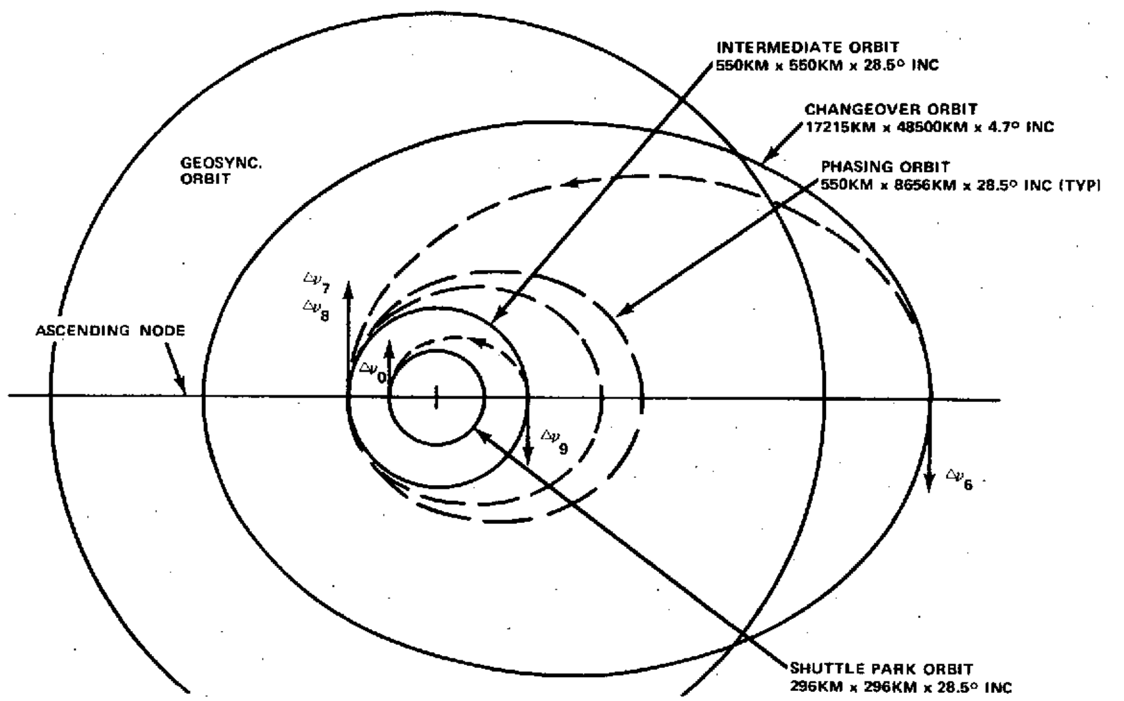


Figure 6-10. REFERENCE TRAJECTORY PROFILE



TUG ASCENT PROFILE



TUG DESCENT PROFILE

Figure 6-11. REFERENCE TRAJECTORY PROFILE

- Closure between Tug and SEPS is to occur within one/half orbital period
- Targeting parameters were selected as follows to assure adequate phasing and allow reasonable injection errors:

  $-30 \text{ km} < \Delta r_a < \Delta -10 \text{ km}$

  $-10 \text{ km} < \Delta r_a + \Delta r_p > 20 \text{ km}$

  where

  r_a = radius of apogee

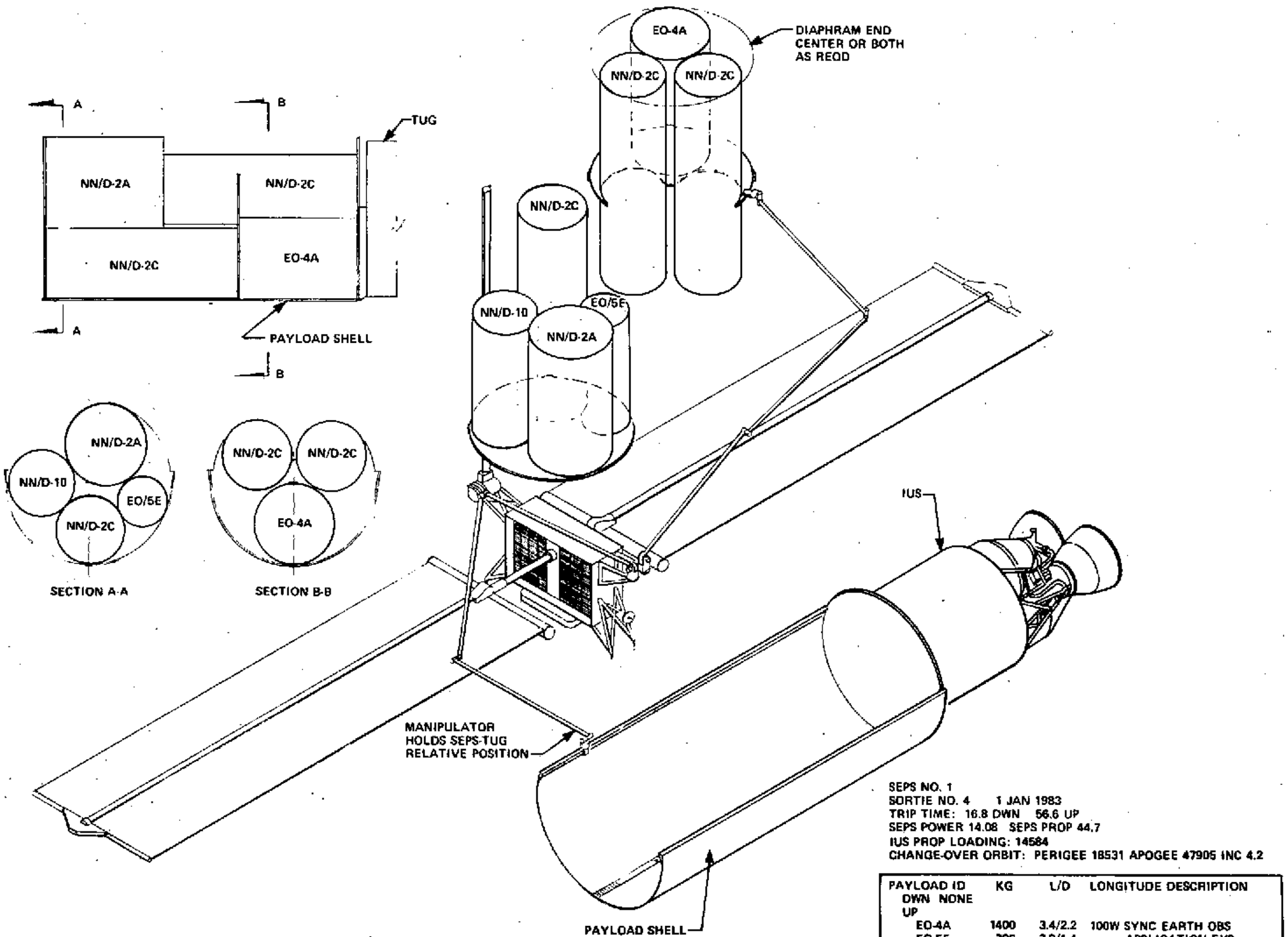
  r_p = radius of perigee
- A two impulse guidance scheme is employed. The first maneuver will retarget the Tug for SEPS intercept. The second burn will match SEPS velocity.

Requirements

- LADAR tracking is required during approach
- Computations of relative motion between SEPS and Tug are required
- Attitude reference is required
- The capability to compute velocity corrections is required
- Control of both SEPS and Tug is required during corrections.

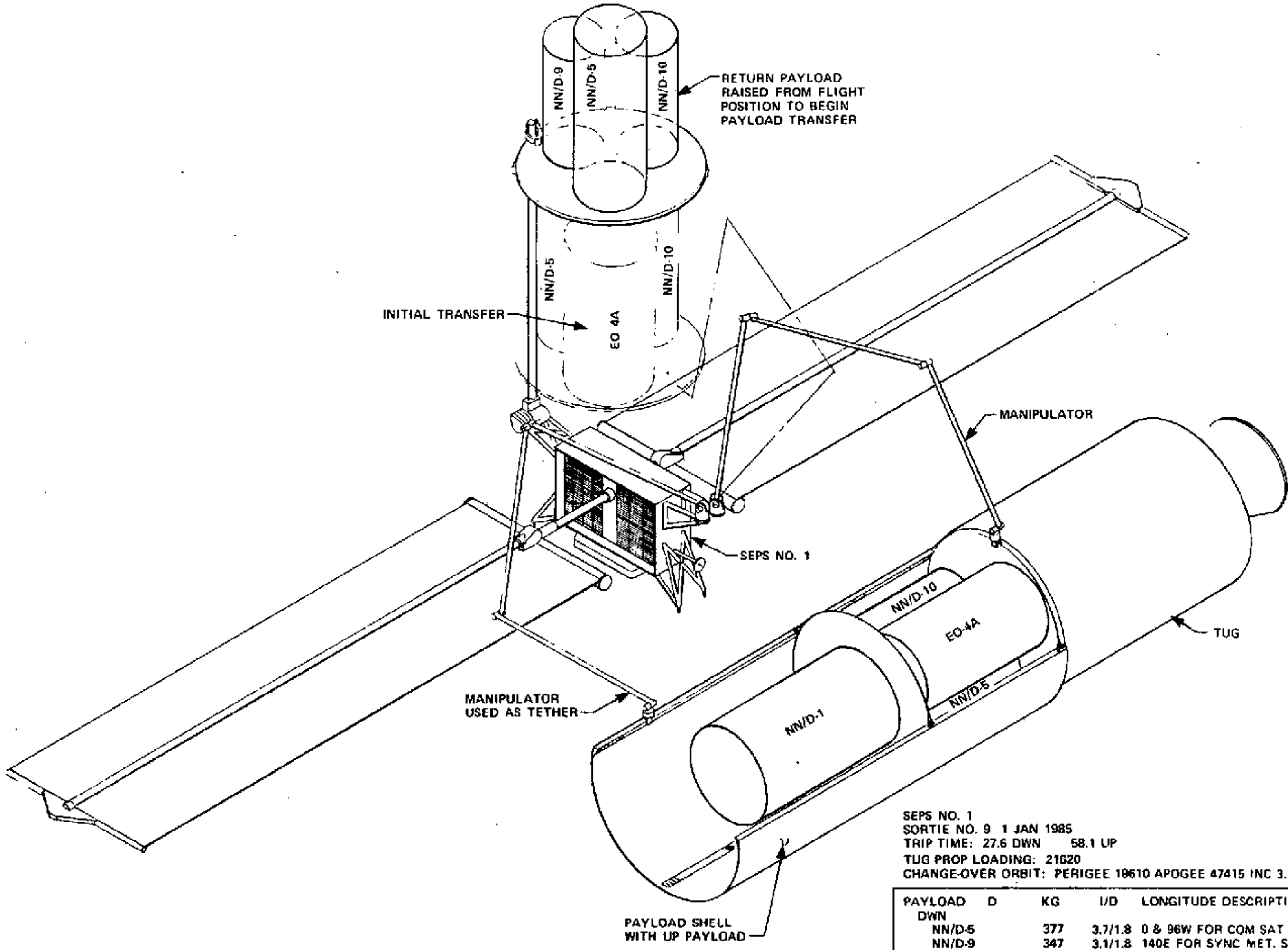
6.11 PAYLOAD EXCHANGE

After the SEPS/Tug rendezvous is complete to within 100 meters, it will be necessary to exchange payloads with the Tug. On a typical sortie three payloads will be transferred from Tug to SEPS. In addition, two payloads which SEPS has retrieved from geosynchronous orbit will be transferred to Tug. Although this process is typical, in accomplishing the 30 mission sorties much variation will occur. The typical exchange problem is developed in subsections 6.11.1 and 6.11.2 to drive out the payload exchange design requirements. Figures 6-12 and 6-13 present the exchange required for sorties number 4 and number 9 of one system operational profile developed. The GPME elements recommended by this study (that is, manipulators, support diaphragms, and the transport half shell) will provide a system with the necessary operational flexibility. If we consider sortie number 4, there are no payloads to transfer from SEPS to Tug but seven payloads from Tug to SEPS. In preparing for sortie number 9 three payloads must be transferred from SEPS to Tug and four from Tug to SEPS.



PAYLOAD ID	KG	L/D	LONGITUDE	DESCRIPTION
DWN NONE				
UP				
EO-4A	1400	3.4/2.2	100W	SYNC EARTH OBS
EO-5E	306	2.9/1.4	–	APPLICATION EXP.
NN/D-2C	441	5.5/1.9	N/A	US DOM SAT C
NN/D-2C	441	5.5/1.9	N/A	US DOM SAT C
NN/D-2C	441	5.5/1.9	N/A	US DOM SAT C
NN/D-2A	493	3.4/2.3	N/A	US DOM SAT A
NN/D-10	386	3.1/1.8	140E	GEOSYNC OPER MET SAT

Figure 6-12. PAYLOAD EXCHANGE SORTIE NO. 4



SEPS NO. 1
SORTIE NO. 9 1 JAN 1985
TRIP TIME: 27.6 DWN 58.1 UP
TUG PROP LOADING: 21620
CHANGE-OVER ORBIT: PERIGEE 19610 APOGEE 47415 INC 3.7

PAYLOAD	D	KG	I/D	LONGITUDE DESCRIPTION
DWN				
NN/D-5		377	3.7/1.8	0 & 96W FOR COM SAT A
NN/D-9		347	3.1/1.8	140E FOR SYNC MET. SAT.
NN/D-10		347	3.1/1.8	140E GEOSYNC OPER MET. SAT.
UP				
EO-4A		1400	3.4/2.2	100W SYNC. EARTH OBS.
NN/D-1		2040	3.7/2.5	40W & 180W INT. COM SAT.
NN/D-5		445	3.7/1.8	0 & 96W FOR COM SAT B
NN/D-10		366	3.1/2.5	140E GEOSYNC OPER MET SAT

Figure 6-13. PAYLOAD EXCHANGE SORTIE NO. 9

GPME including the manipulator system makes it possible to handle all situations by (1) handling individual payloads, (2) handling multiple payloads mounted on diaphragms, and (3) exchanging complete half shells between Tug and SEPS. Except for the fact that a wide variety of payloads and payload combinations must be handled, the payload exchange function will impose the same requirements as "Configure SEPS/Payloads Assembly for Initial Sortie" discussed in subsection 6.1.

6.11.1 Event Timeline

Event	ΔT (min)	Time Complete
1. Arrive at rendezvous with 300 foot separation		0
2. Retract solar arrays to 25 percent	20	
3. Close to within 10 feet of Tug	10	20 min
4. Extend SEPS transport mast	5	20 min
5. Activate TV system	5	20 min
6. Grasp payload assembly #1 with manipulator	5	25 min
7. Disable Tug and SEPS RCS	5	30 min
8. Use manipulator to release diaphragm locks	10	40
9. Remove "up" payload assembly #1 from the Tug and clamp it to transport mast in bottom position	30	1 hr 10 min
10. Use reaction control system to clamp out induced rates	5	1 hr 15 min
11. Use manipulators to position diaphragms in half shell to accept "down" payload	30	1 hr 45 min
12. Remove "down" payload assembly from the top of transport mast	45	2 hr 30 min
13. Install "down" payload assembly in half shell and secure diaphragm to half shell	45	2 hr 30 min
14. Activate RCS to dampen induced rates	5	2 hr 35 min
15. Repeat steps 6 through 10 for "up" payload assembly #2	1 hr 5 min	3 hr 40 min
16. Move SEPS to station 100 meters from Tug	10	3 hr 50 min
17. Deploy solar arrays 100 percent	20	4 hr 10 min

6.11.2 Event Description

By the time of the SEPS and Tug payload exchange, SEPS has been at change-over orbit for one orbit period awaiting the arrival of the Tug. After rendezvous SEPS will remain in standby until authorization is issued by the Tug Flight Director to proceed with payload exchange. At least one SEPS scan platform has Tug within the field of view of its LADAR and TV.

After verification of the subsystems readiness, the TV and remote control system will be activated. One manipulator arm with a TV camera will be deployed and maneuvered to acquire Tug which is at approximately 100 meters in its field of view. Solar panels may be retracted. The second manipulator arm is deployed. The SEPS will be directed to perform maneuvers using ACS thrusters to translate to a position 3 meters from the Tug. The SEPS grasps the transport shell with one manipulator arm. The ACS system is immediately disabled to avoid unnecessary propellant expenditure. The second manipulator arm is used to release the payload diaphragm from the transport shell. The SEPS transport mast is extended to accommodate additional payloads. The second manipulator arm attaches to the released payload diaphragm and transfers it to the transportation mast. A TV camera on the scan platform mounted on the payload mast side of SEPS provides visibility in the placement of the payload on the mast. The payload diaphragm mast clamp will "snap on" to the mast when pushed against it. The ACS thrusters on the Tug will be used to damp any induced rates if required.

The transfer to Tug of the down payloads on their mounting diaphragm is accomplished next. The free manipulator arm unlatches the diaphragm on the transport mast. The free arm is then used to grasp the diaphragm and translate it to position and to insert it in the transport shell. The diaphragm retainers are activated. After the transfers are completed, the SEPS manipulators are used to thrust Tug away so that ACS system operation is not required. SEPS begins preparation for cruise mode.

6.12 EXPENDABLES REPLENISHMENT

To reduce average sortie trip times, SEPS propellants are replenished three times. Refueling will be accomplished at planned levels of consumables. Refueling kits containing the supplies will be loaded in the launch preparation area of the SEPSOC. The kits can be transported on any Tug/Shuttle flight where unused cargo space is available. They will be mounted on diaphragms in the payload half shell. The refueling will occur in the change-over orbit prior to the payload exchange process. This is another function which requires operational flexibility in the General Purpose Mission Equipment. Volume II describes the equipment in some detail.

The manipulator system will be used to mate a probe-type interface connector which will provide for the transfer of each of the four consumables.

It will not be necessary to repressurize the storage tanks with GN_2. This gas is trapped behind a diaphragm so that addition of mercury and hydrazine to their respective storage tanks restores the original gas pressure. Figure 6-14 presents a recommended fueling sequence.

6.12.1 Event Timeline

Event	ΔT	Time Completed
1. Grasp the transport shell with one manipulator arm	5 min	5 min
2. Use second manipulator arm to pull the Hg refueling probe from the kit and insert it into the fill receptacle	5 min	10 min
3. Transfer mercury	2 min	12 min
4. Release mercury probe which is self stowing	1 min	13 min
5. Use second manipulator arm to pull the hydrazine probe from the kit and insert into interface connector	5 min	18 min
6. Transfer N_2H_4	2 min	20 min
7. Release self stowing hydrazine probe	1 min	21 min
8. Begin payload transfer or continue other mission activity.		

6.12.2 Event Description

SEPS servicing (refueling) will be accomplished in the changeover orbit after Tug/SEPS rendezvous. This function can be accomplished either before,

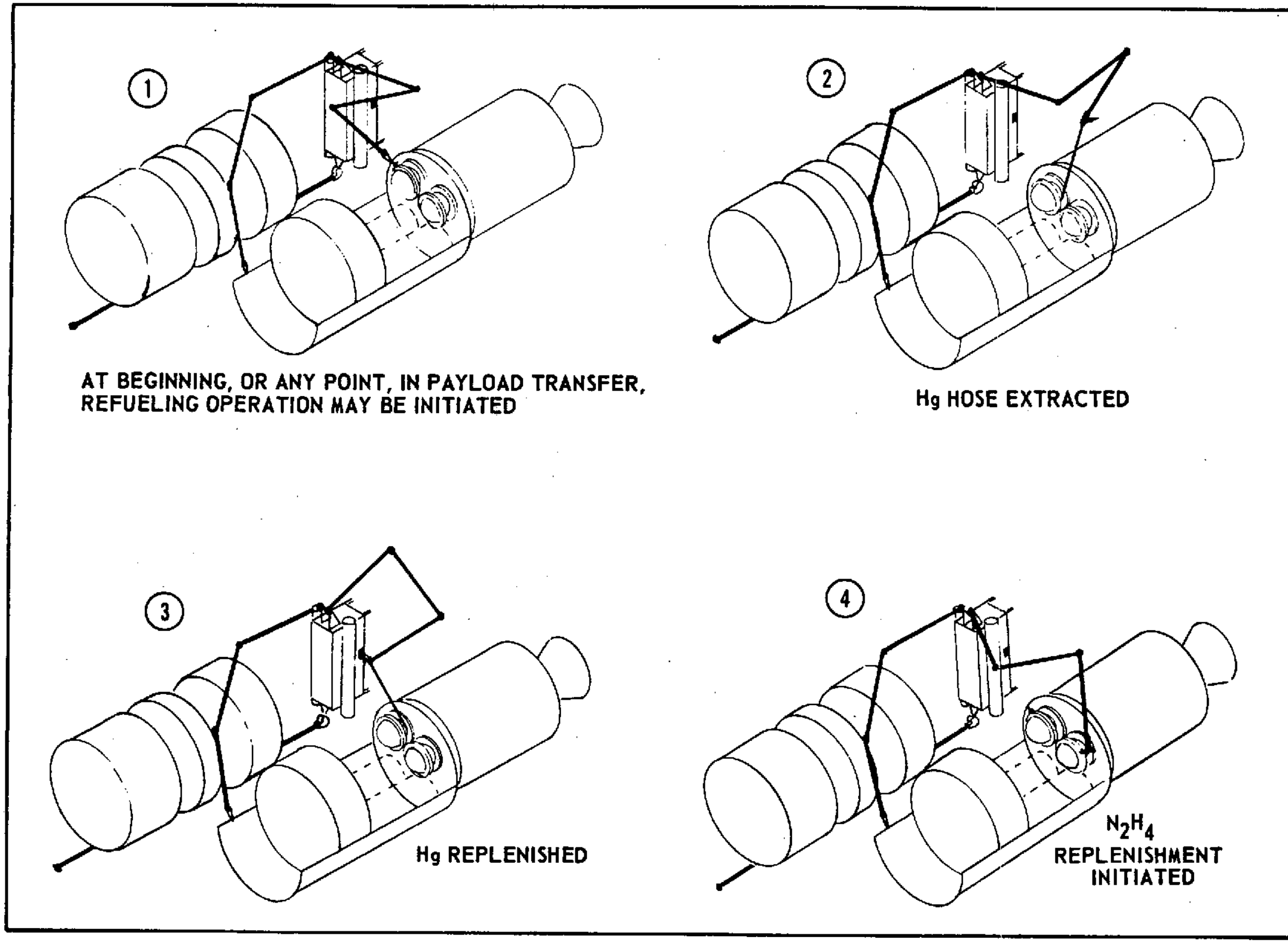


Figure 6-14. REFUELING SEQUENCE

after, or between payload exchange activities. The refueling kits will contain hoses with probe-type interface connectors. Each of the consumable sources will be connected in turn to the counterpart SEPS interface. The consumable will then be transferred to the storage tanks. Men will control and monitor the entire process from the SEPSOC. The manipulator system will be used for handling functions. Control and monitor of the process will require the data management system. The TV system will provide visual monitoring of the entire refueling process.

Section VII

SYSTEM REQUIREMENTS FOR PAYLOAD TRANSPORT AND SERVICING ELEMENTS AND GROUND SUPPORT

This section presents the requirements of certain elements of a system which will meet projected mission functions. The system is composed of a SEPS, general purpose mission equipment, and a ground system. Functions and requirements were indicated in previous sections. This section summarizes GPME payload related requirements and ground support. Personnel requirements are explained in subsection 7.6. Volume II describes the system design concept generated by NSI to meet all SEPS requirements.

7.1 GENERAL PURPOSE MISSION EQUIPMENT

The mission sortie functions discussed in Section VI require operational flexibility in the space handling, servicing, retrieval, and maintenance of payloads without imposing severe configuration restrictions. The preparation of payload manifests must be such that delays due to interference with Tug/Shuttle launch are eliminated. The payload sponsors will require simple, easy access to their payloads. During Tug/Shuttle flight operations, the payloads must be protected against flight loads which include 9g crash loads. Most mission sorties in the years 1981 to 1991 require the deployment of more than one payload. The deployments per sortie vary from one to nine. In addition, economy of operation requires multiple payload retrievals on some sorties. The payloads are of widely varying sizes and configurations with combinations weighing as much as 4,989 kg.

NSI proposes an STS GPME system composed of a transport shell with an orbiter interface longeron, support diaphragms, a SEPS earth orbital operations kit comprising a payload support mast and manipulator system, and standard SEPS refueling kits. This system will meet the existing requirements, provide operational flexibility, and allow payload manifest changes without impacting STS. The equipment was shown on Figure 1-1 and is described in detail in Volume II.

TRANSPORT SHELL WITH ORBITER INTERFACE LONGERON AND SUPPORT DIAPHRAGMS

Requirements

- The GPME must allow decoupling of Tug, Shuttle, and payload package prelaunch activity to the extent practicable.
- This system must permit easy access to the payloads in all phases of the mission cycle.
- This system must provide for mounting individual payload combinations of varying geometry weighing up to 4,989 kg in a manner that does not exceed orbiter attach fitting load limits and does not transmit inertial loads of the payload masses into Tug structure while in the orbiter's cargo bay.
- A means must be provided to support mercury and hydrazine refueling kits during Shuttle/Tug operations.
- The GPME must facilitate full utilization of all the available orbiter cargo bay volume.

PAYLOAD SUPPORT MAST AND MANIPULATOR SYSTEM

Requirements

- Individual or combination of payloads weighing up to 4,989 kg must be supported during SEPS flight operations.
- Provisions must be made to retrieve and support payloads while carrying other payloads to be deployed.
- A handling system must be provided that has the capability to handle any combinations of payloads that can be packaged in the orbiter's cargo bay with Tug. This system must be able to selectively remove and replace individual payloads from the transport shell.
- The handling system shall have the ability to secure and release clamping mechanisms, and to connect and disconnect servicing lines.
- The handling system exchanges individual payloads with the Tug.
- The handling system shall be capable of exchanging multiple payload assemblies with the Tug.
- The handling system shall have the dexterity to service the payload, replace SEPS components such as solar arrays, and to replace payload appendages.
- The system must be able to access any portion of SEPS excluding the deployed solar arrays.
- The system must be able to access any portion of the payload assembly as attached to the mast assembly.
- Software must simplify the control and prevent any motions that would damage the transport system flight articles or payloads.

REFUELING KITS

Requirements

- The hydrazine refueling kit shall have a capacity of 113 kg.
- The mercury refueling kit shall have a capacity of 1,360 kg.
- Transfer hose storage shall provide continuous hose tension and retract the hoses automatically when the probes are released.
- Self-sealing probe type connectors shall be provided for each consumable.
- The refueling kits shall mount on any standard GPME diaphragm.

GUIDANCE, NAVIGATION, AND CONTROL SYSTEMS

Requirements

The requirements for the Guidance, Navigation, and Control system are based on (1) ascent and descent between geosynchronous and the changeover orbit; (2) rendezvous with Tug and with payloads; and (3) positioning payloads in geosynchronous orbit. The system must contain sensing devices, a data management system, and thrust vector control devices. Autonomous operation is required in cruise navigation and guidance, in target acquisition, and in the terminal approach guidance to the target. Manned control will be provided for the final closing maneuver to the target. It will also be provided for control of payload deployment, retrieval, and servicing functions.

7.3 SPACE TRACKING AND DATA NETWORK

7.3.1 Network Description

The network for SEPS operations will consist of the Spaceflight Tracking and Data Network (STDN) which includes a ground terminal station at White Sands, New Mexico. Data transmission to and from the STDN is provided through the NASA Communications Network (NASCOM), a global network providing operational ground communications support. The Tracking and Data Relay Satellite System (TDRSS) will be utilized if it exists. It is not necessary for SEPS operations.

The STDN is a worldwide complex of stations used to provide communications with both manned and unmanned spacecraft. Present plans are for STDN to consist of no more than six to eight stations, three primarily for deep space support, two for launch support, and one to three more for special applications. Current planning includes ground sites at Goldstone, Madrid, Orroral, Alaska, Merritt Island, Rosman, Bermuda (launch only), and Tananarive (launch only). The TDRSS will have two relay satellites at geosynchronous orbit 130 degrees apart with a third satellite spare on operational standby.

Real time operational control and scheduling of the networks are provided by the Network Operations Control Center (NOCC) located at the Goddard Space Flight Center (GSFC), Greenbelt, Maryland.

7.3.2 Network Utilization

The STDN will be the prime network during the SEPS operations that will provide tracking, telemetry, and command support. TDRSS (if it exists) will provide coverage of orbital operations for orbits below 5,000 km. At SEPS operational altitudes, the SEPS/Tug changeover, and geosynchronous orbits, the deep space STDN stations will provide the primary support, with STDN continuous coverage above 5,000 nautical miles. Both subnets will complement each other when required in providing full support and will present the same interface to the STDN user.

Figure 7-1 illustrates the STDN coverage at 5586 nautical miles and shows the ground tracks of three typical SEPS changeover orbits overlaid on a 5586 nautical mile STDN coverage chart. The shaded areas are the only denied coverage at this altitude. As long as the ascending nodes of the changeover orbits are properly located, and they can be during mission planning, no problems exist. Locations of ascending nodes as shown were arbitrarily chosen simply to illustrate the coverage and typical ground tracks on a single figure. The elliptical orbit coverage will be better than shown.

7.3.3 Network Capabilities

Network support will basically be S-band with Ku-band utilized for special wideband data support. Full capabilities for S-band and Ku-band will exist through TDRSS subnet and several STDN sites (in addition to their full S-band capability) will be configured for Ku-band. The SEPS onboard communication

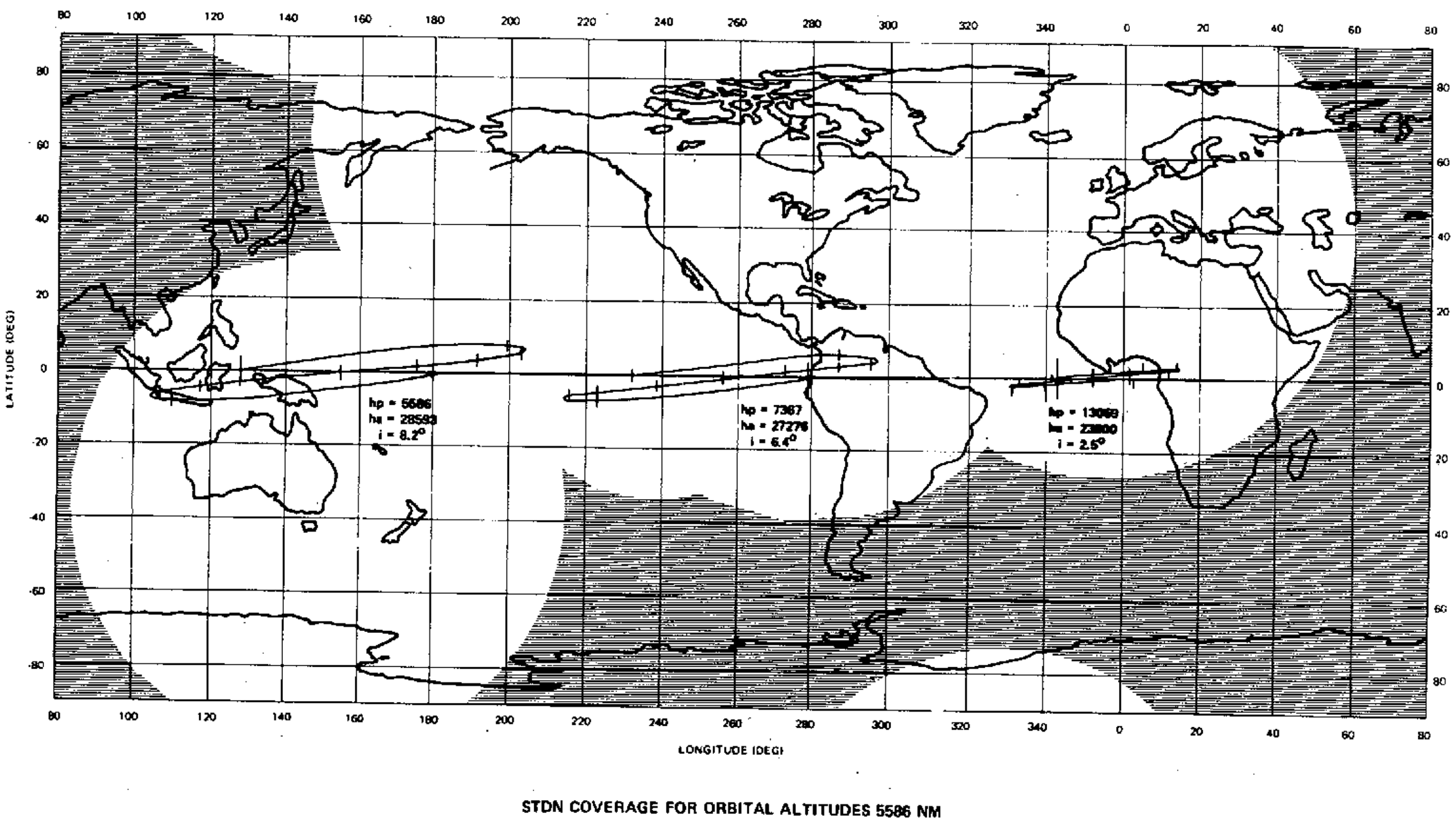


Figure 7-1. STDN COVERAGE FOR 5586 N. MI. ORBITAL ALTITUDES

systems will be compatible with both the STDN and TDRSS. SEPS does not require TDRSS, but will be designed to take advantage of TDRSS capabilities if they exist.

Each STDN site will have full S-band capability with several prime sites configured for Ku-band. Each TDRSS will have dual feed S-band/Ku-band 3.8-meter parabolic antennas plus a multi-element S-band array antenna, used primarily to relay communications to payloads. A 1.8-meter parabolic Ku-band antenna on each TDRSS will be used primarily for transmissions to ground terminals.

7.3.4 Network Data Flow

The various capabilities of NASCOM will be utilized for SEPS: microwave links for TV and high speed telemetry; wideband data circuits for telemetry; and high speed circuits for voice, teletype, command, and low speed telemetry. Where feasible, all data will be directly transmitted to the SEPS Control Center (SEPSCC) with a minimum of computation or processing. TDRSS data will be "bent pipe" through the ground terminal station at White Sands and shipped directly to the SEPSCC. Data downlinked through the remote STDN sites will be routed through GSFC to the SEPSCC. Once the data reaches the SEPSCC it will be split for real-time operations support and the data necessary for data reduction and processing in the Data Reduction Center.

7.3.5 Network Data Flow Requirements

The networks will be required to provide the following capabilities:

- Receive telemetry data from the SEPS vehicle and transfer to the SEPSCC.
- Transfer and uplink command data from the SEPSCC to the SEPS.
- Track the SEPS vehicle (angle, range, and range rate) and transmit data to the SEPSCC.

Estimates of data flow requirements are based upon SEPS unique requirements for telemetry tracking, command, and television. Voice and teletype requirements are based on NASA experience and coordination procedures. Results of this study are presented in Table 7-1. These are within the planned capability of the STDN and present no problems.

Table 7-1. DATA FLOW REQUIREMENTS

INFORMATION	SEPSCC/GSFC	GSFC/EACH STDN SITE
Telemetry	12,600 bits/sec	12,600 bits/sec
Tracking	60 bits/sec	60 bits/sec
Command	720 bits/sec	720 bits/sec
Television	One video line 4.5 MHz (1 link @ 4.2 MHz) (3 links @ .07 MHz)	One video line 4.5 MHz (1 link @ 4.2 MHz) (3 links @ .07 MHz)
Voice	4 lines	2 lines
Teletype	4-100 wpm lines full duplex (180 bits/sec)	1-100 wpm line full duplex (60 bits/sec)

NOTES:

1. *The tracking data flow requirements between GSFC and the SEPSCC are based upon three site concurrent coverage.*
2. *SEPS is in view of at least one STDN station at all times.*

7.3.5.1 Telemetry. SEPS ground station contacts for status checks are planned once each week. All housekeeping data accumulated during the week is stored by the Data Handling Subsystem. During a weekly status check real-time data are downlinked for analysis by console operators in the SEPS Operations Center (SEPSOC). Normally, the stored housekeeping data will be erased following the station pass. However, when anomalies are detected in the real-time data, a contingency mode of operation is initiated. More frequent station contacts are implemented (using more stations as required). Dumping of the stored data is initiated and continued until sufficient data are available to determine the cause and remedy the anomaly. The normal real-time data rate is 4 kilobits per second; the storage data rate is 32 bits per second to minimize the storage requirement (1.9×10^7 bits at 32 bits per second).

Real-time data downlink during remote man-in-the-loop payload handling using manipulators is the most demanding data rate (12.6 Kbps) for the telemetry system. During this interval of approximately 2 hours duration the telemetry rate requirements are itemized below.

Stage Data	1,200 bits/sec
Manipulators (If ground computers monitor onboard computer functions)	
9 elbow angles per arm, 9 torques per arm, 9 motor temperatures per arm (7-bit words sampled 30 times/sec)	11,340 bits/sec
TOTAL	12,540 bits/sec

Raw data flow (without compression techniques) requires a 12.6 Kbps band pass. This rate is the equivalent of 24 NASCOM 600-bit blocks. Compression and compaction techniques will reduce the effective band-pass requirements, but will impose an additional load on the Remote Site Data Processor.

7.3.5.2 Television. During payload deploy, retrieval, and payload handling, using manipulators real-time television is required. It is currently envisioned that as many as four simultaneous views of the operations will be required. To minimize bandwidth requirements three views with 4 frames per second and one high resolution view at 16 frames per second will suffice. Cameras for each will be identical with the capability onboard SEPS for obtaining the high resolution output from any of the four cameras. Bandwidth requirements are itemized below.

One high resolution analog link (512 x 512 lines) x 16 frames/sec	= 4.194 MHz
Three low resolution analog links (128 x 128 lines) x 4 frames/sec x 3	= 0.196 MHz
TOTAL	4.390 MHz

The total bandwidth requirement for all 4 lines is approximately 4.5 MHz, not including separation. Compression techniques could be utilized to achieve 4.5 MHz bandpass if required.

7.3.5.3 Commands. There are four command types applicable to the SEPS.

- Real-Time Commands

  The transmitter is directly modulated from the SEPSOC with a minimal throughput delay consistent with error-free messages. Command words must be error detection encoded. This class command is used to enable or inhibit onboard sequencing.

- Command Loads

  When large blocks of words must be uplinked, such as a burn table or state vector update, or when time coherence is essential, it is most practical to load the remote site computer with the full data load, then to issue an initiate signal of the SEPSOC.

- Maneuver Commands

  Real-time, man-in-the-loop docking presents a unique situation due to the visual assessment/immediate response requirement. This mode requires coupling of the payload/docking console outputs directly to the command uplink with minimal time delay; or with time delay compensation through predictor-extrapolation software. This mode must be preemptive of all other commanding.

- Manipulator Commands

  Real-time, man-in-the-loop manipulator payload operations present a visual assessment/immediate response requirement. This mode requires coupling of the payload/docking console outputs directly to the command uplink with minimal time delay. This mode is preemptive of all other commanding.

The most stringent commanding requirements occur during the payload handling operations via manipulators. The command data flow sizing is based on this mode. This estimate is based on a preliminary manipulator design and experience with the Shuttle manipulator simulator. Requirements are itemized below.

Commands to end effector, one arm maneuvered at a time.	720 bits/sec
9 command words, 8 bits each, 10 updates/sec (3 angular rates, 3 translational rates, 1 end effector control)	1,200 bits/sec

7.3.5.4 Tracking. The tracking network data flow is based on existing Unified S-Band (USB) tracking data formats and characteristics. The data flow requirements for low speed tracking signals were determined as follows:

Low Speed Tracking

* Each sample is 240 bits, but at a rate of one sample per six seconds
* Since 100 wpm teletype is equivalent to 60 bits/sec, one teletype (TTY) line is required for this data.

7.3.5.5 Voice. Two voice lines per STDN site are required for coordination of the ground networks. Four lines are required between the SEPSCC and GSFC.

7.3.5.6 Teletype. The teletype requirements are based on Apollo and Skylab experience. The outbound TTY data to STDN sites will consist of:

- Site configuration messages
- Antenna pointing data messages.

Inbound traffic will be low speed tracking data (see tracking requirements). Consequently, one line fulfills the TTY requirements for each site. During other than prepass and pass periods, the line will be used for administrative traffic. However, separate low speed data lines may be required for each ephemeris being maintained at the SEPSCC, which, for the SEPS mission, requires up to four simplex 100 wpm TTY links.

7.4 SEPS OPERATIONS CENTER (SEPSOC)

The SEPSOC will be used for all program support activities. All mission preparation, flight control, and refurbishment functions will be accomplished at this facility. The mission planning and other support for these functions will also be accomplished at the SEPSOC. This facility is an integral part of the operation concept.

7.4.1 Flight Control Requirements

To implement the flight operations, the SEPS Control Center must provide the overall functional capabilities listed below:

- A means of real-time trajectory determination to provide inputs to the guidance system.
- Methods for sequencing and controlling payload release, payload rendezvous and docking for deployment, retrieval, and for payload exchange with Tug.

C - 2

- A means of controlling vehicle attitude and translational movement during rendezvous and docking.
- A method of monitoring vehicle and system performance and for initiating alternative actions when required.
- Flight controllers to analyze the vehicle and mission status and make decisions regarding contingency operations.
- A means of planning and updating the optimum trajectory.
- A means for controlling changes of orbital trajectory by ion thrusters and/or APS thrust forces.
- A means to guide the vehicle during trajectory changes.
- Facilities to support flight controllers (consoles, plotboards, panels, and so forth).

7.4.2 Mission Preparation Requirements

The mission preparation functions require the following ground support elements.

- A launch preparation area of the SEPSOC facility with storage for eleven SEPS, repair parts for refurbishment and maintenance of GSE. This facility must be approximately 300 x 50 feet. It will also contain an area for launch preparation testing. Figure 5-6 presented a floor plan of this facility.
- Two sets of dual purpose test equipment for (1) end item acceptance and (2) launch preparation. The major items are a test control console (see Figure 4-10), an air table to support the solar arrays during test of the deployment mechanism, a ground power supply, and a computer terminal to control flight readiness testing.
- Space for launch preparation, flight article refurbishment, and GSE maintenance is required.
- Special tools to remove and replace Line Replaceable Units (LRU's) during refurbishment.
- LRU designated as repair parts for refurbishment.
- Refueling kits.
- Storage and transport containers.
- Transport half shells (Tug program).
- Test type applications software.

7.4.3 Mission Planning Requirement

The SEPSOC must provide personnel space for the following functions:

- Software modifications
- Procedure development

- Logistic support
- Interface configuration management
- Flight data evaluation
- Mission sortie planning.

7.4.4 Characteristics

A floor plan of the SEPSOC facility was presented on Figure 5-6. It is divided into two major areas, one area for launch preparation and refurbishment, and a second area for flight control and mission planning.

7.4.4.1 Launch Preparation Area

- This area will provide for
  - (1) Storage of flight inventory, repair parts, and consumables
  - (2) Subsystem test and refurbishment
  - (3) Equipment maintenance
  - (4) Access to a common computer terminal.
- Figure 7-2 presents a test console used for flight readiness testing.

7.4.4.2 Flight Control Center The flight control center will contain:

- Flight Directors Console
- Guidance Dynamics Console
- Avionics Systems Console
- Propulsion and Mechanical Console
- Manipulator Systems
- Computer peripherals
- Data link with STDN
- An engineering support area
- Mission Planning area with office space for the complete program support team
- A computer terminal with access to institutional computer.

The computer size for the SEPS control center is based on memory requirement and speed of execution required. The maximum memory size is based on real-time operation at which time command uplink software, real-time downlink

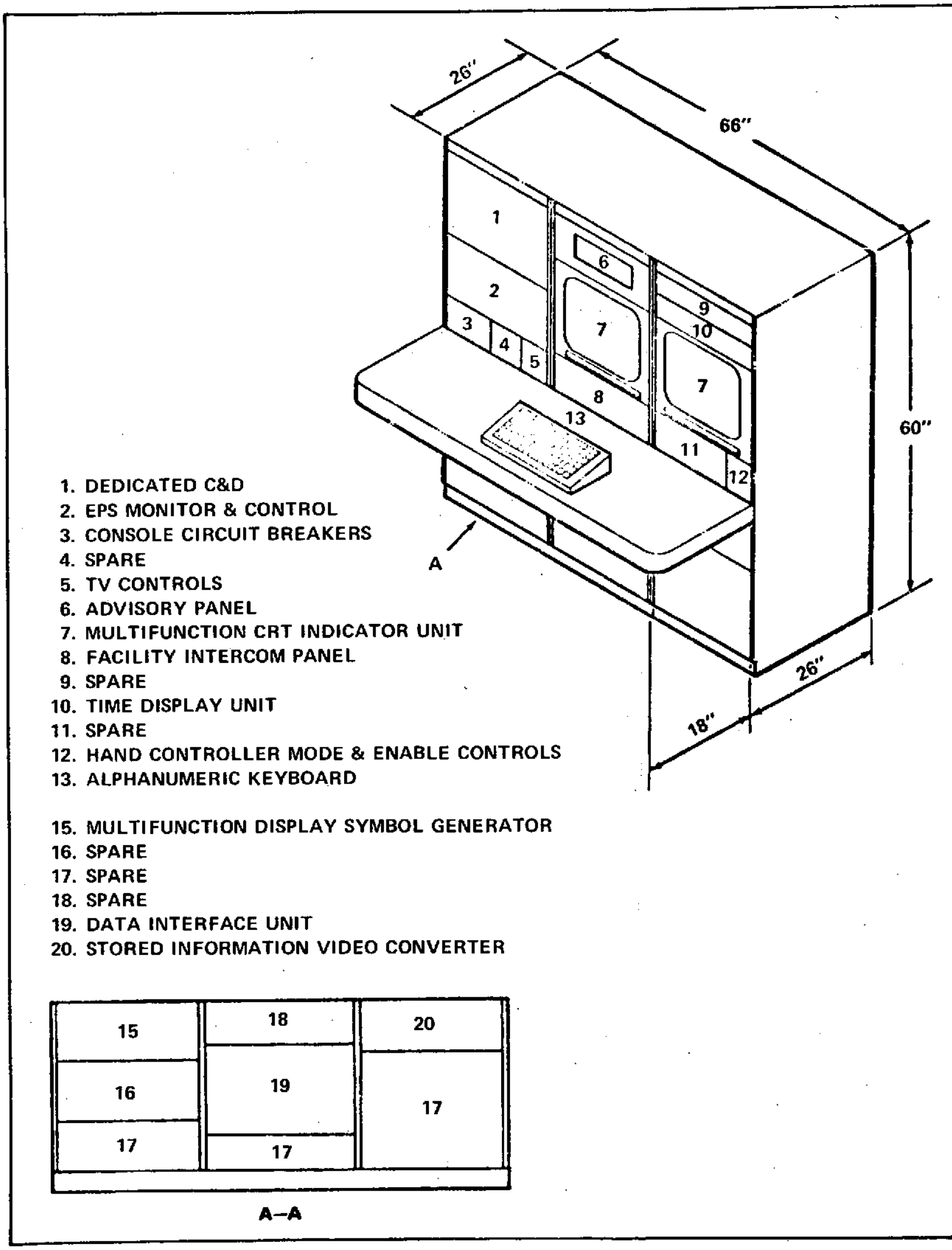


Figure 7-2. TEST CONTROL CONSOLE

software, executive, and trajectory determination software simultaneously occupy the main memory. These are summarized in Table 7-2. The resulting requirement is 2.13 megabits memory requirement. These assessments are based largely on the IBM studies sponsored by MSFC.

Table 7-2. CORESIDENT SUMMARY REQUIREMENTS

SOFTWARE FUNCTION	WORDS	BYTES
Executive	208,456	832,824
Vehicle Systems	156,675	626,700
Mission Profile	167,625	670,500
	532,956	2,130,024

Computational speed is taken to be equivalent to the JPL maximum rate, 3.08×10^6 operations per second. This is approximately 37 percent less than the JSC real-time computer complex maximum rate.

Applying a 50 percent growth factor to the memory and execution rates results in 3.2 megabits of memory and 4.6×10^6 operations per second (megaops) requirement. A computer system which meets this requirement is the IBM 370/158 which provides 4.2 megabits of memory and 12.2 megaops execution rate, providing 97 percent margin for growth in memory and 297 percent margin in execution rate.

7.5 SOFTWARE

The SEPS Control Center software resides in the central computer and provides centralized processing of telemetry and radar tracking data inputs received from the STDN and performs other complex mathematical and logical functions in support of the flight controllers. In addition, software will exist to provide a simulation capability in support of software development, mission controller training and procedures verification, and a normal jobshop environment when not supporting a mission in real time. Emphasis here is on the mission support function.

The functional interfaces of the software and the various control center subsystems is illustrated on Figure 7-3.

Software functional structure for a mission control center is shown in Table 7-3. The software is partitioned into four principal functional areas: vehicle systems, mission profile, control, and simulation. These are identified with major subdivisions.

Table 7-3. MISSION CONTROL CENTER SOFTWARE STRUCTURE

VEHICLE SYSTEMS	MISSION PROFILE	CONTROL	SIMULATION
• Telemetry • Command	• Orbit Trajectory Determination • Orbit Trajectory Computation • Mission Planning • Docking	• Executive • Control Center Support	• SEPS Vehicle • Control Center System • Ground Station • Simulated Data Input Control

The size of software for a SEPS Control Center mission support has been estimated and is summarized in Table 7-4. This is approximately five percent greater than for the Tug control center.

Table 7-4. SOFTWARE SIZE SUMMARY

FUNCTION	NO. OF INSTRUCTION WORDS	NO. OF DATA WORDS	TOTAL
Downlink Processing	93,974	35,675	129,649
Uplink Processing	67,250	31,250	98,500
Mission Profile	254,750	253,400	525,125
Docking	17,700	10,750	28,450
Executive System	221,730	33,226	254,956
Control Center Support	35,175	35,601	70,776
Simulation System	134,000	50,500	184,500
TOTALS	824,579	450,402	1,274,981

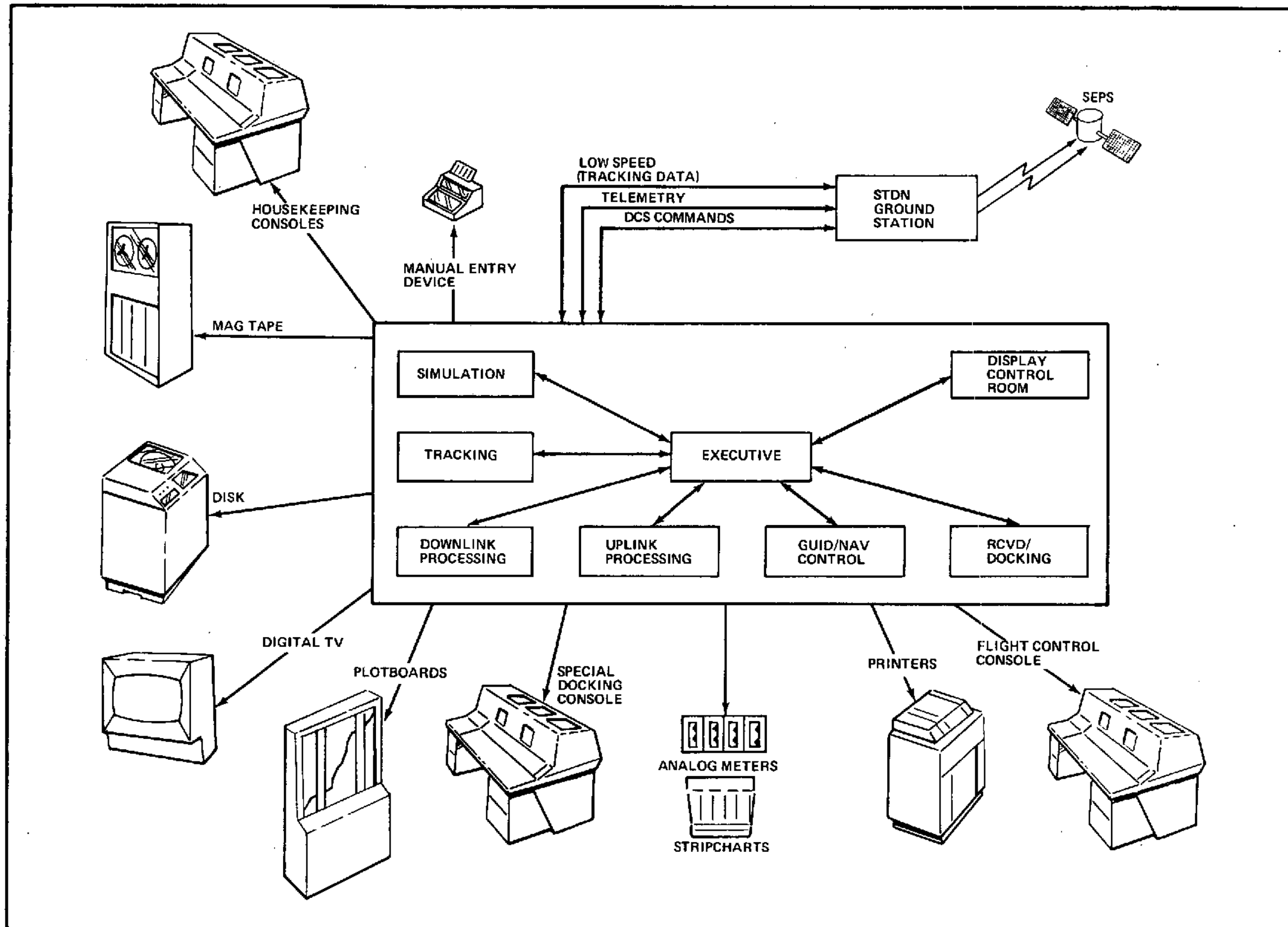


Figure 7-3. SOFTWARE FUNCTIONAL INTERFACES

Each functional software area sized for the SEPS Control Center was examined as were delta estimates to the Tug software to accommodate a combined Tug and SEPS control center. Those were examined in light of relative avionics differences, relative numbers of telemetry and commands, trajectory computations, orbit determination, mission planning, and vehicle simulations.

SEPS has a total of 540 telemetry words; however, when multiples of sets of data are screened out such as for 8 thrusters, the result was 280 basic data words. The Tug estimate was based on 300 data words. No change was made to the downlink processing because SEPS, not including man-in-the-loop maneuvering control, has roughly 30 percent more command functions than Tug. Uplink processing was increased accordingly.

Low speed radar tracking is sufficient for SEPS since its operations can be equated to coast operations for impulsive vehicles. High speed radar processing is not required. As a result, orbit determination software size for SEPS is reduced.

Trajectory computation for SEPS requires approximately 20 percent more software than for Tug.

The net result of decreased radar processing and increased trajectory computations offset one another, mission profile software words being decreased insignificantly.

Mission planning for SEPS involves typically three up, two down payloads where Tug estimates involved only two up payloads per sortie, the impact being increased mission profile data words, principally due to the increase in the size of the mission planning table.

Executive and control center support was not changed as no significant reason for change is apparent.

Simulation software was increased about 25 percent in the vehicle simulation area, an insignificant increase to the total simulation software, however.

7.6 PERSONNEL

Each SEPS flight unit (11) must be prepared for its mission cycle. The total SEPS system must be operated and maintained for the 11-year period of the mission model. Because SEPS is relatively simple and physically small, the mission preparation function is simple. The greatest personnel requirement is to accomplish mission planning and flight control functions.

An analysis was conducted which indicates that all operational phase functions can be accomplished by a multidisciplined 45-man organization. The personnel must know SEPS configuration, functions, subsystems, and components in detail. This organization, shown in Figure 7-4, will perform the following functions:

- Flight Control. Five people are required to control SEPS. Other support people bring the total SEPSOC manning per shift to 15. The control center will be manned for approximately 120 hours during a typical 100-day sortie which is described in Section V. The total man-hours expended will be approximately 1800 per sortie. The Mission Model contains 29 sorties which would require about 52,000 man-hours.
- Launch Preparation and Flight Readiness Testing. Eleven launch preparations are required; eight are for planetary missions. Each cycle will take about 80 hours and require 8 engineers and 12 technicians. This function will require approximately 17,600 man-hours. Post-manufacturing acceptance tests conducted at the manufacturer's plant prior to placing the SEPS in its storage canister are complete flight readiness tests and require 24,400 man-hours. Launch site coordinates will require 1 person full time for a total of 22,000 hours.
- Maintenance and Refurbishment. The maintenance and refurbishment activity will require about 2,000 hours per sortie. Repair parts must be ordered, procedures written, inventories maintained, and equipment maintenance accomplished. Two flight units will be refurbished, (1) the qualification test article and (2) the first earth orbital flight unit. The GSE at the SEPSOC and the GPME must be maintained for 11 years. The total man-hours required is approximately 58,000 for the 29 sorties in the Mission Model.
- Mission Planning and Support Activities. The SEPS operations support personnel must accomplish planning and technical support activities. These include, but are not limited to: software modifications, procedure development, logistic support, interface configuration management, flight data evaluation, ground equipment modifications, payload activity planning, and other mission planning tasks. The remainder of the personnel resources will be used to accomplish these major functions.

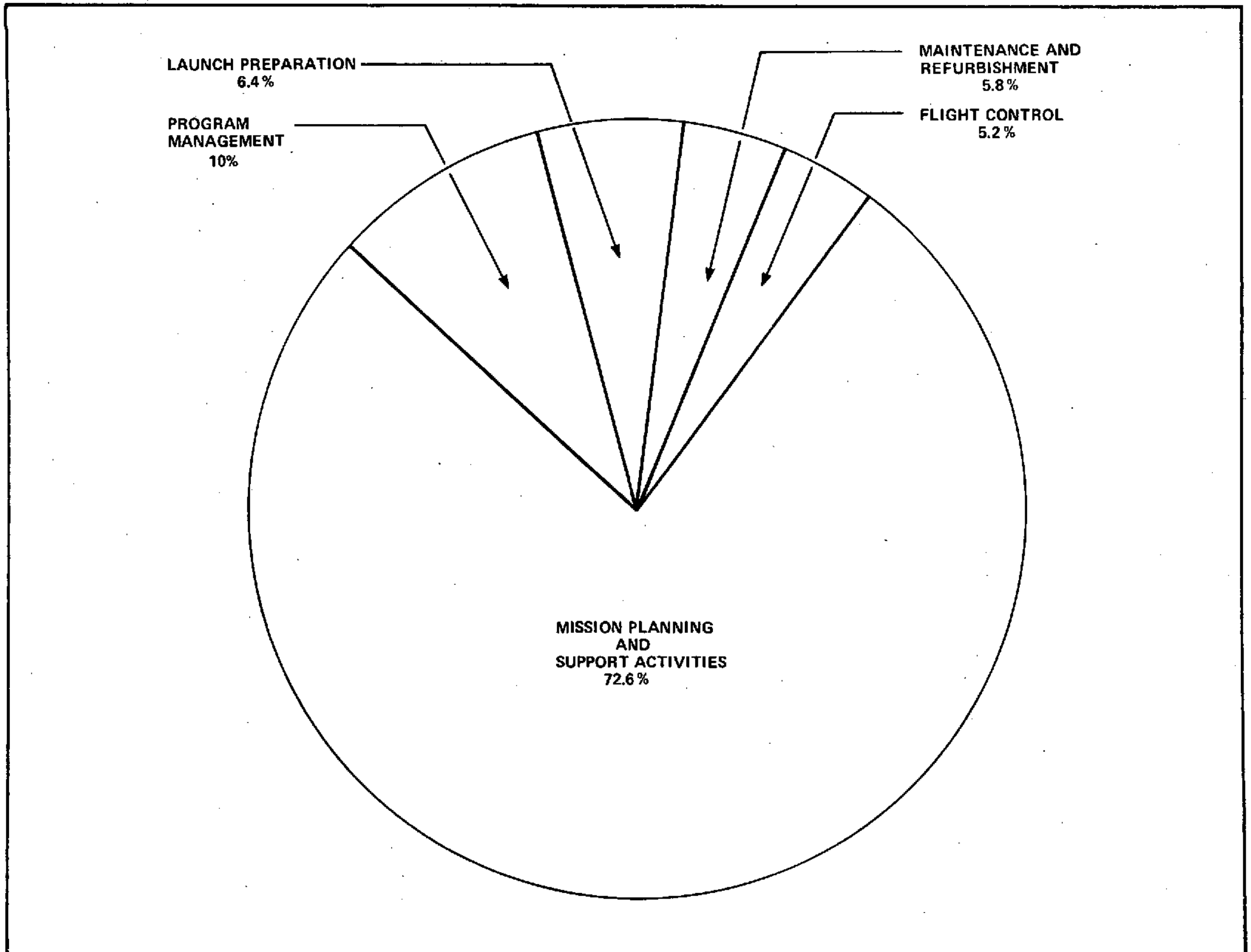


Figure 7-4. SEPS MANPOWER ORGANIZATION

Figure 7-4 presents an estimate of the percentage of the total manpower required for each function. Forty-five people for 11 years represents a total of one million man-hours. The direct hardware preparation and control functions have a low density. The minimum manning level is determined by skill mix and planning requirements. More flight missions sorties could be added without increasing the manning level. Flight control and mission planning are discussed in subsections 7.6.1 and 7.6.2. The mission preparation functions which are discussed in Section V will be accomplished by the vehicle systems engineers and technicians when active flight control is not required.

There are only 30 earth orbital sorties by SEPS over an 11-year period. Since SEPS has an autonomous cruise and terminal approach capability, a sortie has only three periods of peak activity where the flight control crews are fully utilized. These periods are associated with the following functions:

1. Systematic retrieval of payloads and initiation of the cruise phase down to the Tug rendezvous orbit.
2. Rendezvous with Tug, delivery of down payloads, acceptance of up payloads, and the initiation of the ascent cruise phase.
3. Deployment and servicing of payloads.

7.6.1 Flight Mission Control

During a typical 100-day sortie about 117 hours of manned control is required. Payload handling, rendezvous, and tracking are the functions which must be controlled. Section VI contained a detail discussion and time lines of these functions.

These functions will require 27 people as described in Tables 7-5 and 7-6. This manpower is enough to control the functions on a two-shift basis. The active flight control periods represent about 10 percent total mission time. During the inactive periods these people will perform other SEPS functions. They will be organized into two groups under the supervision of a flight director.

Table 7-5. FLIGHT CONTROL GROUP MANNING REQUIREMENTS

POSITION NO.	POSITION TITLE	PERSONNEL PER POSITION
1	Flight Director	2
2	Vehicle Systems Engineer	1
3	Vehicle Avionics	2
4	Vehicle Propulsion and Mechanical Engineer	2
5	Flight Dynamics Engineer	1
6	Guidance/Dynamics Engineer	1
7	Dynamics Data Engineer	1
8	Payloads/Docking Engineer	2
9	Docking/Television Engineer	2
		14

Table 7-6. FLIGHT SUPPORT GROUP MANNING REQUIREMENTS

POSITION NO.	POSITION TITLE	PERSONNEL PER POSITION
10	Flight Support Director	1
11	Data System Supervisor	2
12	Command/Telemetry	2
13	Computer Monitors	2
14	Maintenance and Operations	2
15	Voice/Data Tech	2
16	Display/Television Tech	2
		13

7.6.1.1 Flight Control Group

The Flight Control Group is responsible for the SEPS and the successful accomplishment of its sortie mission. As shown on Figure 7-5, it is divided into three teams: Vehicle Systems, Flight Dynamics, and Payload. Personnel manning the positions in the Flight Control Group will be experienced engineering personnel. They will have design and test responsibility for the system which they monitor and control.

Flight Control personnel are responsible for the real-time control of the vehicle. Preparation requires extensive study and "on-console" training. Backup personnel must also be prepared to provide timely and qualified flight support in contingency situations. Flight controllers must have complete knowledge of vehicle systems, the Control Center data display, command system, and sortie flight plan. The Vehicle Systems Team monitors real-time data and maintains cognizance of the SEPS operational status. The team has two propulsion and avionics responsibilities.

The Flight Dynamics Team is responsible for SEPS trajectory management. This requires the comparison of actual and desired vehicle trajectories, to determine corrective commands. This team is also responsible for maintenance of mission profile software. Functional divisions of the team are Guidance and Dynamics/Data.

The Payload Team is responsible for all payload operations including interfaces with the principal investigator and the Spacecraft operations center. Through this interface, control of payload deployment and retrieval functions will be established. The exchange of payloads between SEPS and Tug, will be coordinated by this team. This team is also responsible for maintaining the SEPS simulator software.

7.6.1.2 Flight Support Group

The Flight Support Group has two responsibilities, Flight and Software Support. It assists the Flight Control Group with commands, communications, and displays, and maintains all equipment within the facility. It provides

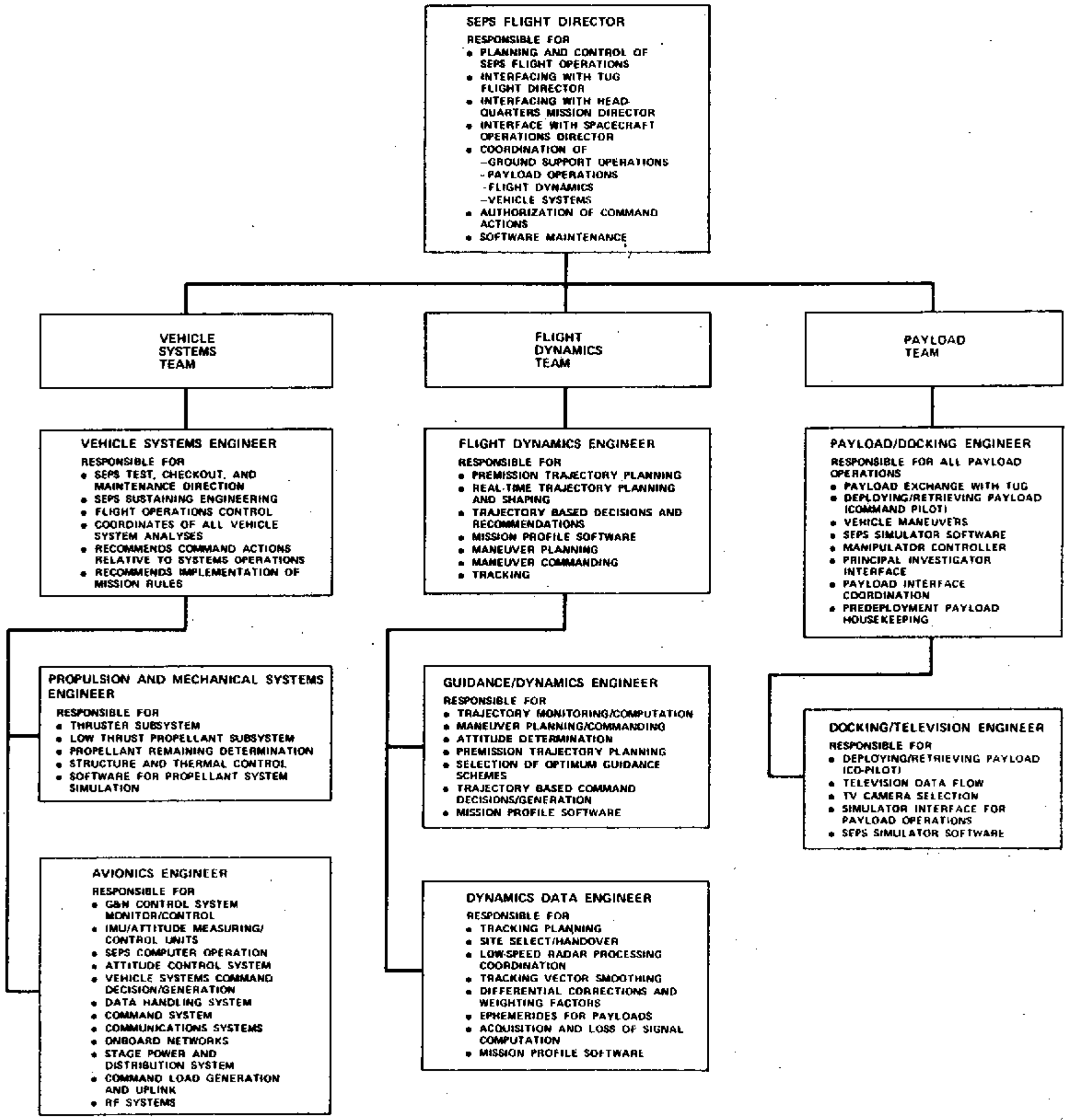


Figure 7-5. SEPS FLIGHT CONTROL ORGANIZATION

software support on telemetry data processing. The Software Support responsibility requires a personnel capable of handling software related problems and operating the equipment within the facility.

Flight Support Team is responsible for SEPS Control Center readiness. During nonmission time periods, Flight Support Personnel reconfigure equipment and train for future missions.

The Flight Support Team is headed by the Flight Support Director as shown on Figure 7-6. A brief description of the duties and responsibilities is included.

Software Support Group. Figure 7-6 shows the Software Support Group and gives a brief description of its responsibilities.

The group is responsible for scheduling computer operations to meet the demands of the flight control center. It is responsible for the functional integrity of the software. The group assures that software is updated to support mission planning, and that maneuver planning changes are implemented.

Software Development is developed and updated to keep pace with mission planning changes and display requirements. This function is accomplished by the user personnel in the Flight Control and Flight Support Groups who are familiar with the software. These are the personnel who detect malfunctions in the system operation and must respond with solutions to software deficiencies.

Mission profile software development and maintenance will be accomplished by Flight Dynamics personnel, vehicle systems software by command/telemetry support personnel, executive and simulation software by computer monitor personnel and simulator software by payload operations personnel.

The Computer Operations Section operates independently of the Flight Control Center. It is responsible to support mission control and training of flight controllers.

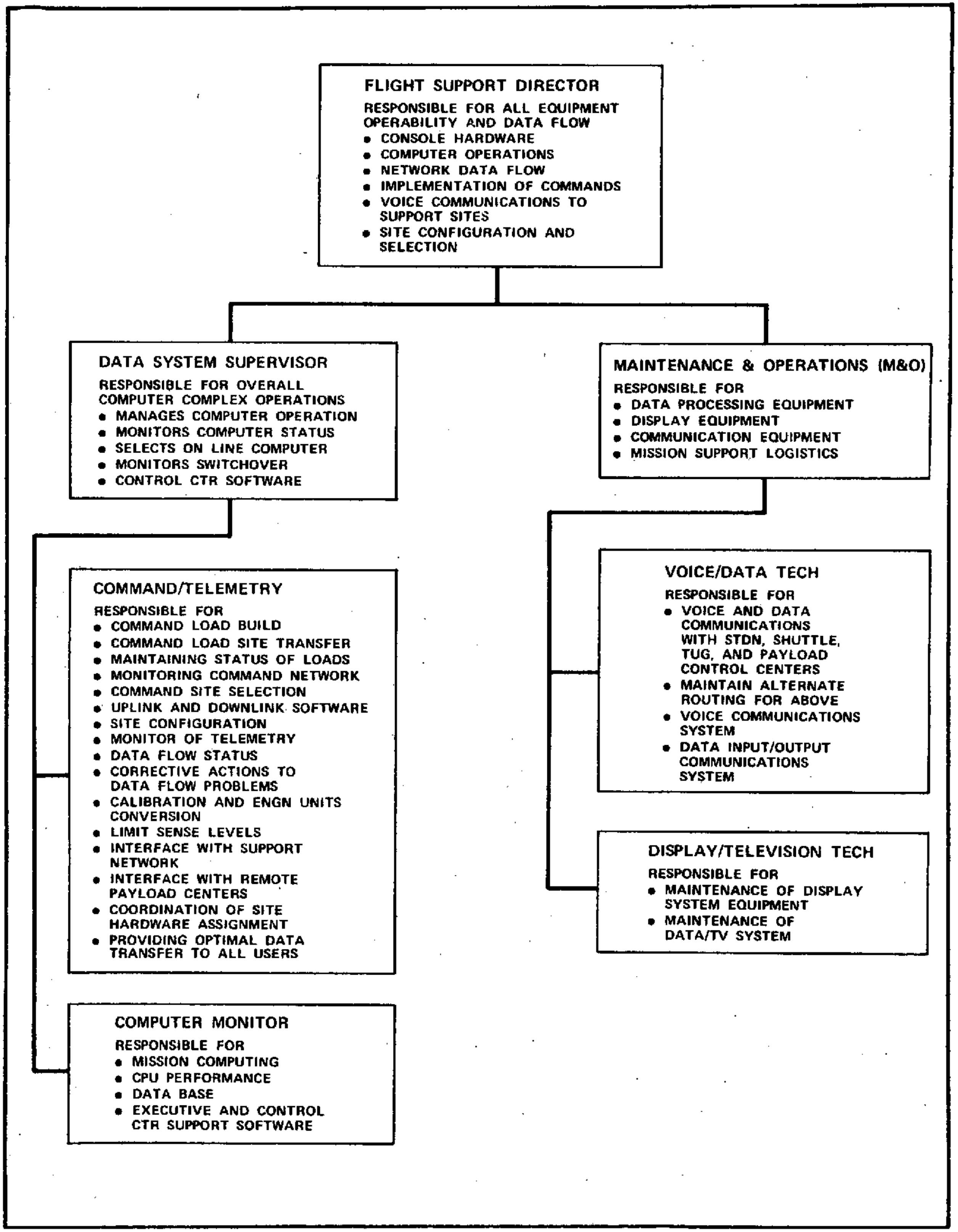


Figure 7-6. FLIGHT SUPPORT TEAM

This computer need not be a new installation. It could be provided by a host computer complex which is administered by the Computer Services Division of the Administrative and Program Support Organization.

Personnel in the computer operations section include computer operators, data processing engineers, keypunch operators, tape librarians, administrative personnel, and customer engineers.

7.6.2 Mission Planning

To place the SEPS mission planning function in proper perspective, its relation to other STS and payload planning functions should be reiterated.

There will be an STS and Space Lab planning and master scheduling function. Policy and formal approval of flight assignments will remain vested in NASA Headquarters. Detailed master schedules, which assign payloads to specific STS flights, will be developed at a NASA center. Flight profiles for these missions will be developed by the same NASA center. This planning operation will use input data from the mission planning groups associated with the Shuttle, Tug, SEPS, and the individual payload operators. The specific firm flight assignments of payloads will be known from 6 months to a year in advance. Tentative assignments will be known in some detail for about 2 years in advance of the flight.

The Orbiter, Tug, and SEPS plans for operations at the launch site, and the schedule of events from lift-off to orbiter return, will be generated and controlled by the Shuttle operations center.

The SEPS mission planning, therefore, consists of the following functions:

- Contribution to the STS utilization and master scheduling function. This is an updating of an original data package generated before the first SEPS are flown. Updating will consist of documentation of specific procedures, changes, and unique payload support requirements evolved from flight experience.

- SEPS mission planners will develop specific detailed plans for the next mission sortie based on the following information supplied by STS operations control and STS and Space Lab utilization planning:
  - Payloads to be retrieved.
  - The payload transfer orbit that will be used for Tug and SEPS rendezvous.
  - Payloads that are to be received from the upcoming Tug and their mission destinations.
  - The dates and time schedules for the Tug and SEPS payload transfer operation.
  - Payload support functions and services to be performed by SEPS through its in-flight interfaces and the SEPSOC data links.

The sortie plan will provide the following information:

- The responsibilities, flight control function, and work schedule of each one of the team members in the 45-man group that is to be involved in flight control.
- Requirements for SEPS flight control software changes.
- Predicted schedule and priority of demands on the computer complex. The number of hours on each day that computers are required.
- Plan for replenishing the RCS and mercury propellants.
- Definition of payload mast clamps and payload transport diaphragms with rotational capability.
- Sequence of events for the sortie.
- Implementation plan and schedule for each SEPS event.

For STDN:

- Schedule of tracking and communications, with times, dates, and durations.
- Optional tracking and communications requirements including schedule for the navigation guidance and payload status data dumps.

For payload developer:

- Schedule of events involving payload and implementation plan for events.
- List of data dumps containing payload status information and scheduled times.
- Plan for joint SEPS and payload control team to carry out any initial deployment, deployment monitoring, or startup servicing of a payload.
- Definition of interfaces and interface activity between SEPS and payloads.

The mission planning function will be largely a task of fitting previously developed standard procedures, standard maneuvers, and standard trajectory profiles together for definition of the specific sortie involved. With the input data available and SEPSOC's set of compatible "automated" mission planning software, 12 men can develop a sortie plan in 1 week.

7.6.3 Mission Support Activities

The SEPS operations organization will plan, support, and supervise both preventive and unscheduled maintenance activities on flight control, ground checkout, and servicing equipment. Recall that this ground equipment comprises 5 flight control consoles, 3 ground checkout consoles and 2 fueling kits.

Logistic Support Planning. The SEPS operations organization will conduct the refurbishment of the first orbital SEPS. During the flight phase this organization will gather and evaluate SEPS performance data to identify the components to be replaced or modified in the refurbishment cycle. The SEPS operations organization will be responsible for logistical support of SEPS flight hardware maintenance and refurbishment.

Software Modifications. The SEPS operations organization will modify first mission software to the configuration required for each subsequent sortie. This includes (1) flight control software, (2) ground operations software, (3) flight trajectory software, (4) manipulator control software, and (5) software for program support activities.

Configuration Management. The SEPS operations organization will be responsible for configuration control of all SEPS elements. This is to include all software, hardware, and facilities.