SATELLITE SERVICES SYSTEM ANALYSIS STUDY

FINAL REPORT
PART II
VOLUME 2

STUDY RESULTS

CONTRACT NAS 9-16121

DRL ITEM NO. MA-834T
LINE NO. 4
22 JULY 1981

LOCKHEED MISSILES & SPACE COMPANY, INC. SUNNYVALE, CALIFORNIA
SATELLITE SERVICES SYSTEM
ANALYSIS STUDY

FINAL REVIEW
PART II

PRESENTED BY
LOCKHEED MISSILES & SPACE COMPANY, INC.
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TO

NASA JOHNSON SPACE CENTER
HOUSTON, TEXAS

CONTRACT NAS 9-16121
DRL ITEM NO. 4,DRD NO. MA-834T
22 JULY 1981
FOREWORD

This document contains the detailed final results of the Satellite Services System Analysis Study Part II performed for NASA Johnson Space Center by Lockheed Missiles & Space Co., Inc. It is submitted, together with the Executive Summary, Volume I in fulfilment of the requirements (DRL Items MA-834T and MA-745T) of Contract NAS 9-16121, which was initiated on 1 August 1980.

This volume includes a summary of the Part I study results which were previously documented in February 1981.
Satellite Services System

Study Results, Part II

1 - SUMMARY OF PART I
2 - SERVICE EQUIPMENT PRELIMINARY DESIGN
3 - PROGRAM PLANS
4 - SYSTEM COST ESTIMATE
5 - CONCLUSIONS
ACRONYMS USED IN THE STUDY
1. Summary of Part I
The Study Objectives are presented in order to orient the reader and to set the stage for the remainder of this presentation.
PART I
- DEFINITION OF SATELLITE USER MARKET
- DEFINITION OF SATELLITE SERVICES CONCEPT AND MISSIONS
- ANALYSIS AND DEVELOPMENT OF DESIGN REFERENCE SCHEDULE BASED ON DESIGN REFERENCE MISSIONS
- SCOPING OF FULL SATELLITE SERVICE SYSTEM PROGRAM RESOURCES

PART II
- PERFORMANCE OF PRELIMINARY DESIGN OF NEW AND MODIFIED SERVICE EQUIPMENT
- PREPARATION OF PROGRAM AND OPERATIONS PLAN
- DEVELOPMENT OF RESOURCES REQUIREMENTS
The organization and costing of the satellite services systems were addressed in the program planning.

**Vice Missions.** Preliminary design was carried out on a selected set of hardware needed for early service functions. Service Kits were defined as collections of equipment applicable to performing one or more service and service assumptions.

A more comprehensive service model was developed based on average revision by mission class. The number of service events of each class was estimated based on the NASAs and ODP mission models segregated and placed on applying equipment in the current NASAs inventory and that in advanced stages of planning.

The hardware needs for accomplishing the service functions were identified with emphasis being placed on achieving equipment in the current NASAs inventory and that in advanced stages of planning.

**Servicing Concepts.** Concepts were developed through mission analysis and STS mission constraints analysis.

Of design reference missions were selected which represented needs for each of the service functions. Service functions were defined and a group of design reference mission were selected through a survey of the potential user market which included NASAs, ODP, commercial and international space ventures. The early mission model was developed through this chart shows an overview of the tasks which made up the satellite services system analyses study.
Classificaiton.

of synchronous-equatorial missions except for a few representational "deployment only" missions.

This figure illustrates the difference in inclination distribution between the NASA/commercial and the

INCIDATION DISTRIBUTION

Random Sample of World Space Objects Inclination Summary

- DOD STS Utilization Plan - May 1980
- DOD STS Utilization Plan - Sept 1980
- STS Flight Assignment Baseline - Sept 1980
- NASA STS Mission Model - 1977

Data entered into the database was drawn primarily from:

and will require propulsion (and guidance) to rendezvous with the orbiter for servicing.

distribution indicates that the preponderance of the satillites are higher than the orbiter capability.

distribution profile is markedly different from the NASA/commercial/foreign missions. The DOD altitude

classification, the average altitude distribution is plotted in this figure. The DOD missions are

excluded. Only a sample of these mission types were included to represent the "deployment only"

This histogram and those that follow characterize the LMSC-2 data base. The listings of planned

AVERAGE ALTITUDE DISTRIBUTION

LOCATION OF PLANNED SATELLITES
Debris removal must wait until the orbits decay to the STS standard orbits.

Transfer vehicle of act recovery/disposal of space debris with general require the use of some form of orbital

Conclusions drawn for:

Garbage disposal missions, will become space debris in the 1983-1993 study timeframe. This sample indicates the potential

between existing operational and dead satellites because most currently operational satellites

This rapid decay of satellites in these orbits. No distinction is

distillation of 11,000 pieces of space objects in the nominal listings. The lack of low altitude pop-

No classified data was entered. The curve can only be considered as a rough indication of the

The space debris and operational satellite altitude distribution

SPACE DEBRIS AND OPERATIONAL SATELLITE ALTITUDE DISTRIBUTION
Space Debris and Operational Satellite Distribution

UNCLASSIFIED DATA BASE

MISSIONS IN DATA BASE (NO.)

STS STANDARD ORBIT

AVERAGE ALTITUDE (NMI)

100 200 300 400 500 600 800 1,000 10,000 20,000
to the widest potential for servicing.

to a specific member of the satellite class, but if it is evident that the free flyers are subject
dictates a potential service function for that class of satellite. Not all functions are applicable
This figure cross-correlates the service need functions and the classes of missions. Each „x“ in-

MISSION CLASSES VS SERVICE FUNCTIONS
## Mission Classes vs Service Functions

<table>
<thead>
<tr>
<th>SERVICE FUNCTIONS</th>
<th>MISSION CLASSES</th>
<th>FREE FLYER</th>
<th>STS INACCESSIBLE</th>
<th>FREE FLYER ACCESSIBLE</th>
<th>FREE FLYER DEBRIS</th>
<th>DEPLOY ONLY</th>
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<td>😡 ORBITER/SATELLITE RETURN</td>
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</table>
set requires the full complement of service functions.

The selected candidates shown here are the Design Reference Missions which were ultimately selected. The selected candidate was evaluated for service functions that are required or useful for the mission. The table illustrates the procedure used to narrow the choice of Design Reference Missions. Each
## Design Reference Missions vs Service Functions

<table>
<thead>
<tr>
<th>SERVICE FUNCTIONS</th>
<th>DESIGN REFERENCE MISSIONS</th>
<th>SPACE TELESCOPE</th>
<th>SOLAR MAX</th>
<th>OAO3</th>
<th>NOSS</th>
<th>COBE</th>
<th>GALILEO</th>
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<td>— DEBRIS COLLECT.</td>
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</table>
The initial categories of new equipment are presented here. Items selected for preliminary design in Part II of the study are indicated. The results of the design effort are given in Section 2 of this report.
### Candidate New Equipment for Preliminary Design (Part II)

<table>
<thead>
<tr>
<th>SAFETY EQUIPMENT</th>
<th>SERVICE EQUIPMENT — ORBITER MOUNTED</th>
<th>CREW PROTECTION AND AUGMENTATION EQUIPMENT</th>
<th>SATELLITE AND DEBRIS CAPTURE HARDWARE</th>
</tr>
</thead>
<tbody>
<tr>
<td>PORTABLE GROUND STRAP*</td>
<td>SATELLITE EXTRACT/INSERT PIVOT/ROTATE TABLE*</td>
<td>NONE</td>
<td>ORBIT ATTACH/REMOVE GRAPPLE FIXTURE*</td>
</tr>
<tr>
<td>SAFEING KIT/TOOLS</td>
<td>UMBILICAL MATE/DEMATE*</td>
<td></td>
<td>GRAPPLE ASSEMBLY STANDOFF FIXTURE*</td>
</tr>
<tr>
<td>SHARP CORNER/EDGE PAD KIT*</td>
<td></td>
<td></td>
<td>DEBRIS COLLECTION CONTAINER</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SERVICE EQUIPMENT — GENERAL</th>
<th>WORK SYSTEMS/AIDS</th>
<th>HAND TOOL EQUIPMENT</th>
<th>MANEUVER/STABILIZE AND RETRIEVAL HARDWARE</th>
</tr>
</thead>
<tbody>
<tr>
<td>GAS/LIQUID EVA CONNECTOR</td>
<td>PORTABLE FOOTRESTRAINT*</td>
<td>RTV COATING APPLICATOR*</td>
<td>EXTENDABLE/ARTICULABLE BOOM</td>
</tr>
<tr>
<td>GAS/LIQUID MANIFOLD</td>
<td>STOWAGE CONTAINER</td>
<td>ENERGIZED DRILL</td>
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<tr>
<td></td>
<td>RACK/TIE-DOWN PLATFORM*</td>
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<td>MANEUVERABLE TV</td>
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</table>

*SELECTED FOR PRELIMINARY DESIGN
The median weight provided for the non-zero payloads of opportunities, based on a log-normal distribution, loads will grow with expanding STS use.

The flight assignment baseline is truncated in 1995 but the opportunities for carrying ancillary pay-

ights is the primary mission has critical launch window constraints.

ights to the target satellite. Rendezvous timing requirements could preclude effective use of a given

standard orbit. For purposes of rendezvous scrutiny, the orbit would be modified to match that

The flight times are grouped by year and inclination. The individual attitudes are the STS low altitude.

showing some payloads will zero length but finite weight and vice versa.

ights. Every STS flight having either weight or length available was listed. This resulted in

The data presented here shows the complete set of opportunity payloads for both NASA and DOD.

It means the identified excess capability in payload weight and length for a given STS flight.

The term "payload of opportunity" is used in the NASA Flight Assignment Baseline but not defined.

PAYLOADS OF OPPORTUNITY
Payloads of Opportunity

<table>
<thead>
<tr>
<th>YEAR</th>
<th>LAUNCHES</th>
<th>AVAILABLE WEIGHT (KLb)</th>
<th>AVAILABLE CARGO BAY LENGTH (FT)</th>
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</thead>
<tbody>
<tr>
<td>1982</td>
<td>28.5°</td>
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<tr>
<td>1983</td>
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<td>1984</td>
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</table>
estimates.

and the identification of service equipment (existing, modified, new) and their first cut cost

the design reference mission to the definition of a comprehensive set of satellite service functions

and traceable progression from the definition of the satellite user market and the selection of

The accomplishments of Part I of the Satellite Services System Analysis Study have been a logical

PART I

PRINCIPAL ACCOMPLISHMENTS
Principal Accomplishments

Part I

- DEVELOPED SATELLITE USER DATA BASE AND MANAGEMENT COMPUTER PROGRAM

- IDENTIFIED SATELLITE SERVICE FUNCTIONS FOR 1983-93 TIME FRAME

- SELECTED SEVEN DESIGN REFERENCE MISSIONS WHICH ENCOMPASS ALL IDENTIFIED SERVICE FUNCTIONS

- DEFINED REFERENCE SERVICE MISSION FOR TIME LINE AND FIRST CUT COST ESTIMATES

- IDENTIFIED PROBLEMS AND DEVELOPED CONCEPTUAL APPROACHES FOR SATELLITE DEBRIS COLLECTION AND EARTH RETURN

- IDENTIFIED REPRESENTATIVE SATELLITE SERVICE HARDWARE FOR 1983-93 TIME FRAME

- ESTABLISHED NEED AND DEFINED 13 MODIFICATIONS TO NASA EXISTING AND PLANNED EQUIPMENT

- ESTABLISHED NEED AND DEFINED 85 NEW SERVICE EQUIPMENT FOR 1983-93 TIME FRAME

- ESTABLISHED FIRST CUT COST ESTIMATES FOR CANDIDATE SERVICE EQUIPMENT
The fact that the current NASA inventory of a space qualified equipment can be used by the astronauts servicing the satellite systems. Of equal importance is the need to design future satellites for on-orbit above and beyond the current STS capability is of prime importance for the development of an effective capability. The principal conclusions of part I of the study are summarized. Requirement for a &a; capability

CONCLUSIONS
Conclusions (1 of 2)

- FUTURE SPACE MISSIONS SHOULD BE DESIGNED FOR ON-ORBIT SERVICING
  - STANDARDIZATION OF SERVICING DOCUMENTATION
  - END-TO-END SYSTEM INTERFACE MANAGEMENT
    
    THESE FACTORS WILL MINIMIZE:
    - SYSTEM INTEGRATION
    - CREW TRAINING
    - DEVELOPMENT PLANNING

- THE CAPABILITY FOR SATELLITE SERVICING EXISTS TODAY
  - EXPANDED CAPABILITY CAN BE DEVELOPED AS STS USAGE INCREASES
  - PROJECTED SATELLITE SERVICE COST BENEFITS RANGE FROM 0.6 TO 1.4 $B/YEAR BY 1990
Conclusions (2 of 2)

- The majority of planned future missions with the potential for in-orbit service requires orbit transfer capability from STS standard orbit to operational orbit - either self-contained or by separate vehicle.

- The elements involved in a satellite design-for-service decision include:
  - Satellite design cost associated with rendezvous, modularity, astronaut contact
  - Simulation of service functions (0 G)
  - Astronaut familiarization and training
  - Reduction of redundancy
  - Extension of mission life
  - Cost of service vs. replacement (shared vs. dedicated flight)
2. Service Equipment Preliminary Design

- Modified Grapple Fixture
- Grapple Fixture Attach Options
- Portable Foot Restraint
- Portable Grounding Strap
- Mating/Demate Umbilical
- Sharp Corner/Edge Padding
- Protruberance Coating Applicator
- Sharp Corner/Edge Pad Kit
- Deployment and Maintenance Platform
- Cargo Bay Rack/Tie-Down Platform
APPLICATIONS: The modified grappling fixture is potentially included in the Earth return, orbital, and deorbital Service Kits.

The grappling probe rod is for transportation by belt ladder. Hand carry and manipulation capability is provided by gripping the grapple fixture by means of a mating, female receptacle and a locking, or "rip", pin. The assembled S/C attachment device is withdrawn from tool kit and affixed to the attachment stud of the tool kit and the interface of the object being retrieved. The most suitable S/C attachment device, after an initial survey of the object being retrieved, is the most portable, modified grappling fixture provided in each recovery tool kit together with...

OPERATIONS: A portable, modified grappling fixture is provided in each recovery tool kit together with...

- Mass (with S/C attach) - 8.39 kg (18.5 lb)
- Size: 297 mm (11.5 in) x 150 mm (5.9 in)
- Crew transportable
- Interface with standard female receptacle on S/C attachments
- Orbital, stowed in RMS tool capabilities
- Design loads - Launch/Landing as stowed

REQUIREMENTS: (The attachment fixture is presented in the next figure.)

The arrestment device with and end fitting of attachment lug suitable for use with a variety of spacecraft attachment devices, a design modification is presented consisting of a stand-off adapter and an adapter for use in recovery of satellites and space debris without a pre-versedality of susceptibility to application (e.g., for use in recovery of satellites and space debris without a pre-stage-destruct for launch/recovery by the orbiter. For the purpose of giving the device portability and detestability for Launch/Recycling by the orbiter. For the purpose of giving the device portability and...

PURPOSE: The existing RMS grappling fixture is designed for permanent emplacement on satellites.
APPLICATION: See modified grapple fixture description.

OPERATION: Weight - not to exceed 8.39 Kg in combination with modified grapple fixture
Size (Max), 510 mm (20 inc) on all three dimensions
Interface with standard male attachment stud or grapple adapter
- Orbit, sustain all RMS load capabilities
  Design loads - launch/landing as stored

REQUIREMENTS:

Utilities

To prevent misalignment, these devices can be tailored to conform exactly to target spacecraft design
- orbiting mission, much wider variety of spacecraft attachment schemes than are shown. In subsequent
It should be noted that the use of a detachable "female receptacle" for the grapple spacecraft inter-
- parallel members.

Example: A "male" receptacle, the female receptacle is made up of an attachment mechanism and a female receptacle suitable
for mating with the male stud on the modified grapple fixture. The stud and receptacle hole are of
hexagonal design for the transmission of RMS torsional inputs.

PURPOSE: The total portable RMS grapple is made up of two elements: (1) a standard RMS grapple

GRAPPLE FIXTURE ATTACH OPTIONS
Grapple Fixture Attach Options

FLEXIBLE BONDING PAD

STRAP-ON ATTACHMENT

JAW (2 REQD)

RECEPTACLE

DRIVE GEAR

DRIVE FOLLOWER

LARGE S/C MEMBER

CINCH BUCKLE (2)

ICE-TONG ATTACHMENT
which are intended to support all service missions.

APPLICATION: The portable foot restraint is included as part of the standard mission support modules.

Want study receptacle.

She arm in the previous chart are directly applicable for PPR employment. They employ the same attachment. For application in unlevelled servicing operations, the specarat/grapple fixture attachment devices are shown in the preceding positions in the ENU.

Steering from working in awkward positions in the ENU.

The redesign which greatly increases the sphere of work activities and lessens or eliminates fatigue is severely limited by the fixed PPR. Therefore, articulation in roll, pitch and yaw are included in the design of the required servicing stiles. For a particular service task, the PPR is brought to the site where periodic servicing is planned, female receptacles for the PPR are included in the specarat fixture where periodic servicing is planned.

Each satellite service kit is provided with a portable foot restraint (PPR) on missions.

OPERATION:
- Power - none
- Mass - 8.16 kg (18 lbs)
- Dimensions - 212 mm (8.39 in) x 509 mm (20 in) x 330 mm (13 in)
- Articulation - ± 30° yaw, ± 30° roll, ± 30° pitch
- Sized for ENU boot
- Extension - 5th percentile female to 95th percentile male
- Ultimate design load is 623 N (140 lbf)

REQUIREMENTS: The portable foot restraint shall comply with and conform to these requirements.

and articulation are advantageous.

Here is the design for application on the space telescope as well as other satellites where portability is required. For much wider application as well as versatility, the design has been extensively modified. Shown in large size and its use is limited in terms of both location and orientation. In order to provide larger systems and its use is limited in terms of both location and orientation. In order to provide a fixed installation in

PORTABLE FOOT RESTRAINT
Portable Foot Restraint

PLATFORM ASSEMBLY

SUPPORT ARM

PITCH AXIS

ROLL PEDAL

YAW AXIS

PITCH CONTROL PEDAL

YAW PEDAL

ROLL AXIS

ATTACH STUD

2-7
APPLICATION: The portable grounding strap is proposed for situations where permanent grounding is not possible, or where the operator must be able to detach the grounding strap at will.

OPERATION: Each applicable service kit is provided with a coiled, 15-meter length grounding strap.

REQUIREMENTS: The principal requirements for this device are:

- Portable
- Low weight
- Physical size (diameter) compatible with space-grove manipulation
- High tensile strength
- High flexibility
- Electrical conductive, compatible with the orbital environment
- High tensile strength and resistance to fatigue failure
- Multi-path electrical conductive
- Positive, preloaded electrical contacts
- Ground potential. The portable grounding strap has been designed for these purposes.

PURPOSE: Large electrical potential differences are known to build up between and within objects in the space charge, which can reach values as high as 25,000 volts; the relatively harmless to personnel due to the low power levels involved, but can cause severe damage to electronic equipment. Any servicing operation involving a direct or indirect exposure to the operator must include a preliminary discharge of these potentials and the maintenance of a common power circuit. Any personnel involved in taking a service task during the maintenance procedure to electronic equipment.
Grounding Strap Attach on EVA Handle

- Shielding
- Braided Cable
- End Terminal
- Male Lug (2)
- Lug Nut with EVA Handles
- Standard ST EVA Handle
OPERATION:

Automatic demate is initialized, upon signal, as a part of the satellite deployment sequence.

- Power is payload specific.
- Mass (common elements) = 8.8 kg (19.5 lbs).
- Size is payload specific (ST design shown is 252 mm x 110 mm x 500 mm).

Physical Characteristics:

- Jettison capability:
  - Display signals for verification of proper mating.
  - Manual override for demate (ratchet wrench/socket) = 2.77 Nm (25-lb-ft).
  - Maximum manual force at mate = 34 Nm (29 lb-ft).
  - E/N/F glove accessibility (physical, visual, tool clearance).

Human Factors Requirements are:

- Demate is automatic with manual override; mate is manual (EVA).
- Power and data transmissions are payload specific and are not supplied or accommodated.
- Grounding some of the portable ground strap.
- Mechanical/Electrical

Electrical, Interface, and Human Factors Considerations.

REQUIREMENTS: The design requirements for the mate/demate umbilical include physical, mechanical.

WIN/DEP/ATE UMBILICAL

During recovery of non-orbital launch satellites, it is necessary to provide the female umbilical exactly with requirements for transmission of power, communications, checkout, control, data, etc. For

P U R P O S E : A definite requirement exists for an electrical umbilical which provides for manual (EVA)
Reconfigure, and Earth Return missions.

APPLICATION: The umbilicals, make/demate is a part of service kits for sortie, changeout/replace

Butterfly handles on the connectors (locks are overridden during the auto-demate).

Connectors in the female receptacles, final lock-in is accomplished through a quarter turn of the large activity after satellite recovery for servicing or Earth return. After insertion of the male mating procedures are always manual, whether performed prior to Orbiter launch or as a part of EVA.

OPERATION: (continued)

MATE/DEXMATE UMBILICAL (CONT)
APPLICATION: Sharp Edge/Corner Padding is a part of the Sharp Edge Padding kit which is part of the Service Kit for each mission type.

APPLICATION:

1. The next chart describes the applicator and coating used. Coatings are coated with coating applicator. The next chart describes the applicator and coating used.
2. Corrosive in the work area have been covered. Sharp sections covered such as bolt heads. Fire, etc., at the fire.
3. Folded about the flange or corner and held in place until the glue begins to set. When all flanges
   have been folded about the flange or corner and held in place until the glue begins to set.

OPERATION: An assortment of pads an protuberance coating applicator is transported to the EVAs.

REQUIREMENTS:

- Pad conformity to EVAs groove manipulation requirements.
- Quick, non-sticky, non-contaminating materials throughout.
- A variety of preformed shapes which anticipate the most common flange and corner contours.
- Non-gas-off, non-contaminating materials which must be satisfied in edge and corner padding area.
- The principle requirements which must be satisfied in edge and corner padding area.

PURPOSE: Provisions are necessary for elimination of hazards to the crew during EVAs posed by sharp

SHARP CORNER/EDGE PADDING
APPLICATION: As a part of the Sharp Edge Padding Kit, the Applicator is included on all service missions.

On the basis of time and expense analysis, several factors must be considered for the applicator to remain cost-effective. A catalyst chamber, requiring redosing, is necessary to maintain the mixing ratios. This is to ensure that the optimal amount of resin and addenda are mixed together. Since the setting time for the applicator mixture is 30 minutes, this ensures that the adhesive layer is applied within that time. The applicator is designed to allow for easy cleaning and maintenance.

OPERATION: The main housing of the applicator is made up of three concentric cylinders. The innermost coating material contacting to requirements stated in Sharp Corner/Edge Padding text.

- Coating material conforming to requirements stated in Sharp Corner/Edge Padding Text.
- Handle designed for easy use
- Quick, reliable shut-off
- Automatic, hand/triggered operation
- Small size and mass for ease of handling and storage in pad carrying case

REQUIREMENTS:

Formulation:

As a Sharp Protrusion Coating Applicator with a small change in flow nozzle shape and material, a complete test piece developed and tested for use in applicator form is ready for field use. This substance, a caulk like material, is ideal for use in a variety of spaces and applications by itself or in combination with other materials. The result, which renders them smooth and resistant to dirt and dust, is described in the previous chapter. For this purpose of applying the resin, which forms a smooth layer and can be applied in a variety of ways, is a coat of an elastomeric spray coat to cover them with a coat of metal. This is completed by applying a layer of safety-wire ends, J-agged hose ends, etc., must be applied to protect the sprayable sections and space of the applicator. A deliberate mark is made on the applicator, screws, nuts, and threaded ends, coat keys.

PURPOSE: Sharp Protrusion Coating Applicator
APPLICATION: The sharp edge paddling kit is included in the service kit for all service missions.

It is attached to the inside floor of the kit by means of two spring clips.

The application kit by means of a velcro at attachment between their bottom edges and the kit liner. The handle is released, pads are held in the surface, but which locks the lid at whatever position the handle is released. The lid is a cam-lock device which allows the lid to slide when pushed or pulled in a direction parallel to the lid.

Contents is achieved by sliding back the "roll top" cover using the lid handle. The letter is a cam-

OPERATION: The kit is transported to the work site by carrying handle or belt tether. Access to the kit is transported to the zero-g prior to use.

Method for handling pads and applicators in place in zero-g prior to use.

- Adequate seating/protection during transport.
- Easily manipulated cover with self-parking characteristics.
- Smooth surface, rounded corners.
- Carrying handle & safety tether loops.
- Size & weight suitable for ease of EVA transport & handling.

REQUIREMENTS: The kit requirements are:

- Products being carried and applicator.

The kit is comprised of the carrying case, an assortment of pad shapes and sizes, and a sharp as well as providing a protective environment. A carrying case suitable for EVA use has been designed. In the interests of simplifying the task of transporting the paddling and carrying elements to the work site.

PURPOSE: Previous figures and text have dealt with the methods and devices and materials necessary.
OPERATION: The OMP is designed to act as the aft launch support on Relativity's Light Weight Satellites.

- Operate on 115 VAC, 400 Hz, 7500 W power supplied by on-board.
- Maximum mass 567 kg (1250 lbs)
- Stow and stanch satellite for earth return.
- The EVA crew personnel.
- Roles for approaches/field deployment, O&M maintenance and refurbishment.

The EVA crew personnel:
- Bring the work to the payload for approaches.
- Perform maintenance and separation at the cargo day to a checkout and separation position.
- Stow the payload out of the cargo bay to a checkout and separation position.
- Rack the manipulator satellites accurately and safely.
- Lift the payload out of the cargo bay to a checkout and separation position.
- Perform the payload out of the cargo bay to a checkout and separation position.
- Lift the payload out of the cargo bay to a checkout and separation position.
- Rack the manipulator satellites accurately and safely.
- Perform the payload out of the cargo bay to a checkout and separation position.
- Lift the payload out of the cargo bay to a checkout and separation position.

REQUIREMENTS: In meeting its design goals, the OMP shall:

- Be able to operate in the deployment and maintenance platforms (OMP) as defined and functional.
- Be able to perform operations from the OMP as defined, including the OMP's ability to perform operations from the OMP as defined.
- Be able to perform operations from the OMP as defined, including the OMP's ability to perform operations from the OMP as defined.
- Be able to perform operations from the OMP as defined, including the OMP's ability to perform operations from the OMP as defined.

PURPOSE: The "satellite extractions/insertion point table" was identified as a needed service tool in the OMP.
APPLICATION: The DMR is used for repair, check, and Earth Return missions.

Latch keys are released and the RMS places the satellite in the separation position. Replacement units and supplies are loaded. After refueling and depopulation, appendage deployment, and checkout, the planned work is completed. After the primary power from the orbiter may be requalified for this mission, the satellite is retrieved and berthed to the DMR and latch keys are returned. Maintenance is completed, objectives are retrieved, equipment change-out, and the deployment position and attitude, retrieved, and stowed on the satellite for Earth Return is the reverse of the foregoing procedures. In missions where refueling, depopulation, and equipment change-out, the RMS is engaged, latch mechanisms released and the satellite is removed to deployment and maintenance platform (cont.)
Deployment and Maintenance Platform

Perspective
II

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3. Program Plans

3.1 SATELLITE SERVICES PROGRAM PLAN
3.2 SATELLITE SERVICES DEVELOPMENT PLAN
3.3 SATELLITE SERVICES OPERATIONS PLAN
expanding distant from orbiter servicing. First in LEO and not directly accessible by the STS.

expanding: directly accessible by the STS.

initial: near-orbiter servicing, involving satellites and services in LEO, directly accessible.

Three major evolutionary steps are envisioned:

1. able service equipment.
2. to keep early year funding relatively low and to take advantage of the existing and soon to be available:
3. evolutionary approach is proposed for the development of the satellite services system, in order to improve the operational capability and reduce cost.

Planning Perspective
3.1 Satellite Services Program Plan
Therefore, an integrated logistics support effort is planned for the S operations. 

Because of the rapidly expanding space operations with the Space Shuttle, special attention is paid to having proper types and quantities of spares. Further, the widened use of expendables for responsive mission support with the Space Shuttle, a significant cost saving can be realized for further space use. This approach, as opposed to buying new equipment, results in significant cost savings. A ground repair and refurbishment depot cycles failed or worn S equipment; the equipment is renewed and maintained for STS-supported missions. When needed, a storage depot keeps on ready status the spare components and S modules and kits to be pre-planned for forthcoming and future mission support ensures that necessary S equipment is available that can apply to many space missions.

The S coordinates the user needs for servicing equipment and provides designs and operating methods plan is based upon this premise. An integrated effort is initiated in which common equipment and facilities are utilized. This program to provide the maximum cost benefits and to simplify the functioning of a satellite servicing system.
S3 Mission Functions

- UNIVERSAL SPACE SERVICING
  - DEPLOYMENT
  - OBSERVATION
  - RETRIEVAL
  - SUPPORT
  - EARTH RETURN

- INTEGRATED FLIGHT OPERATIONS PLANNING

- SPACE STORAGE DEPOT (SOC)

- GROUND REFURBISHING/STORAGE DEPOT

- INTEGRATED LOGISTICS SUPPORT
  - CONSOLIDATED SPARES PROVISIONING
  - BULK PROCUREMENT/STORAGE OF EXPENDABLES
S³ Mission Objective

PROVIDE A STANDARD SATELLITE SERVICING SYSTEM TO SUPPORT
A WIDE VARIETY OF SPACE MISSIONS

- USAF
  - AFSD
  - AFSP
- OTHER NASA CENTERS
- OTHERGOVERNMENT AGENCIES
  - DOA/DOI
  - DOE
  - DARPA
- JSC SATELLITE SERVICING ORGANIZATION (SSO)
- NAVY
- INTERNATIONAL
  - ESA
  - OTHER
- COMMERCIAL
  - COMSATS
  - MATERIAL AND PROCESS
eventual application on such space stations.
and Space Operations Centers indicate that early equipment and operations development be oriented to
All servicing is initially planned to be orbiter based. Future trends to large space platforms

common equipment and design their space vehicles to be compatible therewith.

importance of this requirement is that the various user agencies cooperate in making use of the
This approach permits the application of common equipment and operations to the various users. The
Key to the utility of the 3 is its application to a wide spectrum of the national space resources.

capability of a separate autonomous transfer vehicle capability.
satellite by the orbiter or the maneuvering of the satellite to the STS accessible orbit by its own
services is limited to near-orbiter operations. This implies either accessibility of the serviced
The principal overall system requirements are enumerated here. The near term application of satellite

SYSTEM REQUIREMENTS
System Requirements

• SUPPORT ALL LEO MISSIONS
  - DIRECT ACCESS BY ORBITER
  - ACCESS BY USE OF TELEOPERATOR MANEUVERING SYSTEM (TMS)
  - RETURN TO ORBITER BY SELF-CONTAINED PROPULSION

• UTILIZE MULTIMISSION APPROACH (FOR LOW COST)
  - COMBINE DEPLOYMENT AND SERVICE FLIGHTS TO A COMMON ORBIT

• USE COMMON $S^3$ EQUIPMENT WHERE POSSIBLE
  - ADD SPECIAL EQUIPMENT FOR MISSION-UNIQUE REQUIREMENTS
  - ALTER SOFTWARE TO ACCOMMODATE MISSION-UNIQUE REQUIREMENTS

• ALL SERVICING TO BE SUPPORTED BY STS
  - ORBITER - INCLUDING OMS KITS
  - FLIGHTS FROM ETR AND WTR

• INITIAL $S^3$ EQUIPMENT TO INCORPORATE GROWTH POTENTIAL
  - LATER USE WITH LARGER SPACE VEHICLES AND PLATFORMS
  - TRANSITION FROM PORTABLE SERVICE PLATFORM (ORBITER) TO FIXED ORBITING PLATFORM (SPACE OPERATIONS CENTER OR EQUIVALENT)

3-15
or returned for reuse.

Replacement of Orbital Replaceable Units (ORUs). Failed ORUs will be returned to Earth and repaired.

The Space Telescope and the Solar Max Mission have been designed for retrieval and servicing by

planetary vehicles. It's servicing is therefore limited to deployment in LEO and checkout.

The Galileo satellite attached to an upper stage, IUS, is carried to LEO by the Shuttle. This is a

example of some early satellites which are candidates for near-orbiter service. These are shown.

developed.

other space vehicles. Their servicing needs were reviewed and servicing equipment concepts were

The program plan is based upon in-depth analyses of an inventory of satellites' space platforms, and

Typical Early Satellites
A satellite designed with its own propulsion capability to take it from the STS standard orbit and that are accessible by the orbiter. Inclination changes can also be made by the OTV. It most cases, satellites are placed in orbit planes to the orbiter for repair.

accessible orbit. A variant of this mode provides for the OTV to return the satellite mechanism. It flies to the satellite, docks and makes repair and returns LEO or orbiter.

and return, it carries spare modules for satellite repair and a module exchange.

This larger propulsion stage has propellant capability to transfer from LEO to GEO orbit.

After servicing, the satellite is returned to its operating returns to orbiter. Carried by orbiter, flies from STS standard orbit to the satellite, retrievers it, and TMS - Carried by Orbiter, flies from STS standard orbit to the satellite, retrievers it, and and Orbiter Transfer Vehicles (OTV). not necessarily needs rest servicing. The S3 can include Telescopar Maneuvering System (TMS'), it is evident that the majority of satellites operate above the STS standard orbit. However, this does quantify of missions at each inclination and altitude are shown.

Future space missions, including classified military, have been grouped by operational orbit. The

LOCATION OF PLANNED SATELLITES
Location of Planned Satellites
Center will be operational in LEO. This space platform forms the base for the first Space Station. Operations in space will increase by 1990. A permanent manned facility, the Space Station, will be constructed.

A transition is evident from the smaller science payloads satellites to larger vehicles and space platforms primarily oriented to applications or commercial missions. Larger space vehicles (Advanced Centaur and AV) provide increased propulsion to transfer the orbital supplements by the RFP and 25 kW power system provides increased on-orbit power to the space effort.

This developed plans for future missions. The chart shows a NASA/NO scenario for a gradually expanding beyond the currently committed space missions, most of which are science or military oriented, NASA.
Future NASA/Commercial Missions

Transportation
- Space Shuttle
  - Power Extension Package (PEP)
  - Solar Electric Propulsion System
    - Advanced Centaur
    - Orbital Transfer Vehicle (OTV)
      - Unmanned
      - Manned

Space Platforms
- Spacelab
  - Augmented Spacelab
    - Tethered Satellite System
      - Low Earth Orbit Platforms (Man-Tended)
      - Geostationary Platforms
        - Automated
        - Man-Tended

Orbiter Facilities
- Habitation and Service Modules
  - Permanent Manned Low Earth Orbit Facility
  - Geostationary Orbit Facility

Orbital Services
- Satellite Servicing Near Orbiter and Remote
  - Large Structures Engineering
  - Servicing of Spacecraft From Manned Facility
  - Geostationary Orbit Servicing (Remote)
  - Geostationary Orbit Servicing (Manned)

\( \n = \) Initial Operational Capability (IOC)

3-21
Structural add-ons and modular payloads can be added.

Large Science/Application Platform - The "initial expandable" unit will be operational in 1996.

Consisting of experiment and materials supply and exchange, is provided by the S3.

Habitability Module transforms this platform to a manned facility in 1988. Servicing,

By 1986, a Material Experimentation Module (space processing) will be added in 1987. A space processing/life science facility - the initial life science lab Module will be operable platforms; two of these, are high on the mission-priority list:

In 1986 the 75 MW power system will be available as a free-flyer support spacecraft for a variety of

- Space ORS
- TMST or TV Storage
- Test/checkout Equipment
- Tank Farm for Expandables and Fluid Transfer Modules
- Spares Storage Racks
- Servicing Equipment and Service Platforms

Space Depot consisting:

Periodically by the Shuttle for crew rotation and logistic supply. This base accommodates the S3

The first manned base, the Space Operations Center, is shown. It is operated in LEO and Revisited

Typical Space Platforms
Typical Space Platforms

- Multimission Space Processing/Life Science Platform
- Large Science/Application Platform
- Space Operations Center
These military missions are included in the total summary of potential customers for S3.

The manned-station operational dates appear to lag the NASA planning dates. However, the operation are shown here.

The USAF, DARPA, and Navy agencies plans for their future space missions in four functional areas.

FUTURE MILITARY MISSIONS
## Future Military Space Missions

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<td>ADAPTIVE OPTICS</td>
<td>MANNED STATION</td>
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<td>FLY-BY INTERCEPTOR</td>
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*Illustrations depict various space missions and technologies.*

*Image source: NASA - LOCKHEED*
System Description
Elements of the S₃

S₃ SPACE SUPPORT EQUIPMENT
LAUNCH SITE EQUIPMENT – SPECIAL
GSE/STE
SUPPORT VEHICLES
GROUND DEPOTS AND FACILITIES
SPACE DEPOT
SOFTWARE
INTEGRATED LOGISTICS SUPPORT
developed under the direction of the SS0.

The support vehicles, whose primary operational function is to support satellite service will be

facilities at the launch sites.

The ground Depots need not be new facilities, but rather, modifications of assigned areas of current

facilities to the planned space operations center.

The Space Depot is operated either as an autonomous space base ( manned or unmanned) or as an add-on

and by the SS0.

( SS0) are listed. The design, manufacture, test, and operation of this hardware is contracted for

the elements of the 3 hardware that are under the cognizance of the satellite service organization.

MAJOR HARDWARE ELEMENTS
# Major Hardware Elements

## Space Segment
- **Space Support Equipment**
  - Orbiter Accommodation Equipment
  - Satellite Serviceability Hardware
  - Handling/Servicing/Berthing Devices
  - Crew Aids
  - Stowage/Deployment Equipment
  - Expendable Supply
  - Orbiter I/F Equip
- **Support Vehicles**
  - Teleoperator Maneuvering Stage
  - MTV
  - OTV
- **Space Depot**
  - Propellants
  - Life Support Supplies
  - Cryogens
  - Repair Materials
  - Replacement Units

## Ground Segment
- **Launch Site Equipment**
  - Satellite Simulators
  - Alignment Fixtures
  - Cleanroom Storage and Kitting
  - Kit Assembly and Packaging
- **Ground Depots**
  - Satellite ORU Refurbishment and Inventory
  - \(S^3\) Equipment Refurbishment and Inventory
  - Expendables Supply
- **GSE/STE**
  - Transport and Handling Equipment
  - Service and Checkout Equipment
In orbit, an important servicing function as growing quantities of satellites require long-duration operation. Gases, and other fluids to orbit for replacement of satellites or tank farms, this becomes.

The expendable resupply equipment comprises an inventory of equipment for transporting propellants, vented. The mission unique supplier is supplied to satellite contractors to help meet the requirements for serviceability. Mission, unique suppliers help meet the requirements for serviceability.

The satellite accommodation (also developed as standard supply items [possibly GFE]) they are.

Articles performing the same functions and reducechallenges the different of the orbiter for different missions. The variety of missions is fundamental to this concept. A system concept to reduce the inventory of different missions, items are specifically manufactured for each flight. Commanality, adaptability to a wide

The orbiter accommodation (also called) items that are installed in the orbiter for service equipment. Six basic types of 3 equipment are shown, under each are grouped representative servicing.

3 KITS AND EQUIPMENT
# S3 Equipment

## Orbiter Accommodation Kits
- Display/Control Panels (STD)
- Umbilicals
- I/F Harnesses and J-Boxes
- Berthing/Docking Modules

## Satellite Serviceability Kits
- RMS Interface Fittings
- Docking Targets
- Docking/Stowage Fittings
- Restraint/Tether Receptacles

## Handling/Servicing Modules
- Satellite Checkout Sets
- RMS
- Special End Effectors
- Work Platforms
- Despin Devices

## Stowage/Deployment Equipment
- Pallets
- Spares Racks
- Special Racks
- Bulk Cargo Tiedowns

## Crew Aids
- Hand Tools
- MMU
- Tethers/Restraints

## Expendables Resupply Equipment
- Tank Kits
- Vent/Dump Kits
- Fluid Transfer Modules
Improves, this manned capsule can be mounted on an OTV for servicing round trips to GEO.

manipulation with closeup man-in-loop, a smallman menu lug is planned. As operational confidence
For short-range remote operations with satellites or platforms, where servicing tasks require
The teleoperator can be mounted on the maneuvering stage to attain greater range of remote operations.

Man-in-loop remote control can be substituted for the automated functions or be used as backup mode.

the satellite and module exchange is accomplished automatically with TV monitoring from the orbiter.

The teleoperator stage flies to a remote satellite and exchanges satellite modules, docking with

propulsion stages are refueled from its expendable tanks, also carried by the orbiter.

The maneuvers are used to retrieve satellites from remote locations and return them to

operations exclusively.

those shown will be a part of the 6 equipment inventory. These space vehicles perform space servicing
To ensure an integrated space servicing effort, it is planned that special support vehicles such as

3 SUPPORT VEHICLES
S3 Support Vehicles

MTV

OTV

TMS

MOTV
The ground based depots and facilities identified in the course of the study are listed here.
Ground Depots/Facilities

- INTEGRATED LOGISTICS SUPPORT FACILITY
  - $S^3$ EQUIPMENT REFURBISH/SUPPLY DEPOT

- SATELLITE ORU SPARES REPAIR/REFURBISHMENT DEPOT

- SATELLITE SERVICES OPERATIONS CONTROL CENTER

- $S^3$ DATA PROCESSING FACILITY
The common use of 3 equipment, both on the orbiter and on the space depot, is made a design requirement for strategic forward growth of capability.

The transition from Orbital to Space Depot based servicing can be seen as a major segment of the space operations. The depot is conceived as a major segment of the space operations and EV operations. This space depot can be an autonomous platform, however, to gain the benefits of consolidation. This approach, however, is not without drawbacks. The space depot in concept can be unmanned, with automated equipment monitored remotely, or manned with crew performing the servicing function utilizing TV remote-control.

The Space Depot is a natural extension of the Orbiter-based mode of space servicing. As the orbiter inventory grows, the servicing load will eventually exceed the capability of the STS to meet the demands. Further, the transport up and down of 3 equipment reduces the net payload capacity on each mission. The storage of the servicing equipment and transport expandable on an orbiting space depot provides added servicing capabilities and cost-reduction benefits.

An S depot is a natural extension of the STS to meet the demands. Further, the transport up and down of 3 equipment reduces the net payload capacity on each mission. The storage of the servicing equipment and transport expandable on an orbiting space depot provides added servicing capabilities and cost-reduction benefits.
- **S^3** EQUIPMENT COMPLEMENT*
  - ASSEMBLY/SERVICING PLATFORM
  - CHECKOUT SETS
  - EXPENDABLES AND TANKAGE
  - HANDLING EQUIPMENT
  - STORAGE RACKS
  - ORU REPAIR
  - FLUID TRANSFER KITS
  - TMS
  - DOCKING HANGAR FOR OTV, TMS

- **SERVICING OPERATIONS**
  - SATELLITE REPAIR (TMS RETRIEVAL AND REDEPLOYMENT)
  - ASSEMBLY AND CHECKOUT OF MULTI-STAGE VEHICLES (PLANETARY AND GEO)
  - REPLACEMENT OF FLUIDS FOR OTV, TMS, SATELLITES
  - STORAGE AND MAINTENANCE OF OTV, TMS

*INSTALLED ON MANNED SPACE PLATFORM, SPACE OPERATIONS CENTER, OR EQUIVALENT.
Prototype software is used during the development testing and space operations simulation.

(TDRS, SBN, VSAP-SLS).

ensures workable interaction with the existing ground networks and the space communications network function. Requirements are closely coordinated with the Operations Control Center Organization.

The configuration for software integration resides in the S3 System Engineering and Integration and the GSE/STL.

Software for the S3 operation is developed in parallel with the design of the S3 equipment.
- ORBITER INTERFACE SOFTWARE
  - REMOTE CONTROL OF SPECIAL RMS
  - REMOTE CONTROL OF MTV
  - SATELLITE CHECKOUT
  - TMS CONTROL

- S³ MISSION CONTROL – COMMAND AND TELEMETRY SOFTWARE*
  - REPROGRAMMING
  - DATA ANALYSIS PROGRAMS (SATELLITE CHECKOUT)
  - DATA REDUCTION (FAILURE DIAGNOSIS, SATELLITE STATUS)

- COMMUNICATION INTERFACE SOFTWARE
  - JSC
  - STC
  - POCC (PAYLOAD OPS CONTROL CTR)

*SUPPLEMENTS NORMAL ORBITER AND SATELLITE MONITOR AND CONTROL
Work Breakdown Structure
And Schedule

For space systems that has been developed by the Standardization Subgroup of the Joint Government/Industry Standard Space System MBS.

The MBS shown in this chart indicates where satellite services is placed in the standardized MBS.
S³ Location in Standard Space System WBS

SPACE SYSTEM
01

SPACE TRANSPORTATION SEGMENT
01.03

HARDWARE
01.03.01

SOFTWARE
01.03.02

SERVICES
01.03.03

SPACE TRANSPORTATION OPERATIONS
01.03.03.80

ASTRONAUT SERVICES
01.03.03.80.01

SPACE TRANSPORTATION SERVICES
01.03.03.10

SATELLITE SERVICE SYSTEM
01.03.03.10.02
This standard MBS is end-item oriented; that is, it deals with the dimension of program resources that result in a definable and producible or service. The other dimensions of program cost (i.e., sub-system, appropriate subsystems and lower level end-item blockdowns), tailoring of hardware, software, and services is normally expected. The blocks are to be expanded to accommodate by deleting MBS blocks that do not apply to the instant phase of a program.

Segment level tailoring is normally accomplished by expanding the MBS blocks for subsystem-level end-item tailoring codes that end in zero (e.g., 10) flag MBS blocks in which program, peculiar to each user, division of work and elements of cost, have not been standardized because they tend to be peculiar. 

May be summarized as follows: 3 are fixed; Levels 4 and below are used to implement this tailoring. The philosophy of MBS tailoring is to be tailored to be tailored in both the end-item and time-phasing dimensions of a space system's life cycle. This framework is designed to be tailored to be tailored to all phases of a space system's life cycle. This framework is designed to be tailored to be tailored to the Joint Government/Industry Space System Cost Analysis Group. This MBS is a common framework work breakdown structure (WBS) has been developed by the standardization sub-group of the Joint Government/Industry Space System Cost Analysis Group. This MBS shows the top-level satellite services functions and cost accumulation blocks.

TOP LEVEL MBS
Top Level $S^3$ WBS

SPACE TRANSPORTATION SERVICES
01.03.03.10

LAUNCH VEHICLE SERVICES
01.03.03.10.01

SATELLITE SERVICES SYSTEM
01.03.03.10.02

UPPER STAGE SERVICES
01.03.03.10.03

MISSIONS SUPPORT AND OPERATIONS

FACILITIES

SOFTWARE

HARDWARE

SIMULATION AND TRAINING

SYSTEM LEVEL INTEGRATION AND TEST

PROGRAM MANAGEMENT
Fee
Other Direct Charges
Termination Charges
Other Burdens
General and Administrative Cost
Overhead
Overtime Premium
Reproduction
Travel
Interdepartmental Work Orders
Computer Hours
Subcontracts
Materials
Labor Hours

Typical Elements of Cost

Administration
Tooling and Manufacturing Test Equipment
Test
Quality Assurance
Fabrication and Assembly
Design/Analysis

Typical Subdivisions of Work

Satellite Service System MBS
Development Phase.

Each "X" in the matrix indicates which type of effort accomplished in the corresponding Development Phase Work Items.
### Development-Phase Work Items

<table>
<thead>
<tr>
<th>WBS ELEMENT</th>
<th>PRELIMINARY PLANS</th>
<th>PRELIMINARY ANALYSES</th>
<th>PRELIMINARY DESIGN</th>
<th>FLIGHT EQUIPMENT DESIGN</th>
<th>TEST ARTICLE DESIGN</th>
<th>SIMULATOR DESIGN</th>
<th>TEST ARTICLE AND SIMULATOR</th>
<th>MFG</th>
<th>TESTING AND SIMULATION</th>
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</table>
Planned launch dates for support as early as 1982.

Typical missions in each of four categories are shown. The significant feature of these

CANDIDATE SERVICABLE MISSIONS
### Candidate Serviceable Missions

<table>
<thead>
<tr>
<th>Missions</th>
<th>CY 81</th>
<th>CY 82</th>
<th>CY 83</th>
<th>CY 84</th>
<th>CY 85</th>
<th>CY 86</th>
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<td><strong>ADVANCED MISSIONS</strong></td>
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<td>25 KW POWER SYSTEM</td>
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</table>
The central management of the 5 establishes the working interface with each external segment and interacting with the 5. This plan emphasizes an "integrated servicing" system. Five basic segments are identified as

INTEGRATED HARDWARE/SOFTWARE
Integrated Hardware/Software
The integration and testing of each mission kit is planned in detail by the

Engineering Organization.

 Systems L-1 thru L-4.

5 Kits, selected for each Shuttle flight and satellite mission, are processed through systems.

S Supply Depot at the Launch Site.

All flight articles are processed thru F-1, F-6, F-7 at the factory before transfer to the

item is refurbished and becomes the first flight article.

The qualification articles are subject to factory tests F-2 thru F-5. Each qualification

The test and integration flow for 5 equipment is shown.

S EQUIPMENT

SYSTEM-LEVEL INTEGRATION & TEST
System Level Integration and Test
S^3 Equipment

**F1**
FINAL ASSEMBLY AND MECHANICAL VERIFICATION
- ORBITER CARGO BAY I/F's
- ALIGNMENTS

**F2**
INTEGRATED FUNCTIONAL TEST WITH SATELLITE SIMULATOR
- UMBILICAL MATE - DEMATE
- CHECKOUT SET I/F WITH SATELLITE SUBSYSTEMS
- ORBITER ELEC AND SOFTWARE I/F's

**F3**
ELECTROMAGNETIC COMPATIBILITY

**F4**
ACOUSTIC ENVIRONMENT
- SIMULATE ORBITER LAUNCH/ASCENT

**F5**
THERMAL-VAC ENVIRONMENT
- MINIFUNCTIONAL
- MISSION OPS REHEARSAL
- ORBITER ENVIRONMENT
- ON-ORBIT

**F6**
FINAL ACCEPTANCE

**F7**
FINAL SHIPPING PREPARATION

**F8**
TRANSPORTATION TO LAUNCH SITE

**L1**
PROCESSING AND INTEGRATION

**L2**
RECEIVING/INSPECT AT LAUNCH SITE
- INSPECT
- GSE HOOKUP
- ORBITER I/F VERIFICATION

**L3**
SATELLITE AND S^3 EQUIPMENT INTEGRATION
- I/F VERIFICATION
  - MECHANICAL
  - ELECTRICAL
- INSTALL IN RSS
- MISSION OPS REHEARSAL

**L4**
PRE-INSTALLATION VERIFICATION
- INSTALL IN ORBITER
- PRELAUNCH READINESS CHECK

**L5**
LAUNCH PAD OPERATIONS

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the processing of commands to the S3 crew and equipment. Operations Control Center (SSCC). These include the ground monitoring of service operations and crew considerations have a primary impact on organization and operation of the Satellite Service. All S3 crew activities and training are coordinated by a group within the S3 Management Team. Rehearsals are conducted in simulated orbit conditions at various levels of reality. Crew training includes rehearsal to maximum extent possible of orbit operations. Such activity in EVA mode, require crew participation, either man-in-loop remote control or equipment or direct hands-on operations. Crew operations have a major influence on efficient servicing. All space servicing operations...
S3 Crew Integration

CREW SYSTEMS ENGINEERING
- CREW SAT INTEG REQTS
- CREW SUPPORT I/F AND INTEG REQUIREMENTS
- STS - PAYLOAD ICDs/IRDs
- CREW FUNCTION/TASK ANALYSES
- CREW TIMELINE ANALYSES
- PIP INPUTS
- FLT DATA FILE INPUTS
- MOCKUP/SIMULATOR ANAL/INTEG

SATELLITE SERVICE OPS CONTROL CENTER (SSOCC)
- S3 Interfaces with STS
- S3 Interfaces with Satellites/Platforms
- Network Interfaces:
  - TDRS
  - STC
  - STDN

IN NEAR-ORBITER IV AND EV OPERATIONS
- SAT HANDLING/POSITIONING
- BERTHING/DOCKING
- VISUAL AND CCTV INSPECT
- APPENDAGE OVRD/JETTISON
- CHANGEOUT
- RESUPPLY AND REPAIR
- ORU MANIPULATION

REMOTE MAN-IN-THE-LOOP ORBIT OPERATIONS
- SATELLITE GRAPPLING RETRIEVAL
- TMS OPS WITH REMOTE GRAPPLE AND DOCK
- BERTHING SATELLITES AND PLATFORMS TO ORBITER
- REMOTE MODULE REPLACEMENT
- OBSERVATION/CHECKOUT

CREW TRAINING
- FLT CREW TRNG PROGM INTEG
- SIMULATION PROGM I/F AND INTEG
- MOCKUP/SIMULATOR COORD
- SIMULATION CONDUCT
- VERIFICATION PROGM INTERACT
- DEMONSTRATIONS/FEAS ANAL
- PLANS/PROC DEV/COORD
- DOCUMENTATION I/F
Upon return to earth, the 3 equipment is off loaded and sent to the 3 supply and refuishment depot.

Another satellite may be retrieved for repair or changeout/renconfiguration/reuply and after station keeping free flight.

On-orbit, a checko of the dewpment satelitie is conducted and if necessary simple fixes take place at the Launch base.

The principal segments of the 3 operations are shown on this figure.
Integrated Operations

1. FACTORY OR GROUND SUPPLY DEPOT
2. TRANSPORT TO LAUNCH BASE
3. INSTALL LAUNCH
4. CHECKOUT
5. DEPLOY
6. SATELLITE ORBIT OPERATION
7. RETRIEVE
8. ON-ORBIT MAINTENANCE
9. LANDING
10. RETURN TO DEPOT
11. GROUND REFURB
The consolidation of User needs continues with updated requirements and IDDS issued frequently. Each of the primary interface areas, user's interface function is planned and maintained. Working groups are developed to cover because the users provide a primary influence on the success of the program. A strong user interfaces.
### User Interfaces

#### CONSOLIDATED S^3 USERS
- NASA
- DOD
  - AIR FORCE
  - NAVY
  - ARMY
  - DARPA
- OTHER
  - DOA
  - DOE
  - DOI
- COMMERCIAL
- FOREIGN

#### S^3 INTERFACE WORKING GROUPS
- SATELLITES AND SPACE VEHICLES
- STS
- GROUND FACILITIES
  - LAUNCH SITES
  - REFURBISHMENT DEPOTS
  - SUPPLY DEPOTS
  - SIMULATION AND TRAINING
- COMMUNICATION NETWORKS
  - TDRS, STDN
  - SCF
- ASTRONAUTS
- FLT CREW
- TEST AND VERIFICATION
- FLT DATA
- AIRBORNE SUPPORT EQUIP
- FLIGHT TECHNOLOGY
- P/L INTEG PLAN

#### S^3 INTERFACE DOCUMENTS
- S^3 USERS' GUIDE
- INTERFACE CONTROL DOCUMENTS (ICDs)
- P/L ICDs
- P/L IRDs
- PROCEDURES
- TEST/VER DATA
- SIM DATA
- PIP
- FLT DATA FILE
- TRNG PGR PLANS
- OPS/FUNCTIONS DOC
- ORBITER TO P/L ICD
- FLT MANIFEST DATA
- ETC

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logistic supply flow and timeliness can result from the consolidation of service equipment procurement.

Simplification of Government Procurement, Reduction in Paperwork load, the reduction of the unique basis provides obvious system cost benefits. Consolidated buying, rather than procurement of logistic material on a one-at-a-time mission opportunity to consolidate government procurement to realize these economies.

and storing of space equipment/supplies are available. The 3 operations, economies, procurement with the growth of space activities as a result of the SPS operations, GOVT/SUPPLIER INTERFACES
Government/Supplier Interfaces

Centralized procurement of material and services to support integrated logistics flow:

- \( S^3 \) equipment
- Satellite spare parts
- Expendables resupply

Government Procurement

Contractors

- \( S^3 \) equipment
- Space vehicle spares
- Expendables
  - Propellants
  - Cryogenics
  - Life support

Government Depots

Satellite ORU refurbishment

Satellite spares supply

\( S^3 \) equipment repair/refurbishment

\( S^3 \) equipment supply
In the early Shuttle launches of ISS/satellite packages, experience is gained which can be applied to in-orbit checkout and repair of OTV's as well as attached satellites. The propellant replenishment capabilities are added to the S as the Centaur and hydrazine-fueled RMS are put into service.

Space-reusable: It is applicable to remote S operations (high-altitude and GEO orbits).

(OTV's) will be placed in the STS inventory. The OTV is planned to use cryogenic propellants and be such as IUS and Centaur. As space operations are extended, higher-capability, orbit-transfer vehicles.

The space segment of the Space Transportation System consists of the orbiter and propulsion vehicles.
A separate SSOC contingent may be located at the USAF STC for DOD missions.

The SSOC is located on the JSC site to assure close interfacing with STS Mission Control.

Tasks:
- Prepare schedules for use of the NASA and DOD communications networks.
- The SSOC implements these functions of the Satellite Service Organization to plan, coordinate, and
- COMMUNICATIONS NETWORK INTERFACES
Launch base control, JSC mission control and the Program Office operations centers.

The flight support of the STS operations (the SS0cc) is organized for close cooperation with the

depot activities in order to maintain the flight scheduling.

The integrated logistics flow of the STS is impacted by but to a large extent dictates the STS supply

of the STS equipment, the orbiter, and the payloads. Remote operational planning and checkout consoles,

installation and post flight removal from the orbiter cargo bay. All power and signal interfaces

transportation system ground segment. The STS flight hardware and consumables require preflight

The satellite service system ground operations have significant interfaces with the Space

STS GROUND SUPPORT INTERFACES
S³ Ground Support Interfaces

GROUND
- INTEGRATION
- LOGISTICS
- CONSUMABLES
- GROUND HANDLING
- FACILITY
- DEPOT STOWAGE
- SSOCC
- OTHER

STS
- CARGO BAY INSTALLATION
- SIGNAL/PWR CABLE I/F
- CABIN INSTALLATION
- MULTI-P/L INTERFACE
- PRE-FLIGHT C/O AND VERIFICATION
- POST FLT "TEAR-DOWN"
- POST FLT ORBIT "RECONFIGURATION"
- KSC AND VAFB UNIQUE OPERATIONS

ORBITER
_shop the SSO to ensure maximum application of common

GSE/STE requirements is managed

and any remote depot or supply locations.

Multiple quantities of the GSE/STE are required to support S3
operations at two launch bases.

The appropriate GSE/STE which exists in Government inventory is used wherever possible in the

appropriate and prelaunch verification, and depot testing.

The function of the STE test support during development, qualification, factory acceptance,

S3 equipment during manufacture, test, launch preparation, and depot operation.

The function of the GSE is to support, store, handle, transport, and inspect/align/weigh

This hardware is developed in parallel with the S3 equipment.

The S3 equipment is supported by its own ground support equipment and special test equipment.

GSE/STE
GSE/STE

SUPPORT INITIAL-DELIVERY S^3 KITS, SPARES, AND REPAIR/REFURBISHMENT OPERATIONS AT DEPOTS

- GSE
  - SHIPPING/STORAGE CONTAINERS
  - PROTECTIVE COVERS
  - STORAGE RACKS/PALLETS
  - ASSEMBLY/SUPPORT STANDS
  - DOLLIES/TRANSPORTERS
  - HANDLING SLINGS
  - WT/CG SUPPORT FIXTURE AND MEASUREMENT EQUIPMENT
  - ALIGNMENT FIXTURES AND GAGES
  - MASS SIMULATORS

- STE
  - TEST COMPUTER
  - MONITOR CABLE SETS
  - TEST CONSOLES
  - CHECKOUT SETS
  - ACOUSTIC, VIBRATION TEST SUPPORTS

- GFE
  - AIRCRAFT LOADING FIXTURE – C5A
  - SATELLITE I/F SIMULATORS
  - STDN I/F TEST VAN
  - SATELLITE MASS/SIZE SIMULATORS
  - IUS FUNCTIONAL I/F SIMULATOR
  - CENTAUR FUNCTIONAL I/F SIMULATOR
  - ORBITER FUNCTIONAL I/F SIMULATOR
  - ORBITER MECHANICAL SIMULATOR (CARGO BAY)

MANUFACTURING/TEST SITES

LAUNCH SITES

REPAIR/REFURBISHMENT DEPOT

SUPPLY DEPOT
When the VAB launch site is activated, replication of the KSC S3 facilities is planned.

Lunch base.

The Satellite Spares Depot can be accommodated in an existing building either off-site or at the launch base. Kitting is performed in this depot.

The S3 Repair/Supply Depot is listed as "New". However, it can be implemented by dedication of specific areas within existing buildings at the launch site. The integration of equipment into existing facilities is required. In general, all brick and mortar facilities are in existence. In some cases, modification is required.

The facilities required for manufacturing/test and subsequent operation of the S3 are shown here.

S3 FACILITIES
# S³ Facilities

<table>
<thead>
<tr>
<th>FACILITY</th>
<th>LOCATION</th>
<th>STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>S³ EQUIPMENT REFURBISHMENT/SUPPLY DEPOT</td>
<td>LAUNCH SITE</td>
<td>NEW</td>
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<tr>
<td>ORU REFURBISHMENT AND SPARES DEPOT</td>
<td>OPTIONAL</td>
<td>NEW</td>
</tr>
<tr>
<td>EXPENDABLES SUPPLY DEPOT</td>
<td>LAUNCH SITE</td>
<td>MODIFIED</td>
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<tr>
<td>MOCKUP/SIMULATION/TRAINING</td>
<td>JSC</td>
<td>MODIFIED</td>
</tr>
<tr>
<td>LAUNCH ASSEMBLY/TEST</td>
<td>KSC/VAFB</td>
<td>EXISTING</td>
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<tr>
<td>MANUFACTURING TEST (CONTRACTORS)</td>
<td>VARIOUS</td>
<td>EXISTING</td>
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<tr>
<td>S³ MISSION CONTROL AND DATA PROCESSING</td>
<td>JSC/STC</td>
<td>MODIFIED</td>
</tr>
</tbody>
</table>

![Launch Assembly/Test Facility](image1.png)

![ORU & Spares Refurbishment/Supply Depot](image2.png)

![S³ Equipment Refurbishment/Supply Depot (Integration)](image3.png)

![S³ Mission Control and Data Processing](image4.png)

![Manufacturing/Test Facilities](image5.png)

![Mockup/Simulation and Training](image6.png)

![Expendables Supply Depot](image7.png)
LAUNCH SITE FACILITIES (TYPICAL)
Launch Site Facilities (Typical)

- AREA DEDICATED TO ASSEMBLY AND CHECKOUT OF SERVICING EQUIPMENT MODULES FOR SPECIFIC SHUTTLE FLIGHTS
- STORAGE FOR MODULES TO SUPPORT SEVERAL PLANNED MISSIONS
- KIT REFURBISHMENT CAPABILITY

CARGO INTEGRATION TEST EQUIPMENT (CITE)

- GFE FIXTURE AT LAUNCH SITE
- PRELaunch INSTALLATION OF S³ EQUIPMENT AND OTHER CARGOS TO PROVE FITS AND ELECTRICAL/MECHANICAL INTERFACES

S³ EQUIPMENT FLIGHT-READY AREA
Central management team.

Interface coordination is done. A Facilities Working Group is planned as part of the 3's
the manufacturing! 3's schedules can be accommodated if sufficient advanced planning and facilities
Large floor areas and/or ceiling heights. Although large test facilities are not as numerous as
Many of the 3's equipment items are large (in the assembled configuration) and require fairly

3's hardware/software work load.

And schedule integration, the contractors and government combined facilities can accept the
are not dedicated to the 3's development and production programs. However, with proper planning
Facilities exist today for manufacturing and testing of the planned 3's equipment. They

Production/Test Facilities
Production/Test Facilities

- EXISTING FACILITIES CAN SUPPORT THE PLANNED SATELLITE SERVICING SYSTEM

- LARGE FACILITIES ARE REQUIRED; THE LARGER $S^3$ COMPONENTS WILL TEND TO FILL THE ORBITER BAY – 15 FT DIAMETER
  - DEPLOYMENT PLATFORMS
  - STOWAGE CONTAINERS
  - RESUPPLY TANKAGE

- PRINCIPAL LARGE-FACILITY ITEM OR AREAS:
  - THERMAL VACUUM CHAMBER 30 DIAM X 78 L (FT)
  - ACOUSTIC CHAMBER 40 W X 50 L X 85 H (FT)
  - STRUCTURAL TEST 40 W X 40 L X 50 H (FT)
  - ASSEMBLY AND INTEGRATION 40 W X 100 L X 50 H (FT)
  - CLEAN ROOM
The organization of efforts and the implementing organizations involved can be established by a sequential relationship. The plan presented here indicates the implementation elements required. The tasks required to establish and implement the Satellite Service Systems are shown in the implementation plan.
S3 Implementation Plan

PROGRAM ANALYSIS AND PLANNING → PROGRAM PLAN DEVELOPMENT AND UPDATE → INITIATE PROGRAM HDWR, FACILITIES, AND SUPPORT → LOGISTICS (ILS) AND SCHEDULE DETAIL PLANNING → ILS PROGRAM PLAN DEVELOPMENT

USER COMMUNITY → IMPLEMENT USER COMMUNITY SUPPORT → ILS PROGRAM IMPLEMENTATION → OVERALL SIMULATION PROGRAM PLAN AND SCHEDULES → SIMULATION PROGRAM IMPLEMENTATION

KSC AND VAFB FACILITY BUILDUP AND TRANSITION → IMPLEMENTATION OF SSO → S3 HARDWARE DELIVERY AND INTEGRATION → S3 HDWR/SUPPORT TO USERS

S3 HDWR AND ILS INTEGRATION WITH STS → S3 SYSTEM MANIFESTING AND FLIGHT APPLICATION → POST FLT. S3 HDWR AND ILS IMPLEMENTATION → S3 OPERATIONS INTEGRATION WITH STANDARD STS OPERATIONS
The implementation of facility designs also is critical. To have the facility modification completed when needed for S operation design should start no later than mid-1982.

The accelerated approach is shown in dashed lines. Accelerated approach dates for several of the planned NASA missions are shown to be 1986 and late 1989 under normal development scheduling appear to lag the need development and flight test approach is adopted. The flight data for full completion of S equipment and development and flight test approach is adopted. The flight data for full completion of S equipment and development and flight test approach is adopted. The flight data for full completion of S equipment and development and flight test approach is adopted.

Compressing the schedule is feasible if a high-priority is assigned to the S programs and prototype development schedule. Separately the near- forbid or early S equipment schedule and the longer term HEO/CEO service hardware.

This master schedule for the S development and production phase is divided into two parts showing program schedule.
The basic logistic flow of satellites and equipment and ground operations cycle is shown. Repairs/returfshing and reuse of satellite modules and equipment are emphasized.

Integration contractors assist the central organization in implementing the logistic network.

Equipment with the user hardware.

Desirable. It can direct procurement of equipment modules and direct the integration of this SATELLITE SERVICING LOGISTIC PLAN.
Another is the standardization of documentation which reduces duplication of effort and uncertainty in definition of interfaces.

One is the consolidation of procurement for all materials to support satellite service. The existence of a central organization for all space servicing provides several advantages.

PROCUREMENT STRATEGY
Procurement Strategy

- CENTRAL MANAGEMENT – ESTABLISH SINGLE ORGANIZATION IN SATELLITE SERVICING TO COORDINATE ALL SPACE LOGISTIC MATERIAL REQUIREMENTS AND PROCUREMENT

- PLANNED INVENTORY – CONSOLIDATE SATELLITE SERVICE MATERIAL INVENTORY CONTROL FOR ALL USERS (NASA, DOD, ET AL)

- INTEGRATED PROCUREMENT – BUY QUANTITIES TO SUPPORT ALL USER NEEDS
In addition, working groups and integrating contractors are shown in staff positions to coordinate and maintain interfaces with critical user agencies and support elements.

Organizational (SSO) and a directorate for each of the primary functions of the 53 Program Management. A proposed organizational is shown. It includes the central (JSC) satellite servicing description. The implementation of an effective satellite services system requires effective, well-coordinated support.

53 PROGRAM MANAGEMENT APPROACH
S3 Program Management

**S3 System Integration**
- STS Interface
- S3 Equipment Manifests
- I/F Working Groups
- Simulation and Test I/F

**S3 Operations Control**
- JSC Interface
- STC Interface
- Launch Base Interface
- User Maintenance Data Coordination
- Service Crew Scheduling
- FLT Ops MGT and Control

**S3 Equipment and Supplies**
- Monitor S3 Equipment Design/Build/Test
- Develop New S3 Equipment
- Review New Missions For Requirements
- S3 Users Guide

**Logistics**
- Spares Provisioning: S3 Equipment
- Inventory Management
- Ground Transportation Coordination
- S3 Repair/Refurb Depot
- S3 Equip Kitting, Install/Remove

**Procurement**
- Procure S3 Equipment
- Procure Satellite Spares
- Procure Expendables
- Supplier Interface

**Satellite/Space Sys Maintenance**
- Satellite On-Orbit Repair/Refurbishment
- Space Depot Operations
- Satellite Design Handbook (Servicing)
- Malfunction Report Summaries

**Crew Systems**
- Training Plans/Procms
- Crew Training
- Crew AIDS Coordination
- Servicing Simulations
- Mockup/Simulator Design/Build
- Flight Data Files

**Facilities/Resources**
- Depot Design and Construction
- Depot Maintenance
- Depot Resources Management (Funding, Manpower)
- Special Launch Site Facility Modification Design/Coordination
operation.

The continuity of equipment and skills required for an integrated long-duration servicing
open indefinitely. The 5 ground segment is identified as the system element which maintains
few other "series" of spacecraft equipment, production lines cannot be expected to remain
in tact. However, with the exception of the NASA spacecraft modules (ORU's) and a selected
The ORU Redeployable may process ORU's back to the supplier if production lines are still
ment. These deports may or may not be collocated.
The planned 5 maintenance and supply deports can refurbish orbit replaceable units and 5

GROUND SEGMENT MAINTENANCE OPERATIONS
Ground Segment Maintenance Operation

IMPLEMENT TWO FUNCTIONAL GROUND DEPOTS:

**S\(^3\) Equipment**
- Repair S\(^3\) equipment
- Refurbish and retest S\(^3\) equipment periodically
- Maintain spares in ready status

**Satellite and ORU**
- Repair ORUs
  - Command/Data Management
  - Guidance/Control
  - Electrical Power
- Maintain spares ready status
3.2 Satellite Services Development Plan

INTRODUCTION
ENGINEERING AND DEVELOPMENT REQUIREMENTS
STS REQUIREMENTS/INTERFACES
DEVELOPMENT TESTS AND SIMULATION
DDT&E SCHEDULE

Lockheed
SERVICE SYSTEM. The Program Plan and Operations Plan complete the set.

This Development Plan is one of three documents defining the implementation of the satellite.
Development Plan Objective

- Define the requirements for and the activities necessary to design, build, and test the prototype units of the $S^3$ and verify readiness for space operations with the STS and a wide variety of satellites and platforms in the 1983 to 1993 time period.

  - The development plan is a major portion of the program plan.
  - The development phase ends with the space-qualification testing of the first articles. The $S^3$ program continues with the production and space operation of duplicate sets of the development hardware.
However, all three planning should include all three echelons to ensure an eventual full-service capability. These can be separately implemented if the funding is constrented.

Because of the wide scope of the proposed satellite service system, the development is divided.

SCOPE OF DEVELOPMENT PLAN
Scope of Development Plan

DEVELOPMENT OF HARDWARE AND SOFTWARE TO COVER THREE PHASES OF SATELLITE SERVICE:

INITIAL: NEAR-ORBITER
- SERVICING OF SATELLITES AND SPACE VEHICLES IN LEO; DIRECTLY ACCESSIBLE BY ORBITER

EXPANDED: REMOTE OPERATIONS
- SERVICING OF SATELLITES REMOTE FROM ORBITER (HIGH-ALT, ELLIP. ORBIT, OR GEO)
- LARGER VEHICLES AND PLATFORMS IN LEO

SPACE BASED
- SERVICING OF SPACE VEHICLES, IN SAME LEO ORBIT INCLINATION AS MANNED SPACE STATIONS (SPACE OPERATIONS CENTER OR EQUIVALENT)
- SERVICING DONE ON SPACE DEPOT, UTILIZING TMS AND OTV
Generally applicable equipment requirements are outlined in this chart.

The S requirements will be established in detail in the development phase. Several of the

S REQUIREMENTS
• DESIGN LIFE
  - (WITH PERIODIC REFURB) _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ 15 YEARS

• STORAGE
  - LONG-DURATION DORMANT _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ 5 YEARS
  - GROUND OR SPACE ENVIRONMENT

• REPAIRABLE
  - MODULAR CONSTRUCTION
  - REPAIRABLE ON-ORBIT AND GROUND

• OPERATION BY ON-ORBIT CREWPERSON
  - REMOTE CONTROL VIA DISPLAY/CONTROL PANEL
  - PARALLEL MECHANISM FOR MANUAL OPERATION
  - EVA BACKUP FOR AUTOMATED EQUIPMENT (MOTORS, ETC)

• VERSATILITY
  - USABLE WITH ORBITER OR SPACE DEPOT AS OPERATING BASE

• SAFETY
  - MAN-SAFE RATING
Development of the listed items is included in 3 implementation plans.

The principal hardware elements requiring development or completion of development are listed on this page conducted by EVA.

Typical development hardware
- **DEPLOYMENT AND MAINTENANCE PLATFORM** – PROVIDES SECURE ATTACHMENT OF A SATELLITE IN THE ORBITER BAY AND THE NECESSARY DEGREES OF ROTATIONAL FREEDOM FOR PERFORMING SERVICE FUNCTIONS OF DEPLOYMENT, CHANGEOUT, RECONFIGURATION, RESUPPLY, REPAIR, OR STOWAGE FOR EARTH RETURN.

- **BULK CARGO STOWAGE OR TIEDOWN** – RESTRAINS IRREGULAR HARDWARE ELEMENTS IN ORBITER CARGO BAY FOR RETURN TO EARTH. ACCOMMODATES SATELLITES AND OTHER SPACE EQUIPMENT WHICH ARE DAMAGED OR DO NOT HAVE PROVISIONS FOR NORMAL ORBITER SILL OR KEEL MOUNTS.

- **MODULE EXCHANGE KIT – REMOTE AUTOMATED** – USED IN CONJUNCTION WITH TMS OR OTV FOR REPAIRING SATELLITE IN SITU (WITHOUT RETURNING TO ORBITER OR SPACE DEPOT). USED IN INITIAL REPAIRS TO SATELLITES IN GEO: OTV CARRIES REPLACEMENT ORUs TO GEO, DOCKS AND EXCHANGES ORUs, AND RETURNS TO DOCK WITH ORBITER OR SPACE DEPOT IN LEO. USED IN CONJUNCTION WITH TELEOPERATOR MODULE.

- **SATELLITE CHECKOUT SET** – MODULE FAILURE DISCRIMINATION AND TEST OF PRIMARY SUBSYSTEM FUNCTIONS. CHECKOUT VIA HARDLINE UMBILICAL TO SATELLITE. ALSO, WITH ADAPTIVE SOFTWARE, CHECKOUT OF MTV, OTV, AND TMS.
- **FLUID TRANSFER MODULE** – TRANSFER OF FLUIDS FROM TANKAGE IN ORBITER CARGO BAY TO SATELLITE, OTV, TMS. FLUIDS INCLUDE HYDRAZINE, LH₂, LO₂, NITROGEN. HIGH FLOW RATE TO ALLOW TRANSFER UP TO 15000 LB/HR. ANCILLARY MODULES TO TRANSFER CRYOGENS TO SATELLITE DEWARS.

- **TELEOPERATOR MANEUVERING SYSTEM**
  - **TELEOPERATOR FUNCTION** – MECHANISM FOR DOCKING WITH FREE-FLYING SATELLITE AND PERFORMING BASIC MECHANICAL FUNCTIONS: OBSERVATION, OPEN DOORS, EXCHANGE SMALLER ORUs, ACTIVATE/DEACTIVATE, OR DISASSEMBLE/JETTISON APPENDAGES. MOUNTS ON MANEUVERING STAGE.
  - **MANEUVERING FUNCTION** – TRANSFER SATELLITES OR OTHER CARGO BETWEEN FREE-FLYER ORBIT AND ORBITER OR BETWEEN SPACE DEPOT AND FREE-FLYER ORBIT. CARRY LARGE PROPELLANT LOADS, UP TO 8000 LB. FLY ON PRE-PROGRAMMED TRAJECTORY WITH AUTOMATED RENDEZVOUS/DOCKING WITH SATELLITE. FLOWN BY REMOTE CONTROL FROM ORBITER (OR GROUND) WITH TV FEEDBACK.

- **ORBITER BERTHING/DOCKING MODULES** – PROVIDES FOR RENDEZVOUS AND DOCKING OF ORBITER TO LARGE SPACE VEHICLES AND PLATFORMS: E.G., 25kW POWER SYSTEM, SCIENCE/APPLICATION PLATFORMS, SOC, ETC. MOUNTS IN ORBITER FWD CARGO BAY. USES RANGE/RANGE-RATE, ANGULAR, AND DOCKING-AXIS ALIGNMENT SENSORS INPUTTING TO ORBITER VERNIER RCS FOR AUTOMATED DOCKING (MANUAL OVERRIDE WITH TV LOOP). AUTOMATED ELECTRICAL UMBILICAL CONNECT/DISCONNECT WITH MANUAL BACKUP.
• **RENDZVOUS/DOCKING – REMOTE CONTROL** – PROVIDES CONTROL FROM ORBITER OR SPACE DEPOT FOR REMOTE RENDZVOUS AND DOCKING; OTV OR TMS TO SATELLITE, SPACE PLATFORM, ORBITER. INCLUDES VISUAL DISPLAYS AND SENSING/PROPULSION ELECTRONICS.

• **MANNED TUG** – PRESSURIZED COMPARTMENT WITH INTEGRAL PROPULSION AND TRANSLATION/ATTITUDE CONTROL. DOCKING MECHANISM AND TELEOPERATOR ARMS CONTROLLED FROM WITHIN. USED FOR CREW MOBILITY IN INSPECTION, MINOR SERVICING, APPENDAGE REMOVAL, AND TRANSFER OF SATELLITE IN GENERAL VICINITY OF ORBITER OR SPACE DEPOT.
The SSUS, Centaur, and LUS, mounted in the orbiter will be supported by S3 equipment.

During revisits to the space platform, permanent platform, the SOC, or the planned S3 space depot, replenishment propellant is supplied.

A low-thrust-level boost stage can accomplish a round-trip to perform HEO/GE0 satellites. A newly added STS inventory item, it provides boost for space probes and orbiter positions.

The SSUS, Centaur, and LUS, mounted in the orbiter and returned to the S3 space depot, will be supported by S3 equipment.

The spin stabilized upper stage (SSUS) is utilized to deliver spinning satellites to the terminal.

The principal elements of the STS are illustrated; they support and supplement the S3 operations.

SPACE TRANSPORTATION SYSTEM
A primary operations interface involves the free-flight control of the MTV and TMS vehicles and includes the approach and docking of the free flyers. Dynamic simulation of all operations involving the positioning and translation of the orbiter. Orbiter equipment and operations, mechanical and functional testing, simulation and training is part of the S3 development program. Development of the S3 equipment emphasizes the need for interface matching with the existing standard.

PRINCIPAL S3/S3 INTERFACES
**Principal STS/S^3 Interinterfaces (1 of 2)**

- S^3 INTERFACES WITH THE STS ARE ESTABLISHED EARLY, MAINTAINED ON ICDs, AND REVIEWED/UPDATED BY FREQUENT MEETINGS OF AN STS INTERFACE WORKING GROUP

- THE ORBITER INTERFACE COORDINATION WILL BE EXTENDED TO OTVs AS LATTER ARE USED FOR REUSABLE PROPULSION STAGES
ORBITER INTERFACES:

- FLIGHT CONTROL
  - I/Fs AMONG ORBITER VERNIER AND MAIN RCS CONTROLS, RMS CONTROLS, SATELLITE/TMS/MTV FOR RETRIEVAL, DOCKING, AND DEPLOYMENT

- STRUCTURAL
  - MOUNTING AND LOAD TRANSFER FOR S3 RACKS/PLATFORMS

- ELECTRICAL
  - I/F WITH ORBITER POWER SUPPLY: VOLTAGE AND FREQUENCY

- DATA PROCESSING
  - I/F WITH ORBITER ONBOARD COMPUTERS AND DATA MANAGEMENT SYSTEM

- COMMUNICATION
  - I/F VIA ORBITER WITH TDNS, STDN, AND DoD SGLS COMMUNICATION SYSTEMS

- FLUID SYSTEMS
  - SPECIAL VENT AND ABORT DUMP I/Fs FOR S3 REPLENISHMENT FLUIDS
The exact definition of what constitutes "Satellite Service" Equipment and what equipment is stressed.

Mission-unique designs are avoided; multi-dimension application of common equipment is stressed.

Development Program.

The design of equipment necessary to interface the S3 hardware to the orbiter is a part of the S3 accommodations.

Requirements for orbiter interfaces are covered in Vol. XIX, USC 07170 Space Shuttle System Payload.

The orbiter capability is supplemented by special S3 orbiter accommodation equipment.
THE S^3 ORBITER ACCOMMODATION EQUIPMENT SUPPLEMENTS THE ORBITER CAPABILITY

<table>
<thead>
<tr>
<th>ORBITER CAPABILITY</th>
<th>S^3 ACCOMMODATION EQUIPMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>• STRUCTURAL MOUNTING POINTS – CARGO BAY</td>
<td>• LONGERON BRIDGE FITTINGS</td>
</tr>
<tr>
<td>• PAYLOAD OPERATOR STATION</td>
<td>• MISSION-UNIQUE DISPLAY/CONTROL PANELS</td>
</tr>
<tr>
<td></td>
<td>– SATELLITE CHECKOUT PANEL</td>
</tr>
<tr>
<td></td>
<td>– TMS/MTV REMOTE OPS CONTROL PANEL</td>
</tr>
<tr>
<td></td>
<td>– SATELLITE RETRIEVAL/DOCK/DEPLOY CONTROL PANEL</td>
</tr>
<tr>
<td>• COMPUTER/DATA PROCESSING</td>
<td>• SOFTWARE</td>
</tr>
<tr>
<td>• RMS</td>
<td>• SATELLITE CHECKOUT SET</td>
</tr>
<tr>
<td></td>
<td>• SPECIAL PURPOSE RMS</td>
</tr>
<tr>
<td></td>
<td>• SPECIAL END EFFECTORS</td>
</tr>
</tbody>
</table>
# Orbiter Accommodations for S³ (2 of 2)

<table>
<thead>
<tr>
<th>ORBITER CAPABILITY</th>
<th>S³ ACCOMMODATION EQUIPMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>• COMMUNICATION LINKS (RF, VOICE)</td>
<td>• S³ I/F UNIT</td>
</tr>
<tr>
<td></td>
<td>• SPECIAL S³ DATA MULTIPLEXING AND DATA COMPRESSION PACKAGE</td>
</tr>
<tr>
<td>• BASIC ILLUMINATION AND TV</td>
<td>• ANCILLARY LIGHTS (PORTABLE) AND TV CAMERAS</td>
</tr>
<tr>
<td>• CREW SUPPORT EQUIPMENT FOR TWO CREW MEMBERS</td>
<td>• ADDITIONAL CREW EQUIPMENT AND LIFE SUPPORT SUPPLIES FOR ADDED EVA</td>
</tr>
</tbody>
</table>

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PAGE 3-128 INTENTIONALLY BLANK 3-129
Integrating contractor is needed to accomplish the integrated-system testing. The tests are separately done by each equipment supplier on an equipment-by-equipment basis. An hardware and the qualification testing of first-article flight items.

In the broad sense, development phase testing includes both the development testing of prototype.

DEVELOPMENT TESTS
# Development Tests

<table>
<thead>
<tr>
<th>Tests</th>
<th>Test Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Component/Module Tests</strong></td>
<td>• Mechanical Loading Fixtures</td>
</tr>
<tr>
<td>• Structural Load/Dynamic</td>
<td>• Dynamic Test Fixture</td>
</tr>
<tr>
<td>• Outgassing</td>
<td>• Envir. Test Fixtures</td>
</tr>
<tr>
<td>• EMC</td>
<td>• Acoustic Test Chamber</td>
</tr>
<tr>
<td>• Acoustic</td>
<td>• Thermal/Vac Test Chamber</td>
</tr>
<tr>
<td>• Thermal Vacuum</td>
<td>• Power Supply</td>
</tr>
<tr>
<td>• Mechanical Function</td>
<td>• Test Consoles and Software</td>
</tr>
<tr>
<td><strong>Integrated System Function</strong></td>
<td></td>
</tr>
<tr>
<td>• Umbilical Mat/ Demate</td>
<td>• Satellite Functional Simulator</td>
</tr>
<tr>
<td>• Satellite Checkout</td>
<td>• S³ Checkout Set (Breadboard)</td>
</tr>
<tr>
<td>• Software Proofing</td>
<td>• S³ Display/Control Panels (Breadboard)</td>
</tr>
<tr>
<td></td>
<td>• Prototype S³ Software (Ground and Flight)</td>
</tr>
<tr>
<td></td>
<td>• Power Supply</td>
</tr>
</tbody>
</table>
In performing the service,

later phases using remote and automated operations require even more extensive simulation.

Simulation program verifies the equipment and operations design for ease and safety of the crew.

Early phase satellite servicing involves a large measure of man-in-the-loop execution. The
design, the design of operational timelines, and the constraints placed on the user satellite

GROUND SIMULATION TESTING
<table>
<thead>
<tr>
<th>SIMULATION</th>
<th>PROTOTYPE S³ EQUIP AND SIMULATORS</th>
</tr>
</thead>
<tbody>
<tr>
<td>• MODULE (ORU) REPLACEMENT – EVA</td>
<td>• STD RMS AND END EFFECTORS (GFE)</td>
</tr>
<tr>
<td>- SATELLITE ON RMS</td>
<td>• SPECIAL RMS (2ND)</td>
</tr>
<tr>
<td>- SATELLITE ATTACHED TO DMP</td>
<td>• DEPLOYMENT AND MAINTENANCE PLATFORM</td>
</tr>
<tr>
<td>- (NEUTRAL-BUOYANCY, 6 DOF, OR 1G)</td>
<td>• SATELLITE SIMULATOR</td>
</tr>
<tr>
<td>• MODULE (ORU) REPLACEMENT – AUTOMATED</td>
<td>• ORU SIMULATORS</td>
</tr>
<tr>
<td>- MODULE EXCHANGE MECH</td>
<td>• MODULE EXCHANGE MECHANISM</td>
</tr>
<tr>
<td>- RMS TRANSFER</td>
<td>• SATELLITE SIMULATOR</td>
</tr>
<tr>
<td>- (1G AIR-BEARING FLOOR)</td>
<td>• ORU SIMULATORS</td>
</tr>
<tr>
<td>• MODULE REPLACEMENT – REMOTE FROM SHUTTLE</td>
<td>• RMS AND END EFFECTORS</td>
</tr>
<tr>
<td>- TMS OR OTV</td>
<td>• S³ DISPLAY/CONTROL PANELS</td>
</tr>
<tr>
<td>- (1G AIR-BEARING FLOOR)</td>
<td>• S³ DISPLAY/CONTROL PANELS</td>
</tr>
<tr>
<td>• RETRIEVE/DOCK SATELLITE/PLATFORM TO ORBITER</td>
<td>• BERTHING/DOCKING MODULE (PROTOTYPE)</td>
</tr>
<tr>
<td>- (1G AIR-BEARING FLOOR)</td>
<td>• DISPLAY/CONTROL PANELS – S³</td>
</tr>
<tr>
<td></td>
<td>• LARGE PLATFORM OR SATELLITE SIMULATOR (PARTIAL)</td>
</tr>
<tr>
<td></td>
<td>• VISUAL DOCKING AIDS</td>
</tr>
<tr>
<td></td>
<td>• SENSING/CONTROL LOOP – DOCKING (BREADBOARD)</td>
</tr>
</tbody>
</table>
Simulation Testing (2 of 2)

Simulation

- Lighting and TV
  - Apply lighting variations to all simulations
    - EVA operations
    - Remote operations (TMS or OTV)

- Free-flyer retrieval by RMS
  - (1G air-bearing floor)
    - Satellite stabilized
    - Satellite slow tumble

Prototype S³ Equip and Simulators

- Illumination lights – fixed and portable
- TV cameras
- Space illumination simulation facility

- RMS and end effectors
- Satellite simulator
- Deployment and maintenance platform
Early commitment of facilities, floor space and reservation of special test facilities is necessary. The design of modifications, floor layouts, utilities, etc., in a primary early development phase activity plans the facilities in detail and initiates some manufacturing and test facilities to S functions. Community facilities can support the S development. Modifications are necessary to adapt analyses and definition of satellite service equipment indicative that existing aerospace development facilities.
Development Facilities

- **EXISTING FACILITIES** CAN SUPPORT THE PLANNED SATELLITE SERVICE SYSTEM DEVELOPMENT

- **LARGE-SIZE FACILITIES** ARE REQUIRED; THE LARGER $S^3$ COMPONENTS WILL TEND TO FILL THE ORBITER BAY – 15 FT DIA
  - DEPLOYMENT PLATFORMS
  - STOWAGE RACKS
  - RESUPPLY TANKAGE
  - TMS
  - MODULE EXCHANGE MECHANISM
  - DOCKING MODULE

- **PRINCIPAL LARGE-FACILITY ITEM OR AREAS:**
  - THERMAL VACUUM CHAMBER 30 DIA X 78 L (FT)
  - ACOUSTIC CHAMBER 44 W x 50 L x 85 H (FT)
  - STRUCTURAL TEST 40 W x 40 L x 50 H (FT)
  - ASSEMBLY, INTEGRATED TEST, AND SIMULATIONS 40 W x 100 L x 50 H (FT)
  - MULTIPLE DOCKING FACILITY (MDF)
  - NEUTRAL BUOYANCY/WATER IMMERSION FACILITY
are years later. This approach minimizes the program cost.

Production of all equipment needed to satisfy the service system over a 10-year span is shown.

Some qualification units are refurbished and used as the first operational service equipment.

In general, the development phase is considered ended with the completion of qualification.

Documentation and qualification. Such elements can shorten the normal development schedule.

All hardware elements are presumed to go through prototype design and development test phases.

and space-based service operations.

The potential growth of the service system required to undertake remote service, large platforms, the scope of this study, i.e., all-weather and near-orbiter service, the second phase shows the development of the equipment necessary to initiate and maintain the service system within.

In each phase, examples of the more ambitious equipment are shown. The first phase indicates

The schedule shown in this chart depicts two phases of satellite services equipment development.
S³ Equipment Development Schedule (1 of 2)

<table>
<thead>
<tr>
<th>Year</th>
<th>NEAR-ORBIT SERVICING EQUIPMENT</th>
<th>REMOTE-FROM-ORBITER SERVICING EQUIPMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980</td>
<td></td>
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<tr>
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<td>1982</td>
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<tr>
<td>1983</td>
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<td>1984</td>
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</table>

**TYPICAL NEW-EQUIPMENT DEVELOPMENT SPANS:**

- MANEUVERABLE TV
- DEPLOYMENT, MAINTENANCE PLATFORM
- WORK STATION
- CARGO CONTAINMENT SYSTEM
- TIEDOWN PLATFORM
- FLUID TRANSFER
- MODULE TRANSFER
- TMS WITH CAPTURE EFFECTORS
- FLUID REPLACEMENT TANK MODULES
- ELECTRONIC WELDER/BONDER
- REMOTE DOCKING MECHANISM
- REMOTE SERVICE MODULES
3.3 Satellite Services Operations Plan

INTRODUCTION

REQUIREMENTS

TYPICAL S\(^3\) LAUNCH AND FLIGHT OPERATIONS

TYPICAL S\(^3\) GROUND SUPPORT OPERATIONS

S\(^3\) OPERATIONAL PLANNING DOCUMENTATION
the preflight planning era.

The specific mission operations plan is to be built on the generic plans in a cumulative manner. The resolution of the problem was to outline the plans for identification of the responsibilities. The resolution implies a lack of definition of the Satellite Service System organization.

These generalizations indicate a need for definition for the first and second categories. The approach to this plan is to identify the elements required for the first and second categories.

- Specific mission operations
- Ground support operations
- Flight support operations for each of 6 generic missions
- Mission operations plans are identified as falling into one of several categories:

Objectives of the 5 Operations Plans
Objective Of S3 Operations Plans

DEFINE THE REQUIREMENTS FOR AND THE ACTIVITIES NECESSARY TO PROVIDE SERVICING OF OPERATIONAL SPACE SYSTEMS, BOTH IN ORBIT AND ON THE GROUND. THE STS AND THE SATELLITE SERVICES SYSTEM (S3) ARE COMBINED TO SUPPORT DEPLOYMENT, OBSERVATION, RETRIEVAL, REPAIR, RESUPPLY, CHANGEOUT, RECONFIGURATION, AND EARTH RETURN.

- SATELLITES
- UPPER STAGES
- OTVs AND TMS
- SPACE PLATFORMS
- PLANETARY VEHICLES
A multi-agency approach is planned combining the servicing requirements for NASA, DoD, other U.S.

other's).

Government agencies, and eventually the commercial and international agencies (ESA, Japan, and

The operational S supports the total earth-orbiting inventory of space vehicles and the checkout/

Scope of the operation S
Scope of the Operational S³

- Servicing is provided for a variety of satellites, space platforms (e.g., SOC), OTVs, and other space systems
  - Early phase (circa 1983) servicing includes:
    - Satellite deployment and recovery
    - Orbital unscheduled EVA override of appendages
    - Limited changeout of 'modules' and black boxes
  - Later phases extend service to more extensive changeout, resupply, debris capture/retrieval, repair and deorbit
- All STS users and some expendable launch vehicle users are potential customers for S³: NASA, USAF, DARPA, NAVY, COMMERCIAL, INTERNATIONAL
Specific responsibilities for management of each basic area are assigned within the Space Servicing Elements making up the $S$ Operations area listed and defined in this figure.

MISSION OPERATION REQUIREMENTS
S$^3$ Mission Operation Requirements

PRELAUNCH OPERATIONS
- Verify S$^3$ equipment performance and satellite/S$^3$ interfaces
- Verify S$^3$ equipment fit and functional interfaces with orbiter

ORBIT OPERATIONS
- Perform service function on assigned space vehicle

GROUND CONTROL CENTER OPERATIONS
- Control of flight segment service
- Performance analysis of service

NETWORK COMMUNICATIONS
- Interface with networks: TDRS, STDN, USAF-SGLS (secure)

SERVICE CREW TRAINING AND SIMULATION
- Prepare crew for space servicing operations
- Proveout and rehearse - S$^3$ service methods and equipment functions

GROUND REPAIR/REFURB
- Repair/Refurb of returned S$^3$ equipment
- Refurb returned satellite orbit replaceable units (ORU)

LOGISTIC SUPPLY
- Depot supply of: S$^3$ equipment kits and spare parts, expendables for resupply, and ORUs
base is shown to be either the orbit or the space. The Servicing

The diagram shows the various elements of the Space Segment and their Interfaces. The Servicing

SPACE SEGMENT SPACE OPERATIONS ELEMENTS
The primary operations are indicated.

The elements of the $S^3$ Ground Segment are shown in this figure. Examples of the interfaces with $S^3$ Ground Segment Operations Elements...
Cost Section of this Report.

The ground rules and assumptions upon which this model is based are discussed in detail in the
poses of the Sortie Payload.
other types because the limited endurance of the orbiter will likely be fully dedicated to the pur-
Sortie missions might be shared with HEO/LEO/Planetary/Spacecraft/Deploymens but not likely with the

Dedicated service missions could be planned but it will likely be significantly more costly.
estimating. In this way, the cost allocated to a servicing mission can be kept relatively low.
Retriever missions. The service missions are presumed to be "shared" missions for the purpose of cost
Multiple deployment missions can be accomplished on the same flight that performs one or more rendezvous/
service missions.

An analysis of planned missions for period 1983 to 1993 shows the distribution among the genera

§ MISSION SUPPORT MODEL
<table>
<thead>
<tr>
<th>SERVICE CATEGORY</th>
<th>PRIMARY MISSIONS</th>
<th>DEPLOYMENT</th>
<th>REPAIR</th>
<th>CHANGEOUT RECONFIGURE RESUPPLY</th>
<th>EARTH RETURN</th>
<th>DEORBIT</th>
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<td>42</td>
<td>15</td>
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</table>
Typical $S^3$ Launch and Flight Operations
A large portion of the near term, near orbiter service missions, because EVA servicing offers a lower-cost approach with minimal extra equipment, it is preferred for the automation mode preferred for servicing operations such as rendezvous and dock with satellite.

The crew EVA backup is required to provide maximum probability of mission accomplishment. Both EVA and remote-control servicing modes are planned. For most of the remote control operations, remote control & crew EVA servicing...
Remote Control and Crew EVA Servicing

- Servicing functions performed utilizing automated equipment remote-controlled from pressurized orbiter aft flight deck
- Backup for all servicing provided by crew IVA and EVA operation
- Selected servicing performed with EVA as primary mode
- EVA operations include:

<table>
<thead>
<tr>
<th>Class</th>
<th>Actions</th>
</tr>
</thead>
</table>
| INSPECT/CHECKOUT | • Examine/Observe  
                   • Diagnosis/Isolation  
                   • Assess/Analyze  
                   • Activate/Self-Check |
| OVERRIDE        | • Extend/Retract  
                   • Open/Close  
                   • Latch/Unlatch |
| SAFING          | • Unfasten/Fasten  
                   • Inspect/Verify  
                   • Mate/Demate  
                   • Activate/Deactivate  
                   • Shield/Cover |
| MANEUVER        | • Tether  
                   • Stabilize  
                   • Transfer/Translate |
| CHANGEOUT       | • Remove/Replace  
                   • Unfasten/Fasten  
                   • Align/Match/Index |
| REPAIR          | • Replace Item  
                   • Start/Shut-Down  
                   • Apply Coating |
The space telescope re-visit and service mission uses the DM to hold the satellite at the proper angle in the cargo bay and rotates it to allow crew access to all circumferential module locations.

InS in attaining earth-escape velocity, must be refueled before deployment and InS ignition because of the high loads applied by the payloads are then checked out. If payloads are extended for a more complete checkout, they may be released after deployment, The InS shall be ejected by rotation out of the cargo bay; spacecraft and the galileo space vehicle is mounted on an InS upper stage, which transmits into planetary trajectory.

...second, optimally located grasp fixture...

module-exchange mechanism seized by crew EVAs. EVAs may be required prior to RMS grasp to attach a orbital RMS, powered into a light support system. Satellite modules can be changed out by the solar maximum mission, utilizing the NAVA/GSCR RMS moduleized spacecraft is acquired by the...

Three typical servicing concepts are illustrated in this figure.
**Servicing Concepts (Typical)**

*S³ SERVICE FUNCTIONS*
- DESPIN/RESPIN
- DEORBIT
- CHANGEOUT/RESUPPLY
- REPAIR
- DEBRIS HANDLING
- CHECKOUT

*SOLAR MAX MISSION***

**RETRIEVAL/REPAIR**

**GALILEO**

**CHECKOUT / DEPLOYMENT**

**SPACE TELESCOPE**

**CHANGEOUT**
and reported on the orbiter or returned to earth for repair.

possible in orbiter-docked mode are checked. If malfunction is noted, satellite can be retrieved
PQCC. Functions such as solar array rotation and torquing of spacecraft for attitude control, not
keeping force-tight as final verification of verification of subsystems is made via RF link with the

The final step in deployment sequence is the separation of satellite from the orbiter and station.

check can be done from the orbiter. 

check out and its payload. Detailed checkout is accomplished through the mission PQCC, a lesser health
still docked to the orbiter or attached to the PDS. This allows end-to-end checkout of the space-

The orbiter checkout of the satellite verifies its flight-readiness before final deployment. The

and checkout phases are identified and the functions comprising each are listed.

A typical checkout/deployment mission profile is shown here. The predeployment, satellite extension,
Deployment Mission Profile (Typical)

1. OPEN PAYLOAD DOORS
2. PERFORM PREDEPLOYMENT OPERATIONS
3. SATELLITE EXTENSION
   - MOVE SATELLITE TO POSITION ON PLATFORM USING RMS
   - EXTEND SATELLITE SOLAR ARRAY ANTENNAS, AND OTHER APPENDAGES
4. ON-ORBIT CHECKOUT
   - RETRACT RMS ARM
   - VERIFY COMMAND LINK
   - COMMAND SYSTEMS ON SATELLITE
   - VERIFY SATELLITE ACS STATUS
   - VERIFY ORBITER ACS STABILIZATION
   - VERIFY ELECTRIC POWER STATUS
   - VERIFY TO-ORBITER POWER TRANSFER
   - VERIFY THERMAL SYSTEM STATUS
   - VERIFY SATELLITE-TO-ORBITER FUNCTIONAL INTERFACE
   - CONFIRM SATELLITE OPERATIONS READINESS
   - PERFORM POWER-ON CHECKOUT OF SATELLITE SUBSYSTEMS
   - DISCONNECT SATELLITE UMBILICAL

DEPLOY AND ORBITAL STORAGE
ORBITER RETURN TO EARTH
and preflight training/rehearsal activities. They are used for orbit operations checkoff lists.

As the operations planning matures, these sequences are expanded into detailed task/activity lists.

mission duration, and the interfaces with other mission operations requirements.

specific mission to establish the total flight timeline, the necessity to extend the orbiter.

A typical sequence of service functions is shown in this figure. Timelines are generated for each

RETRIEVAL/SERVICE/REDEPLOYMENT SEQUENCE
Retrieval/Service/Redeployment
Typical Sequence of Operations (1 of 2)

SATELLITE CONFIGURATION/STATUS VERIFICATION
- DETERMINE CONDITION, MOTION RATES, APPENDAGE ORIENTATION
  FROM POCC VIA TLM OR DIRECT OBSERVATION (VISUAL OR MTV)

RETRIEVAL READINESS
- DEACTIVATE SATELLITE PROPULSION/ACS, MONITOR CAUTION/
  WARNING READOUTS ON TELEMETRY LINK VIA POCC OR DIRECT

ORBITER READINESS CHECK
- VISUAL CHECK CARGO BAY, DOOR POSITION
- CHECK RMS FUNCTION
- CHECK DEPLOYMENT AND MAINTENANCE PLATFORM (DMP)

DOCKING
- FINAL APPROACH MANEUVER (PROXIMITY OPERATIONS)
- GRAPPLE SATELLITE
- BERTH TO DMP
- UMBILICAL CONNECT

CHECKOUT/CHANGEOUT RECONFIGURE, RESUPPLY/CHECKOUT
- DIAGNOSTIC CHECKOUT OF SATELLITE
- EVA
- REPLACE ORUs AS REQUIRED AND PREPLANNED
- REPLENISH EXPENDABLES
- CHECKOUT ALL SUBSYSTEMS
REDEPLOY

- CHECK ORBITER STATUS; DEACTIVATE RCS
- RMS GRAPPLE SATELLITE
- RELEASE HOLD-DOWN LATCHES
- EXTRACT/EXTEND SATELLITE
- DEPLOY APPENDAGES
- RECHECK SATELLITE WITH SOLAR ARRAY AND ANTENNAS OPERATING
- RELEASE UMBILICAL
- RELEASE SATELLITE

STATION-KEEP CHECK

- SAMPLING OF SATELLITE RESPONSE TO RF COMMANDS FROM ORBITER OR VIA POCC
- SATELLITE HEALTH VERIFICATION FROM ORBITER OR VIA POCC
Division.

The kit returnishment, repair and storage is the responsibility of the Space Systems Maintenance

orbiter are the responsibility of the Logistics Division of the Satellite Servicing Organization.

The task of preparing the service kits, the coordination of their installation and removal from the

is a constraint and is carefully planned and coordinated with all other orbiter and user requirements.

Time from landing to the following launch, the installation and removal of the 3 equipment kits

The processing and prelaunch checkout of the 3 equipment is not a constraint upon the Shuttle cycle

outlined.

Processing to create an integrated flow plan, the numerous launch site operational steps are

The 3 equipment and satellite ORU logistic flow is shown combined with the Shuttle launch site

3 LAUNCH SITE OPERATIONS
S3 Launch Site Operations
The Performance Evaluation Group assembles and disseminates data relative to the performance of the equipment, crew, and mission operations. It also maintains equipment maintenance records to pin-

point weak design features in the equipment.

The principal interface with the user agencies is maintained by the Mission Management Group. It are recorded for dissemination to user agencies and other key organizations. All service operations, real-time displays are continuously monitored. Selected status data and IY during satellite service operations, the flight operations control group operates continuously during

Three important functions of the SSOC are shown together with the corresponding subfunctions.
Satellite Services Operations Control Center (SSOCC)

- SSOCC is focal point of all S³ MISSION ACTIVITIES, PROVIDING CONTROL OF ORBITAL SERVICING OPERATIONS
- PLANS, SCHEDULES, AND OPERATES THE S³ FLIGHT SEGMENT

### MISSION MANAGEMENT
- TDRS AND DOMSAT AND DSCS SCHEDULE COORDINATION
- GROUND COMMUNICATIONS LINK COORDINATION
- DAILY AND LONG-RANGE S³ ACTIVITY PLANNING
- MANAGEMENT OF GROUND REFURBISHMENT/SUPPLY DEPOTS FOR S³
- INTERFACE WITH USERS
- STS SCHEDULE COORDINATION
- CREW SCHEDULING
- CONTINGENCY PLANS FOR NON-NORMAL OPERATIONS

### FLIGHT OPERATIONS CONTROL
- COMMAND GENERATION FOR ORBIT OPERATIONS
- DISPLAY OF ORBIT SERVICING DATA:
  - TV
  - CRT OF TELEMETRY STATUS READOUTS
- REALTIME MONITOR OF ORBIT OPERATIONS
- PROCESS TLM DATA
- FLIGHT DYNAMIC ASSESSMENT:
  - SATELLITE DOCKING
  - TMS FREE-FLY
  - MTV FREE-FLY
- STATUS INFORMATION DISSEMINATION (REALTIME)

### PERFORMANCE EVALUATION
- PROBLEM INVESTIGATION
- SATELLITE DIAGNOSTICS: EVALUATION FOR SERVICE OPERATIONS SCHEDULING (REPAIR KITS, SPARE ORUs)
- SUMMARY TROUBLE/FAILURE REPORTS
- REPAIR/REFURBISH TREND DATA AS BASE FOR SCHEDULING PERIODS OF REVISIT
The Crew Systems Division of the Satellite Services Organization has the responsibility for defining and conducting simulation and training programs.

Except the remote operations to be performed by the TMS or OY, an override mode is the use of crew EVA for backup of all automated operations. An override mode is used in the case of unexpected space operations to guide the actual crew on orbit. The recording is used to study and improve the specific operations. A step-by-step flight checklist is specially designed simulator duplicated to maximize the possible extent using prototype hardware adapted to simulation or using simulation is not limited to crew EVA operations. Completely automated servicing modes are brought into the inventory, crews are retained.

To ensure error-free and effective servicing of space vehicles, rigorous ground simulation and training...
Service Simulation and Crew Training

PROVIDE FOR:

- TESTING SATELLITE INTERFACES WITH $S^3$ EQUIPMENT
- DESIGN OF SATELLITE SIMULATOR
- DESIGN OF ADDITIONAL OR MODIFIED $S^3$ EQUIPMENT
- GROUND REHEARSAL OF SERVICE OPERATIONS
- VERIFICATION OF TIMELINES FOR ORBIT OPERATIONS (SIMULATION)
- VERIFICATION OF CREW INTERFACE WITH $S^3$ EQUIPMENT

TYPICAL SIMULATIONS – AUTOMATED AND CREW (EVA):

- SATELLITE CHECKOUT
- SATELLITE APPENDAGE EXTEND/RETRACT/JETTISON (EVA)
- CHANGEOUT (MODULE REPLACEMENT)
- SATELLITE DEPLOYMENT/RETRIEVAL
- RMS AND END EFFECTOR OPERATION
- COMMON REPAIRS

TYPICAL CREW TRAINING:

- EQUIPMENT MOVEMENT-ZERO "G" HANDLING OF SATELLITES, ORUs, DEBRIS, ETC.
- REMOTE CONTROL OPERATIONS – SIMULATE CONTROL OF MTV, TMS, RMS, ETC.
- ILLUMINATION – VISIBILITY AUGMENTATION
- SAFETY – HAZARD AVOIDANCE
Units if the manufacturer is not under contract to perform these functions or is unable to do so.

However, they are the natural choice for performing the repair/return/shipping of orbital replaceable.
The Depots are primarily concerned with supply and maintenance of the satellite service equipment.

It has a strong intimate interface with the Logistics Division.
The responsibility for the depots falls under the Satellite System Maintenance Division of the SSO.

Factors may dictate separating the activities functionally and/or geographically.

These functional depots may or may not be colocated. It is assumed that all functions are performed

Supply, Repair, Refurbish Depots
$S^3$ EQUIPMENT AND EXPENDABLES

- MAINTAIN SUPPLY OF FLIGHT-READY EQUIPMENT AND EXPENDABLES
- REPAIR FLIGHT-RETURNED EQUIPMENT, AS REQUIRED
- REFURBISH FLIGHT-RETURNED EQUIPMENT
- SUPPLIER INTERFACE MANAGEMENT

ORBIT REPLACEABLE UNITS

- TRANSHIP FLIGHT-RETURNED UNITS TO SUPPLIER FOR REWORK
- REPAIR/REFURBISH UNITS HAVING NO PRODUCTION/MAINTENANCE SUPPLIER
- MANAGE TURN-AROUND CYCLE AND INVENTORY
S³ Operations Planning Documentation
Sign-offs are probably required by other associated organizations.

The Satellite Servicing Organization is responsible for the preparation of these plans and the

The specific mission plans are generated after manifesting is firm and far enough in advance of

The flight date to permit accomplishment of the defined simulations and training. It must also be
can be generated at the time a clear definition of responsibilities is achieved.

Two types of operational plans are identified and separated in time. The generic mission plans

OPERATIONS PLANS
GENERIC MISSION PLANS – CAN BE GENERATED NOW

- DEPLOY
- SORTIE
- REPAIR
- CHANGEOUT
- RECONFIGURE
- RESUPPLY
- EARTH RETURN
- DEORBIT

SPECIFIC MISSION PLANS – PREFLIGHT GENERATED/FORMALIZED/ APPROVED

- SOLAR MAXIMUM
- SPACE TELESCOPE
- LDEF
- - - - -
- - - - -
Coordination sign-offs are probably required by other associated organizations. Required by at least the Mission Planning and Analysis Division and the Flight Operations Panel.

Coordination with all affected organizations and functions. Approvals are anticipated to be

The Satellite Servicing Organization is responsible for the preparation of these plans and the

and for the specific mission plan.

contaminated in a complete operations plan. The outline serves both for the generic mission plan

The outline shown on this and the following table indicates the principal factors that must be

Operational plans content
S3 Operations Plans Content

RESPONSIBILITY DEFINITION

- SATELLITE SERVICE ORGANIZATION
  - SSOCC
  - LOGISTICS
  - PLANNING INTERFACE MANAGEMENT
- JSC MISSION CONTROL
- CREW SYSTEMS
- USER
- KSC OR VAFB
- JPL MISSION CONTROL
- SOC

SERVICE SYSTEM REQUIREMENTS

- HARDWARE
  - FLIGHT
  - SUPPORT
- SOFTWARE
- COMMUNICATIONS AND DATA HANDLING
- FLT CREW SIMULATION AND TRAINING
- MOCKUPS AND SIMULATORS
- PIP AND FLT DATA FILE(S)
- ORBITER TO P/L ICDs AND IRDs
- POWER
- PURGE AND/OR CONDITIONING
- HAZARDS/SAFETY AND MONITORING
- TEST OR FUNCTION VER/MONITORING
- EXPENDABLES
- MISSION AND FLIGHT INTEGRATION
- LOADS AND ENVIRONMENT
- ETC
IN-FLIGHT SERVICE TIMELINE
- PRIMARY
- WORK-AROUND

SSOCC FLIGHT SUPPORT
- MANNING REQUIREMENTS
- EQUIPMENT REQUIREMENTS

CREW SYSTEMS
- READINESS VERIFICATION
- TRAINING FACILITY SCHEDULE REQUIREMENTS

LOGISTICS SUPPORT
- REPAIR/REFURBISHMENT PLAN
- INSTALL/REMOVE TIMELINE

FACILITY USE REQUIREMENTS
- DOCUMENTATION
4. System Cost Estimate
Satellite Services System Cost Estimate

- OVERVIEW
- SERVICE SYSTEM MISSION MODEL
- SERVICE EQUIPMENT KIT DEFINITION
- AVERAGE MISSION RECURRING COSTS
- PRORATION OF FIXED COSTS
- TOTAL PROGRAM RESOURCE REQUIREMENTS
Satellite Services System Cost Estimate

- OVERVIEW
- SERVICE SYSTEM MISSION MODEL
- SERVICE EQUIPMENT KIT DEFINITION
- AVERAGE MISSION RECURRING COSTS
- PRORATION OF FIXED COSTS
- TOTAL PROGRAM RESOURCE REQUIREMENTS
mission model, the third shows the system user cost breakdown to the generic missions.

The second shows the distribution of the service mission types in the whole system hardware costs. This is the funding requirements for NASA to establish the needed equipment. The results are shown in this chart. The first pie figure indicates the proportion of the service event cost to the user was estimated by pro-rating the cost of the service equipment. The unit service event cost to the user was estimated by the number of such events predicted by the mission model in the time frame of 1983-1993.

The cost of procuring that equipment estimated using a parametric approach (the RCA "RAICE" Model).

The component of service equipment required to support the total mission model was defined and the cost of need of revisits, and the numbers of spacecraft designed for in-orbit service.

The total mission model was based on assumptions on the frequency of predicted anomalies, etc. The total system costs, averages were used in terms of equipment carried, time spent in orbit, etc. The seven generic missions were defined in the course of the SSIA Study Part II.
System Cost Overview

1983 - 1993

($1981)

PRORATED HARDWARE COST
($205M THROUGH 1987)

SERVICE EVENT POPULATION

TOTAL USER COST BREAKDOWN ($2.12B)
stage (e.g., TMS).

From their operational orbit to the orbiter by autonomous means or through the action of another
free flyers either because they utilize one of the STS standard orbits or are capable of returning
assumption was made that the STS orbiter could rendezvous with those satellites which are
The cost factors that were found to be intractable at this time are listed on the right. The
derived from the STS cost Reimbursement guide and experience factors for similar programs, etc., for each of the 65 identified equipments that make up the service kits. Other costs are
this chart, the RCA "PRICE" model includes the DOTIE, program management, test, integration
The elements that were included in and excluded from the system cost estimates are indicated in

SYSTEM LEVEL COST ELEMENTS
### System Level Cost Elements

#### INCLUDED IN COST ESTIMATE

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<td>Refurbishment</td>
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<tr>
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#### SIMULATION AND TRAINING

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#### INSUFFICIENT DEFINITION FOR INCLUSION

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<td>Communications for Flight Operations</td>
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<tr>
<td>Deliverable Software</td>
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<tr>
<td>Mission Data Processing and Reporting</td>
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<tr>
<td>Ground Support of Flight Operations</td>
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</tbody>
</table>
The central block indicates those cost elements involved which are over and above the hardware.

By a centralized organization, the right-hand block indicates the accumulation of costs if all service functions are provided.

Incorporation of independent function cost gives an indication of the costs that could be incurred by separate space programs utilizing their own service needs rather than centralizing the satellite service system were dedicated to performing one and only one service function. This function.

The costs were converted in two ways. Shown on the left is the cost to the user as if the quantities provided the time phased hardware costs for each service kit. The output provided the data that provided to the RCA price model together with the kit need dates and the needs of the seven generic mission functions. These kits are made up of 66 separate hard-

This figure represents a road map to the costing activity. The S3 kits were defined to provide

SYSTEM LEVEL COST METHODOLOGY
System Level Cost Methodology

**S^3 KIT DESCRIPTIONS**

- **USER MISSION MODEL**
  - NEED DATES AND QUANTITY
  - RCA "PRICE"
  - SERVICE MODULE COSTS
    - INDEPENDENT AVERAGE MISSION UNIT INTEGRATED COST
      - UNIT USER COSTS
        - DEPLOY
        - SORTIE
        - REPAIR
        - CHANGEOUT, REconfigure, RESupply
        - EARTH RETURN
        - DEORBIT
  - PROGRAM COST ESTIMATES
    - SIMULATION TRAINING
      - STS TRANSPORTATION
        - INSTALL/REMOVE
        - REFURBISH
        - LAUNCH
        - ON-ORBIT SUPPORT
        - PAYLOAD SPECIALIST
      - FACILITIES
  - INTEGRATED SYSTEM COST
    - PRORATED UNIT USER COST
      - TIME PHASED SYSTEM RESOURCE REQUIREMENTS
Satellite Services System Cost Estimate

- OVERVIEW
- SERVICE SYSTEM MISSION MODEL
- SERVICE EQUIPMENT KIT DEFINITION
- AVERAGE MISSION RECURRING COSTS
- PRORATION OF FIXED COSTS
- TOTAL PROGRAM RESOURCE REQUIREMENTS
The total events identified for the 1983 through 1993 time frame is 637.

Included on the right hand border to indicate the cumulative nature of the chart, the sum total of all constituents, the individual service event quantities for the year 1993 are presented on the following two charts. This is an aggregate chart with the top line indicating composite graph shows the mission model that was generated using the data and assumptions.
The model represents an estimate of the total space missions in the STS era and is not yet expected in the era where mission planning is not well defined.

1. The year of operation was slipped to accommodate the STS delay.
2. The current flight manifests were over-plotted to update the original data.
3. A growth rate beyond the limits of the current flight manifests was used to reflect current planning.

Modified in the following ways:

The mission model was based on the NASA STS Mission Model (Referencing A in the figure). It was

SERVICE OPPORTUNITY MISSION MODEL DEVELOPMENT
Service Opportunity Mission Model
Development

![Graphs showing projected payload deployments and STS free flyer missions](image-url)
The assumptions made here—in are judgmental in nature and equally valid assumptions could result in significant shifts in the service mission model.

The statement of approximately one event per year through 1992, requirement of anywhere near the low altitude assumption (excepted to be 10% of the low altitude population, leads to an extrapolation of the error frequency of decreasing satellites is more significant, but the德尔福 function is not likely to be important in the time frame of interest for collision.

The Earth return assumption is that 40% of the STS launched and accessible free flyers are designd for any or all of significant importance to require retrieval and return to earth in the order.

The Earth return assumption is that 10% of the STS launched and accessible free flyers are designd for any or all of significant importance to require retrieval and return to earth in the order.

For the deployment and sortie missions, it is assumed that single opportunity nature of these generic missions defined in the shuttle model.

To define the opportunities for satellite services, a number of assumptions were made for each service event and acquisition model rationale.
Service Event and Kit Assignment
Model Rationale

| DEPLOYMENT | • NASA STS MISSION MODEL MODIFIED BY CURRENT FLIGHT MANIFESTS AND DoD MISSION MODELS; PROJECTED AT 15 PERCENT YEARLY GROWTH RATE
|            |   - EACH FLIGHT CONSTITUTES A SERVICE OPPORTUNITY NECESSITATING INCORPORATION OF SERVICE KIT |
| SORTIE     | • FIVE PERCENT OF INITIAL DEPLOYMENT PAYLOADS PLUS
|            | • TEN PERCENT OF ACCESSIBLE FREE FLYERS IN SERVICE FOR THREE OR MORE YEARS (PRE-STS LAUNCHES EXCLUDED)
|            |   - SERVICE KITS ONLY CARRIED FOR SCHEDULED REPAIR TASKS |
| REPAIR     | • THIRTY PERCENT OF ACCESSIBLE FREE FLYERS IN SERVICE FOR THREE YEARS WITHOUT CR&R SERVICE
|            | • SERVICE INTERVAL = 3 YEARS
|            |   - SERVICE KIT SELECTED FOR SPECIFIC MISSION REQUIREMENTS |
| CHANGEOUT  | • FOUR PERCENT OF ALL FREE FLYERS LAUNCHED BY STS
| RECONFIGURE| • INTERVAL BETWEEN REPLACEMENT AND RETURN = 2 YEARS
| RESUPPLY   |   - SERVICE KIT IS TAILORED TO SATELLITE REQUIREMENTS |
| EARTH      | • ONE PERCENT OF ALL FREE FLYERS LAUNCHED BY STS PLUS
| RETURN     | • ONE PERCENT OF PRE-EXISTING FREE FLYERS BELOW 600 KM
| DEORBIT    |   - SPECIFIC SERVICE KIT CARRIED TO MATCH MISSION PARAMETERS |
Satellite Services System Cost Estimate

- OVERVIEW
- SERVICE SYSTEM MISSION MODEL
- SERVICE EQUIPMENT KIT DEFINITION
- AVERAGE MISSION RECURRING COSTS
- PRORATION OF FIXED COSTS
- TOTAL PROGRAM RESOURCE REQUIREMENTS
of the class.

Kits, but for the purposes of cost estimating an average kit was defined and used for each member

more of the modules. Particular mission requirements will dictate a variation of the generic

generic service missions were identified as having an associated service kit made up of one or

which can be thought of as the logistics building blocks for the service missions. The six

orbiter, and 1983-93 time frame. These hardware items were grouped into 16 functional modules

ware items needed to meet the user requirements under the ground rules governing the study (near

examination of the service functions and mission scenarios led to the identification of 66 hard-

SERVICE KIT DEFINITION DEVELOPMENT
Service Kit Definition Development

66 IDENTIFIED SERVICE EQUIPMENTS
EXISTING, MODIFIED, OR NEW

18 FUNCTIONALLY RELATED
SERVICE EQUIPMENT MODULES

SIX SERVICE KITS
ONE EACH FOR SIX GENERIC MISSIONS

- DEPLOYMENT
- SORTIE
- REPAIR
- CHANGEOUT, RECONFIGURE, RESUPPLY
- EARTH RETURN
- DEORBIT
are planned for manifesting on each STS flight.

Modules A and B constitute those equipments which are needed for single "unplanned" services and

data generated to support the cost estimation.

the system costs. Module B is representative of the remainder of the modules and indicates the

intert and the cost of the equipment itself and its transportation into orbit are not included in

useful to all service missions. Since it is standard equipment, its mass and volume are not per-

the cost estimation. As indicated, the module A is a grouping of STS standard hardware that is

generated for all the equipment with the important parameters identified that were important to

This example shows the definitions of modules "A" and "B" (right hand column). These sheets were

This chart indicates how the 16 modules were identified as groups of the 6 service equipments.

SERVICE MODULE DEFINITION SHEET
<table>
<thead>
<tr>
<th>EQUIPMENT</th>
<th>QTY</th>
<th>UNIT MASS/WT (KG/LB)</th>
<th>INSTALLED OR STOWED LOCATION</th>
<th>SIZE mm/IN.</th>
<th>MODULE ID.</th>
</tr>
</thead>
<tbody>
<tr>
<td>TETHERS* (2 FOR P/L)</td>
<td>2</td>
<td>N/A</td>
<td>MIDDECK-AIRLOCK</td>
<td>N/A</td>
<td>A</td>
</tr>
<tr>
<td>EMU*</td>
<td>2</td>
<td>N/A</td>
<td>AIRLOCK</td>
<td>N/A</td>
<td>A</td>
</tr>
<tr>
<td>HELMET LIGHTS/BAT.*</td>
<td>4</td>
<td>N/A</td>
<td>AIRLOCK</td>
<td>N/A</td>
<td>A</td>
</tr>
<tr>
<td>TOOL CADDY*</td>
<td>2</td>
<td>N/A</td>
<td>MIDDECK-AIRLOCK</td>
<td>N/A</td>
<td>A</td>
</tr>
<tr>
<td>PORTABLE LIGHT*</td>
<td>2</td>
<td>N/A</td>
<td>MIDDECK-AIRLOCK</td>
<td>N/A</td>
<td>A</td>
</tr>
<tr>
<td>RATCHET WRENCH</td>
<td>2</td>
<td>0.75 (1.5)</td>
<td>CARGO BAY</td>
<td>300 x 200 x 60 (12 x 8 x 2 1/2)</td>
<td>B</td>
</tr>
<tr>
<td>POWER TOOL/BAT.</td>
<td>1</td>
<td>6.7 (13.5)</td>
<td>CARGO BAY</td>
<td>280 x 300 x 150 (11 x 12 x 6)</td>
<td>B</td>
</tr>
<tr>
<td>CUTTERS</td>
<td>1</td>
<td>0.5 (1)</td>
<td>CARGO BAY</td>
<td>180 x 25 x 75 (7 x 1 x 3)</td>
<td>B</td>
</tr>
<tr>
<td>FOOT RESTRAINT</td>
<td>2</td>
<td>8.9 (18)</td>
<td>CARGO BAY</td>
<td>3100 x 860 x 330 (22 x 10 x 9)</td>
<td>B</td>
</tr>
<tr>
<td>TOOL STOW PALLET</td>
<td>1</td>
<td>5.4 (11)</td>
<td>CARGO BAY</td>
<td>1070 x 610 x 75 (42 x 24 x 3)</td>
<td>B</td>
</tr>
<tr>
<td>SHIP CORNER/EDGE KIT</td>
<td>1</td>
<td>3.7 (7.5)</td>
<td>CARGO BAY</td>
<td>300 x 300 x 250 (12 x 12 x 10)</td>
<td>B</td>
</tr>
<tr>
<td>SAFEING KIT/TOOLS</td>
<td>1</td>
<td>1.7 (3.5)</td>
<td>CARGO BAY</td>
<td>200 x 300 x 250 (8 x 12 x 10)</td>
<td>B</td>
</tr>
</tbody>
</table>
a generalization, this chart indicates the recommended service hardware.

It is recognized that specific missions may not require the full complement of modules, but as

entity for manifesting as it is only used in conjunction with one of the other service kits.

satellite to be serviced is spin stabilized. However, the spin service kit is not a separate

A seventh mission functional kit was identified as spin service which is required when the

The right side shows the applicability of the module to the six general mission service kits.

To identify the purpose.

The 18 modules are listed in the first column of this chart. A descriptive title is given

SERVICE KIT SYNTHESIS FROM SERVICE MODULES
Service Kit Synthesis
From Service Modules

<table>
<thead>
<tr>
<th>MODULE DESIGNATOR</th>
<th>MODULE TITLE</th>
<th>DEPLOY</th>
<th>SORTIE</th>
<th>REPAIR</th>
<th>CHANGEOUT RECONFIGURE RESUPPLY</th>
<th>EARTH RETURN</th>
<th>DEORBIT</th>
<th>SPIN SERVICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>STD ORBITER PROVIDED CREW AIDS</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
</tr>
<tr>
<td>B</td>
<td>UNSCHEDULED SERVICING CREW AIDS</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
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</tr>
<tr>
<td>C</td>
<td>DESPIN DEVICE</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
</tr>
<tr>
<td>D</td>
<td>MOUNTING PALLET AND DESPIN ATTACH ELEMENTS</td>
<td>☑️</td>
<td>☑️</td>
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<td>☑️</td>
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<td>☑️</td>
</tr>
<tr>
<td>E</td>
<td>COMMAND/COMMUNICATION/SIGNAL UNIT</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
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<tr>
<td>F</td>
<td>DEORBIT DEVICE</td>
<td>☑️</td>
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<tr>
<td>G</td>
<td>SPARES AND DEBRIS CONTAINER</td>
<td>☑️</td>
<td>☑️</td>
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</tr>
<tr>
<td>H</td>
<td>MODULE TRANSFER MECH AND WORK STATION</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
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<tr>
<td>I</td>
<td>CLOTHESLINE AND SERVICE TRAY</td>
<td>☑️</td>
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<tr>
<td>J</td>
<td>MISCELLANEOUS SERVICING AIDS</td>
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<tr>
<td>K</td>
<td>FLUID TANKAGE AND TRANSFER DEVICES</td>
<td>☑️</td>
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<tr>
<td>L</td>
<td>SERVICE AID STOWAGE PALLET</td>
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<tr>
<td>M</td>
<td>DEPLOYMENT MAINTENANCE PLATFORM</td>
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<tr>
<td>N</td>
<td>REPAIR SERVICING AIDS</td>
<td>☑️</td>
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<td>O</td>
<td>REPAIR KIT STOWAGE PALLET</td>
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<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
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<tr>
<td>P</td>
<td>RESPIN DEVICE</td>
<td>☑️</td>
<td>☑️</td>
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<td>☑️</td>
<td>☑️</td>
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</tr>
<tr>
<td>Q</td>
<td>DEBRIS HANDLING SERVICING AIDS AND PALLET</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
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<tr>
<td>R</td>
<td>MMU AND STATION</td>
<td>☑️</td>
<td>☑️</td>
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<td>☑️</td>
<td>☑️</td>
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</tr>
</tbody>
</table>
only expandable hardware identified.

Expandables are provided for each service event. The deployable motors and guidance stage is the

at each launch base: a total complement of 6 units.

would be dedicated to each of the orbiters and that a spare would be held in the supply depot

the next usable flight. At a demand rate of 20/year it was postulated that a module of each type

number it was assumed that a module could be off-loaded from one orbiter and made available to

one launch base until the service events using a given module grew to 10 per year. Below this

VAFB as well as KSC. It was assumed that a single module would serve all the traffic from

model. The second and subsequent need dates are based on the growth of traffic and the need at

need date corresponds to the first scheduled service event which is identified in the service

The quantity and first need dates are given for each of the service equipment modules. The first

SERVICE MODULE QUANTITY AND NEED DATES
### Service Module Quantity and Need Dates

<table>
<thead>
<tr>
<th>MODULE DESIGNATOR</th>
<th>MODULE TITLE</th>
<th>PRODUCTION QUANTITY&lt;sup&gt;(1)&lt;/sup&gt;</th>
<th>FIRST NEED DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>STD ORBITER PROVIDED CREW AIDS</td>
<td>6</td>
<td>83</td>
</tr>
<tr>
<td>B</td>
<td>UNSCHED SERVICING CREW AIDS</td>
<td>6</td>
<td>83</td>
</tr>
<tr>
<td>C</td>
<td>DESPIN DEVICE</td>
<td>4</td>
<td>84</td>
</tr>
<tr>
<td>D</td>
<td>MOUNT. PALLET AND DESPIN ATTACH ELEMENTS</td>
<td>4</td>
<td>84</td>
</tr>
<tr>
<td>E</td>
<td>COMMAND/COMMUNICATION/SIGNAL UNIT</td>
<td>6</td>
<td>84</td>
</tr>
<tr>
<td>F</td>
<td>DEORBIT DEVICE</td>
<td>8*</td>
<td>85</td>
</tr>
<tr>
<td>G</td>
<td>SPARES AND DEBRIS CONTAINER</td>
<td>6</td>
<td>83</td>
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<tr>
<td>H</td>
<td>MODULE TRANSFER MECH AND WORK STATION</td>
<td>6</td>
<td>83</td>
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<tr>
<td>I</td>
<td>CLOTHESLINE AND SERVICE TRAY</td>
<td>6</td>
<td>83</td>
</tr>
<tr>
<td>J</td>
<td>MISCELLANEOUS SERVICING AIDS</td>
<td>6</td>
<td>83</td>
</tr>
<tr>
<td>K</td>
<td>TANKAGE AND TRANSFER DEVICES</td>
<td>6</td>
<td>83</td>
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<tr>
<td>L</td>
<td>SERVICE AID STOWAGE PALLET</td>
<td>6</td>
<td>83</td>
</tr>
<tr>
<td>M</td>
<td>DEPLOYMENT MAINTENANCE PLATFORM</td>
<td>6</td>
<td>83</td>
</tr>
<tr>
<td>N</td>
<td>REPAIR SERVICING AIDS</td>
<td>6</td>
<td>83</td>
</tr>
<tr>
<td>O</td>
<td>REPAIR KIT STOWAGE PALLET</td>
<td>6</td>
<td>83</td>
</tr>
<tr>
<td>P</td>
<td>RESPIN DEVICE</td>
<td>6</td>
<td>84</td>
</tr>
<tr>
<td>Q</td>
<td>DEBRIS HANDLING SERVICING AIDS AND PALLET</td>
<td>4</td>
<td>84</td>
</tr>
<tr>
<td>R</td>
<td>MMU AND STATION</td>
<td>4</td>
<td>84</td>
</tr>
</tbody>
</table>

<sup>(1)</sup>MORE THAN 20 SERVICE EVENTS PER YEAR REQUIRES FULL COMPLEMENT OF KIT HARDWARE, I.E.,
1 PER ORBITER AND 1 SPARE EACH KSC AND VAFB = 6 TOTAL

*EXPENDABLE – ONE PER SERVICE EVENT
The installation/remote time spans were estimated from the complexity of the equipment involved.

Similarly, the cost of the payload specialist who might be needed on any one of the missions. Similarly, the several missions, it was identified as used on each of the Earth return and onboard.

There are expected to be relatively few uses of the MDR and rather than spread a small fraction. The EVA events are likely to be one or two depending on the complexity of the service event.

STS is planned and charged to sortie payloads.

Servicing on the sortie missions cannot extend the mission because the total endurance of the spacecraft is 25%. This rationale accounts for the non integral factors shown in the table. The need for these events were necessary, since the service model assumed a need at 5% of the deployments service event. The deployment kit has a mass of 25 kg and would require an added day on orbit if a service event occurred. This chart provides the details of the service kits defined for the average generic service.

AVERAGE SERVICE EVENT PARAMETERS
# Average Mission Service Event Parameters

<table>
<thead>
<tr>
<th>MISSION SERVICE FUNCTION</th>
<th>SERVICE KIT</th>
<th>ON-OBJECT SUPPORT</th>
<th>EVA EVENTS/MMU USES</th>
<th>PAYLOAD SPECIALIST</th>
<th>INSTALL/REMOVE TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MASS (kg)</td>
<td>WEIGHT (lb)</td>
<td>(DAY)</td>
<td># / #</td>
<td>MASS (kg)</td>
</tr>
<tr>
<td>DEPLOY</td>
<td>26 (57)</td>
<td>0.05</td>
<td>0.05/0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>SORTIE</td>
<td>1803 (3975)</td>
<td>0.0</td>
<td>1/0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>REPAIR</td>
<td>986 (2174)</td>
<td>2.5</td>
<td>1.5/0</td>
<td>120 (242)</td>
<td>6/3</td>
</tr>
<tr>
<td>CR AND R</td>
<td>2372 (5230)</td>
<td>3.0</td>
<td>1.5/0</td>
<td>120 (242)</td>
<td>11/5.5</td>
</tr>
<tr>
<td>EARTH RETURN</td>
<td>1960 (4320)</td>
<td>2.0</td>
<td>1/1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>DEORBIT</td>
<td>630 (1387)</td>
<td>2.0</td>
<td>1/1</td>
<td>0</td>
<td>5/2</td>
</tr>
<tr>
<td>DESPIN/RESPIN</td>
<td>216 (477)</td>
<td>N/A</td>
<td>N/A</td>
<td>0</td>
<td>2/1</td>
</tr>
</tbody>
</table>
also produces return to earth on that day, resulting in the reaction day also being charged to a complete work cycle and essentially requires an accrued day on orbit. The performance of an EVA time is that the time involved in preparing for executing, and post operations EVA occupies a service event on-the-average. The essential ground rule used in establishing the stay This chart presents the rationale for estimating the number of EVA operations required for.

MISSION ON-ORBIT SERVICE TIME CHARGEABLE TO SSUS USER
## Mission On-Orbit Service Time Chargeable to SSS User

<table>
<thead>
<tr>
<th>MISSION CLASS</th>
<th>NO. EVA OPERATIONS</th>
<th>ON-ORBIT TIME (DAYS)</th>
<th>GROUND RULES</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEPLOY (95%) (5%)</td>
<td>0</td>
<td>0</td>
<td>SERVICE FOR DEPLOYMENT ONLY MISSION CONSISTS OF SIMPLE FIXES OR EARTH RETURN OF 5% OF PAYLOADS EXPERIENCING INITIAL FAILURE</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>SORTIE</td>
<td>1</td>
<td>0</td>
<td>SORTIE MISSIONS MAKE FULL USE OF ORBITER ENDURANCE. SERVICE CANNOT EXTEND ORBIT TIME</td>
</tr>
<tr>
<td>REPAIR</td>
<td>1-2</td>
<td>2-3</td>
<td>MAXIMUM CASE REQUIRES SATELLITE ATTITUDE STABILIZATION AND BERTHING IN FIRST EVA; REPAIR, CHECKOUT, REDEPLOY IN SECOND</td>
</tr>
<tr>
<td>CHANGEOUT RECONFIGURE RESUPPLY</td>
<td>1-2</td>
<td>2-4</td>
<td>MAXIMUM CASE = SPACE TELESCOPE MAINTENANCE TIMELINE</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>MINIMUM CASE = MMS SERVICE FROM STABILIZED INITIAL CONDITION</td>
</tr>
<tr>
<td>DEORBIT</td>
<td>1</td>
<td>2</td>
<td>SINGLE EVA TO MATE DEBOOST STAGE, DEPLOY, BACK OFF, AND COMMAND</td>
</tr>
<tr>
<td>EARTH RETURN</td>
<td>1</td>
<td>2</td>
<td>STABILIZATION OF SPACECRAFT, BERTHING, STOW IN 1 EVA</td>
</tr>
</tbody>
</table>

*STAY TIME PRESUMES NO MISSION SHARING, I.E., RETURN DAY IS CHARGED TO SERVICE MISSION*
Satellite Services System Cost Estimate

- OVERVIEW
- SERVICE SYSTEM MISSION MODEL
- SERVICE EQUIPMENT KIT DEFINITION
- AVERAGE MISSION RECURRING COSTS
- PRORATION OF FIXED COSTS
- TOTAL PROGRAM RESOURCE REQUIREMENTS
The recurring costs given here are those costs incurred for the service operations and are over
and above the basic payload and mission operations cost.

and the more complex electro-mechanical.

Kit refurbishment charge is an experience number which varies between purely mechanical equipment

Initiation orbits.

charge is a weighted average of the charges/1b for launching a payload into low and high

The cost for all the recurring items are drawn from the STS cost reimbursement guide. The STS

On the basis of the foregoing charts, the recurring charges to the 5 user are given in this

RECURRING USER SERVICE COSTS △
# Recurring User Service Costs*

<table>
<thead>
<tr>
<th>AVERAGE MISSION</th>
<th>INSTALL AND REMOVE COST ($K)</th>
<th>ON-OBJECT SUPPORT COST ($K)</th>
<th>EVA COST ($K)</th>
<th>PAYLOAD SPECIALIST TRAINING ($K)</th>
<th>SPACE TRANSPORTATION AT $910/LB</th>
<th>3-KIT REFURB AT $10,0/LB MECH $14,6/LB ELECT</th>
<th>TOTAL RECURRING</th>
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<td>DEPLOY</td>
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<td>5</td>
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<td>84</td>
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<td>250</td>
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<td>60</td>
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<td>47</td>
<td>3974</td>
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<tr>
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<td>268</td>
<td>1339</td>
<td>161</td>
<td>134/220</td>
<td>2199</td>
<td>27</td>
<td>4348</td>
</tr>
<tr>
<td>CHANGEOUT RESUPPLY</td>
<td>491</td>
<td>1607</td>
<td>161</td>
<td>134/220</td>
<td>4980</td>
<td>62</td>
<td>7435</td>
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<td>1071</td>
<td>179</td>
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<td>3931</td>
<td>52</td>
<td>5738</td>
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<tr>
<td>DEORBIT</td>
<td>209</td>
<td>1071</td>
<td>179</td>
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<td>16</td>
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</table>

*OVER AND ABOVE PRIMARY MISSION COST
Satellite Services System Cost Estimate

- OVERVIEW
- SERVICE SYSTEM MISSION MODEL
- SERVICE EQUIPMENT KIT DEFINITION
- AVERAGE MISSION RECURRING COSTS
- PRORATION OF FIXED COSTS
- TOTAL PROGRAM RESOURCE REQUIREMENTS
The bottom of this chart shows the proportion of the hardware costs to the service kits. The proportion was performed on the basis of the number of service events given in the service specification. The first row which indicates a total system cost of $205M in 1981 dollars. This row and sum describes procurement of the total quantity of modules defined with the need dates as specified. The hardware costs were generated by applying the RCA "PRICE" model to the individual equipment.
# S3 System Hardware Cost Prorated by Mission Type (1 of 2)

## TOTAL SERVICE MODULE COST (1981 $M)

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
<th>K</th>
<th>L</th>
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<tr>
<td>N/A</td>
<td>1.4</td>
<td>18.9</td>
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<td>2.9</td>
<td>17.4</td>
<td>30.4</td>
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<td>0.2</td>
<td>8.5</td>
<td>1.0</td>
<td>4.9</td>
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## PRORATED SERVICE MODULE COST (1981 $K)

<table>
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<tr>
<th>NUMBER USES</th>
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<tr>
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<td>SORTIE</td>
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<td>226</td>
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<tr>
<td>REPAIR</td>
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<tr>
<td>EARTH RETURN</td>
<td>31</td>
<td>76</td>
<td></td>
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<td>304</td>
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<td>17,400</td>
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</tbody>
</table>

4-41
### S3 System Hardware Cost Prorated by Mission Type (2 of 2)

#### TOTAL SERVICE MODULE COST (1981 $M)

<table>
<thead>
<tr>
<th></th>
<th>M</th>
<th>N</th>
<th>O</th>
<th>P</th>
<th>Q</th>
<th>R</th>
<th>INTEC.</th>
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<tr>
<td>INTEGRATED SYSTEM</td>
<td>21.4</td>
<td>77.5</td>
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<td>7.8</td>
<td>8.4</td>
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<td>205.585</td>
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</table>

#### PRORATED SERVICE MODULE COST (1981 $K)

<table>
<thead>
<tr>
<th>Mission Type</th>
<th>ALLOCATED MISSION TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEPLOY</td>
<td>2</td>
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<tr>
<td></td>
<td>613</td>
</tr>
<tr>
<td>SORTIE</td>
<td>123</td>
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<tr>
<td></td>
<td>39397</td>
</tr>
<tr>
<td>REPAIR</td>
<td>106</td>
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<tr>
<td></td>
<td>33910</td>
</tr>
<tr>
<td>CHANGEOUT RESUPPLY</td>
<td>182</td>
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<tr>
<td></td>
<td>58430</td>
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<tr>
<td>EARTH RETURN</td>
<td>68</td>
</tr>
<tr>
<td></td>
<td>21798</td>
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<tr>
<td>DEORBIT</td>
<td>66</td>
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<td></td>
<td>21200</td>
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<tr>
<td>SPIN SERVICE</td>
<td>94</td>
</tr>
<tr>
<td></td>
<td>30120</td>
</tr>
</tbody>
</table>
The Cost Estimate Section.

The possibility that the Satellite Services Organization would support less than the total number of service events results in a higher user unit cost. This is discussed in charts at the end of the model.

The right hand column represents the average-fee user cost if the 3 supports all the missions recurring costs were added to the prototyped hardware, facilities, and training and simulation costs. The total cost to the individual user is estimated in this chart by the mission type.
<table>
<thead>
<tr>
<th></th>
<th>TOTAL EVENTS 1983-1993</th>
<th>RECURRING</th>
<th>HARDWARE</th>
<th>FACILITIES</th>
<th>TRAINING AND SIMULATION</th>
<th>TOTALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEPLOY</td>
<td>294</td>
<td>84</td>
<td>2.3</td>
<td>6</td>
<td>0</td>
<td>92</td>
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<tr>
<td>SORTIE</td>
<td>92</td>
<td>3974</td>
<td>427</td>
<td>6</td>
<td>25</td>
<td>4432</td>
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<td>REPAIR</td>
<td>95</td>
<td>4348</td>
<td>356</td>
<td>6</td>
<td>13</td>
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<td>CHANGEOUT RECONF</td>
<td>112</td>
<td>7435</td>
<td>520</td>
<td>6</td>
<td>27</td>
<td>7988</td>
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<tr>
<td>RECONFIGURE RESUPPLY</td>
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<tr>
<td>EARTH RETURN</td>
<td>31</td>
<td>5738</td>
<td>701</td>
<td>6</td>
<td>81</td>
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<td>SPIN SERVICE</td>
<td>50</td>
<td>528</td>
<td>602</td>
<td>0</td>
<td>5</td>
<td>1135</td>
</tr>
</tbody>
</table>
The costs to the user which are directly controllable by the Satellite Services Organization are a small fraction of the total.

Transportation cost has been broken out from the other recurring charges. The support (changeout, reconfiguration, re-supply) class of service mission. In this chart, the STS dominant factor in the user unit service cost. This chart shows the percentage breakdown. It is evident from the "recurring cost" estimate that the STS transportation cost is the pre-

UNIT SERVICE EVENT COST BREAKDOWN
Unit Service Event Cost Breakdown

Prorated System Cost

- Training and Simulation (13%)
- Other Recurring
  - Install/Remove
  - On-Orbit Support
  - EVA
  - Payload Specialist
  - Kit Refurbishment (31%)
- STS Transportation (62%)
- Hardware (6%)
- Facilities (0.1%)

Changeout, Reconfigure, Resupply
The dates shown here are the earliest times on this chart. The start date for development of the extended capability equipment, etc., the expenditures for these were not estimated but are also shown in dashed for the extended capability 3 more complex equipment is required e.g., ATV, TPS, Platform.

The year by year and cumulative funding is indicated.

This chart represents the funding required to procure the hardware to support the mission model.

S E Q U I P M E N T  C O S T
It is important to note that these expenditures are not NASA or DoD funding requirements but, service mission model.

The total expenditures for satellite services by the user community is presented here. It is

$\text{Total User Expenditures}$
S3 Total User Expenditures

POTENTIAL MARKET

$B (1981)

1.0

2.0

82 83 84 85 86 87 88 89 90 91 92 93

AVERAGE COST
PER USER $3.3M

CUMULATIVE

TIME PHASED

0.386 2.12
cost to perform the CKKR and the Earth Return missions but not the others.

The shaded area on the chart indicates the items that would be summed to arrive at the hardware

functions are performed rather than the individual.

Indicate the advantages that accrue to the user community if the total spectrum of service

This presentation and that on the following chart when compared to the earlier presentation charts

generic service function is performed exclusively of all other service functions.

Kits. The right hand column indicates the cost of the hardware under the condition that the

This chart indicates the cost of the service modules applicable to each of the generic service

3 HARDWARE COST SUMMARY
## S3 Hardware Cost Summary

**NASA**

(1981 $M)

<table>
<thead>
<tr>
<th>Service Module</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
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</thead>
<tbody>
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<tr>
<td>SORTIE</td>
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<td>30.4</td>
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<td>30.4</td>
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<td>1.4</td>
<td>2.2</td>
<td>2.9</td>
<td>17.4</td>
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<tr>
<td>SPIN SERVICE</td>
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<td>2.9</td>
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<td><strong>COMBINED MISSION</strong></td>
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4-55
## S3 Hardware Cost Summary (Contd)

(1981 $M)

<table>
<thead>
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<th>SERVICE MODULE</th>
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<th>K</th>
<th>L</th>
<th>M</th>
<th>N</th>
<th>O</th>
<th>P</th>
<th>Q</th>
<th>R</th>
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<td>7.8</td>
<td>31.9</td>
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</tr>
</tbody>
</table>

| INDIVIDUAL KIT TOTAL    | 155.6                  |

PAGE 4-56

INSTRUCTION PLANT

4-57
This chart when compared to the previous unit service event cost chart based on proportion of the fixed costs provides an insight into the savings accruing to the user community if the 3 consolidated services are integrated all service functions. Since the recurring transportation costs are predominant, the overall savings on the unit user costs amount to approximately 10% for the integrated system.

The total user cost for each of the generic mission classes is shown here for the case where...
## Unit Service Event Cost

### S\(^3\) Performs Single Functional Mission

<table>
<thead>
<tr>
<th></th>
<th>Total Events 1983-1993</th>
<th>Recurring</th>
<th>Prorated by Service Events</th>
<th>Training and Simulation at 5% Hardware</th>
<th>Unit Mission Total</th>
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<tbody>
<tr>
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5. Conclusions

- HARDWARE
- PROGRAM PLANS
- OPERATIONS PLANS
- COST ANALYSIS
- OVERALL STUDY
Hardware Conclusions

- MANY EARLY-PHASE SERVICE MISSIONS CAN BE ACCOMPLISHED WITH SIMPLE EVA TOOLS
- FUTURE MISSIONS REQUIRE MORE COMPLEX HARDWARE
- IMMEDIATE FUTURE PRELIMINARY DESIGN CANDIDATES ARE:
  - CARGO CONTAINMENT SYSTEM TO TRANSPORT ORUs AND TOOLS INTO ORBIT; ORUs, TOOLS, DEBRIS, AND RETURNING SATELLITES TO EARTH
  - FLUID TRANSFER SYSTEM TO PERMIT RESUPPLY OF PROPELLANTS, REACTANTS, AND LIFE SUPPORT
  - ΔV SYSTEM TO PERMIT ACCESS TO HIGHER ALTITUDE AND OUT-OF-PHASE OR OUT-OF-PLANE SATELLITES
  - STANDARDIZED CHECKOUT SYSTEM FOR PERFORMING MINIMUM SATELLITE STATUS TESTING FROM ORBITER
Program Plan Conclusions

- LOCKHEED'S OUTLINE PROGRAM PLANS INDICATE NEED FOR CONTINUED PLANNING AT THE SYSTEM MANAGEMENT LEVEL:
  - CONTINUE DEVELOPMENT OF SATELLITE SERVICE TEAM
- IDENTIFIED NEAR-TERM IMPLEMENTATION ACTIONS
  - SURVEY CURRENT USER AGENCY NEEDS AND DESIRES
  - DETAIL PROGRAM PLAN FOR CONSOLIDATED AND INTEGRATED S³
  - OBTAIN COOPERATION AND WORKING AGREEMENTS WITH USER AGENCIES
    - NASA CENTERS
    - DoD
    - COMMERCIAL
    - INTERNATIONAL
LONGER-RANGE PLANNING

- DEFINE FUNCTIONS AND RESPONSIBILITIES FOR:
  - SATELLITE SERVICES OPERATIONS CONTROL CENTER (SSOCC)
  - INTERFACE WORKING GROUPS
  - S³ LOGISTICS ORGANIZATION
  - S³ CREW SYSTEMS INTERFACE ORGANIZATION
  - SUPPLY/REPAIR/REFURBISHMENT DEPOTS
Operations Plan Conclusions

- Ground and space operations elements have been identified.
- Satellite services organization responsibility for each identified element is yet to be defined.
- Interfaces between $S^3$ operations and other operations organizations have not been defined.
- Detailed development, ground and flight operations plans depend on answers to the foregoing definitions.
Cost Analysis Conclusions

- EARLY TIME FRAME RESOURCE COMMITMENTS ARE MODERATE
  '82 $15 M
  '83 $47 M
  '84 $74 M
  TOTAL THROUGH 1987 = $205.5 M
- LATE TIME FRAME REQUIRES MORE SUBSTANTIAL OUTLAYS FOR LARGE SPACE STRUCTURES AND REMOTE SATELLITE SERVICE
Cost Analysis Conclusions (Contd)

- USER CHARGE FOR HARDWARE IS 2 TO 3 TIMES HIGHER FOR SINGLE GENERIC MISSION APPROACH THAN FOR INTEGRATED TOTAL SYSTEM APPROACH
  - TOTAL USER SERVICE EVENT COST IS 10% TO 12% HIGHER WHEN STS CHARGES ARE INCLUDED

- PROVIDING FOR DEPLOYMENT SERVICE IS MOST COST EFFECTIVE
  - 0.3% OF EQUIPMENT COST
  - 1.3% OF USER COST
  - 41% OF SERVICE EVENTS
Cost Analysis Conclusions (Contd)

- DEORBIT IS LIKELY LEAST COST EFFECTIVE
  - 10% OF EQUIPMENT COST
  - 2% OF TOTAL USER COST
  - 1% OF SERVICE EVENTS

- THE MOST USEFUL "CHANGEOUT, RECONFIGURE RESUPPLY" CLASS ACCOUNTS FOR
  - 28% OF THE EQUIPMENT COST
  - 45% OF TOTAL USER COST
  - 18% OF SERVICE EVENTS
Principal Conclusions

• THE VERSATILITY OF MAN-IN-SPACE CAN BEST BE AUGMENTED BY PROVIDING THE ASTRONAUTS WITH SIMPLE TOOLS AND AIDS THAT FACILITATE A WIDE VARIETY OF SERVICE FUNCTIONS TO BE PERFORMED BY EVA

— THIS APPROACH LENDS ITSELF TO EARLY IMPLEMENTATION AT MINIMUM COST

— MUCH OF THE EQUIPMENT NEEDED FOR IMMEDIATE FUTURE SERVICING EXISTS TODAY
Principal Conclusions (Contd)

• MODULAR SERVICE EQUIPMENT DESIGNED FOR MULTI-MISSION APPLICATION CAN ACCOMPLISH ALL IDENTIFIED NEAR-ORBITER SERVICE FUNCTIONS
  — THIS BASELINE EQUIPMENT COMPLEMENT FORMS THE BASIS FOR EXTENDED HEO/GE0 SERVICING

• SERVICE EXTENSION TO HEO/GE0 REQUIRES OTV DEVELOPMENT

• EARLY IMPLEMENTATION CAN BE ACCOMPLISHED AT MODERATE FUNDING LEVELS FOR SERVICE EQUIPMENT
  — ORGANIZATION OF INTERFACE WORKING GROUPS
    1982  $15 M
    1983  $47 M
    1984  $74 M

    TOTAL THROUGH 1987 = $205 M
• TASK 1: MISSION REQUIREMENTS AND ECONOMIC ANALYSIS
  – CONDUCT AN ANALYSIS TO ESTABLISH THE BENEFITS TO THE USERS OF ON-ORBIT SERVICING

• TASK 2: CARGO CONTAINMENT SYSTEM DEFINITION
  – PERFORM A PRELIMINARY DESIGN AND PRODUCE A TOP LEVEL SPECIFICATION FOR THE CONTAINMENT OF SPACE OBJECTS THAT WERE NOT DESIGNED FOR EARTH RETURN IN THE ORBITER
Part III Study Logic Flow

TASK I MISSION REQUIREMENTS AND ECONOMIC ANALYSIS

SAT hoe SERVICE SYSTEM STUDIES PART I AND II NAS 9 - 16120 NAS 9 - 16121

DRM SYST REQ 1.2
DRM SCENARIOS 1.4
SELECT DRM SATELLITES AND COMPOSITE MISSION 1.3
DRM EQUIPMENT REQ 1.5
DRM MISSION COST 1.5A
ECONOMIC BENEFIT ANALYSIS 1.5D

VISIT JSC
MID-TERM BRIEFING JSC MA-745T
VISIT JSC
FINAL BRIEF REPORT JSC MA-745T
FINAL BRH 15

STUDY PLAN PART III MA - 742T

CCS REQ 2.2
CCS CONCEPTS 2.1
CCS PRELIM DESIGN 2.4
CCS SPEC 2.3
CCS COST AND SCHED 2.5

TASK II CARGO CONTAINMENT SYSTEM DEFINITION

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