CR-184037

Geostationary Platform Study

ADVANCED ESGP / EVOLUTIONARY SSF ACCOMMODATION STUDY

Contract Extension
- Mod 16 -

FINAL REPORT
DR - 12

Contract NAS8 - 36103

AUGUST 1990

NASA Marshall Space Flight Center

Lockheed Missiles & Space Company, Inc.
ASTRONAUTICS DIVISION

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NASA SPACE FLIGHT

CONTENTS

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ACRONYMS

ACRONYM	MEANING	ACRONYM	MEANING
ASPS	Attachment, Stabilization, and Positioning Subsystem	MSFC	Marshall Space Flight Center
ASRM	Advanced Solid Rocket Motor	MSI	Microwave Sounder/Imager
AWP	Assembly Work Platform	MSS	Mobile Servicing System
BOL	Beginning of Life	MT	Mobile Transporter
CCZ	Command and Control Zone	NASA	National Aeronautics and Space Administration
CIEM	Computer Integrated Engineering and Manufacturing	OMS	Operations Management System
CLAES	Cryogenic Limb Array Etalon Spectrometer	OMV	Orbital Maneuvering Vehicle
DDCU	DC to DC Converter Unit	ORU	On-Orbit Replaceable Unit
EPS	Electrical Power Subsystem	OTV	Orbital Transfer Vehicle
ESGP	Earth Science Geostationary Platform	PDGF	Power and Data Grapple Fixture
EVA	Extra-Vehicular Activity	PTF	Propellant Tank Farm
FOD	Space Station Freedom Operations Database	RD	Research/Development Growth Emphasis for SSF
fps	Feet per Second	RF	Radio Frequency
FTS	Flight Telerobotic Servicer	RPCM	Remote Power Controller Modules
GEPS	Geostationary Earth Processes Spectrometer	SI	Science Instrument
GHz	Gigahertz	SMOD	Science Mission Operations Database
GN&C	Guidance, Navigation and Control	SODAS	Space Operations Database and Analysis System
HEI	Human Exploration Initiative	SOW	Statement of Work
HEPI	High-Resolution Earth Processes Imager	SPDA	Secondary Power Distribution Assembly
IDEAS2	Integrated Design, Engineering and Analysis Software System	SSAT	Space Station Assembly Technology
IVA	Intra-Vehicular Activity	SSF	Space Station Freedom
Kw	Kilowatt	SSRMS	Space Station Remote Manipulator System
LARC	Langley Research Center	STV	Space Transfer Vehicle
Lb	Pound	TBD	To Be Determined
LEE	Latching End Effector	TLI	Trans-Lunar Injection
LFMR	Low Frequency Microwave Radiometer	TN	Transportation Node Emphasis for SSF
LMSC	Lockheed Missiles and Space Company	TPDA	Tertiary Power Distribution Assembly
LTV	Lunar Transfer Vehicle	UARS	Upper Atmosphere Research Satellite
MPAC	Multi-Purpose Applications Console	VPOD	Vehicle Processing Operations Database
MRS	Mobile Remote Servicer	WAM	Worksite Attachment Mechanism
MSC	Mobile Servicing Centre		

INTRODUCTION

ESGP/SSF ACCOMMODATION STUDY BACKGROUND

The object, approach and output products for the ESGP/SSF accommodation study were based on the NASA/HQ RTOP associated with the study effort and were a major input to the study plan document.

An accommodation assessment on the evolution SSF involves a study of how space and resources are controlled and allocated. Allocation of finite resources will be a major long-term problem for SSF, requiring careful configuration and resource management.

Utilization of a system engineering process is required which allows developing database evolution scenarios to assist in controlling the SSF evolution process.

Standard methods of finite resource allocation tracking involve various operational databases that will be used as control tools to help manage resources (such as power, assembly area and volume, EVA and IVA time and robotic manipulators) critical to the evolutionary SSF.

The output of the ESGP/SSF accommodation study task is the eventual input to user accommodation handbooks, user procedures, and organizational planning and interface definition documentation.

ESGP / SSF ACCOMMODATION STUDY BACKGROUND

OBJECTIVE:

TO ASSESS THE IMPLICATIONS ON THE EVOLUTIONARY SS OF ACCOMMODATING GEO FACILITIES SUCH AS UNMANNED SATELLITES AND PLATFORMS, MANNED ELEMENTS, AND TRANSPORTATION AND SERVICING VEHICLES/ELEMENTS.

APPROACH:

UTILIZE LATEST EXISTING DEFINITIONS OF TYPICAL UNMANNED GEO FACILITIES AND TRANSPORTATION AND SERVICING VEHICLES/ELEMENTS. DETERMINE THE PHYSICAL AND FUNCTIONAL DESIGN IMPLICATIONS AND THE OPERATIONS IMPLICATIONS AT THE SS. UTILIZE VARIOUS CONCEPTS OF THE SS FROM PAST STUDIES RANGING FROM THE IOC MULTIFUNCTION SS TO A "BRANCHED" TRANSPORTATION NODE SS, AND ASSESS THE IMPLICATIONS OF ACCOMMODATING THE GEO INFRASTRUCTURE AT EACH TYPE.

PROVIDE PARAMETRIC DATA WHERE POSSIBLE TO SHOW THE IMPLICATIONS OF VARIATIONS IN SIZES AND QUANTITIES OF ELEMENTS, LAUNCH RATES, CREW SIZES, ETC. IDENTIFY AND ASSESS THE USE OF ADVANCED AUTOMATION AND ROBOTICS EQUIPMENT AND AN EFFICIENT MIX OF MANNED/AUTOMATED SUPPORT FOR ACCOMPLISHING NECESSARY ACTIVITIES AT THE SS.

PRODUCTS:

CONFIGURATION SKETCHES, RESOURCE REQUIREMENTS, TRADE STUDIES, PARAMETRIC DATA.

STUDY LOGIC FLOW DIAGRAM

The study objectives were converted to three specific tasks. The relationships of these tasks and the iterative process used during the study are illustrated on the facing diagram. Individual tasks subelements are clearly identified. Also shown is the main study product: the Final Report (DR-12).

Task 1. Configuration Definition

The objective of this task is to determine the physical, functional design and operations implications for accommodation of the Advanced Earth Science Geostationary Platform (ESGP) at Space Station Freedom (SSF).

Task 2. SSF Resource and Functional Requirements

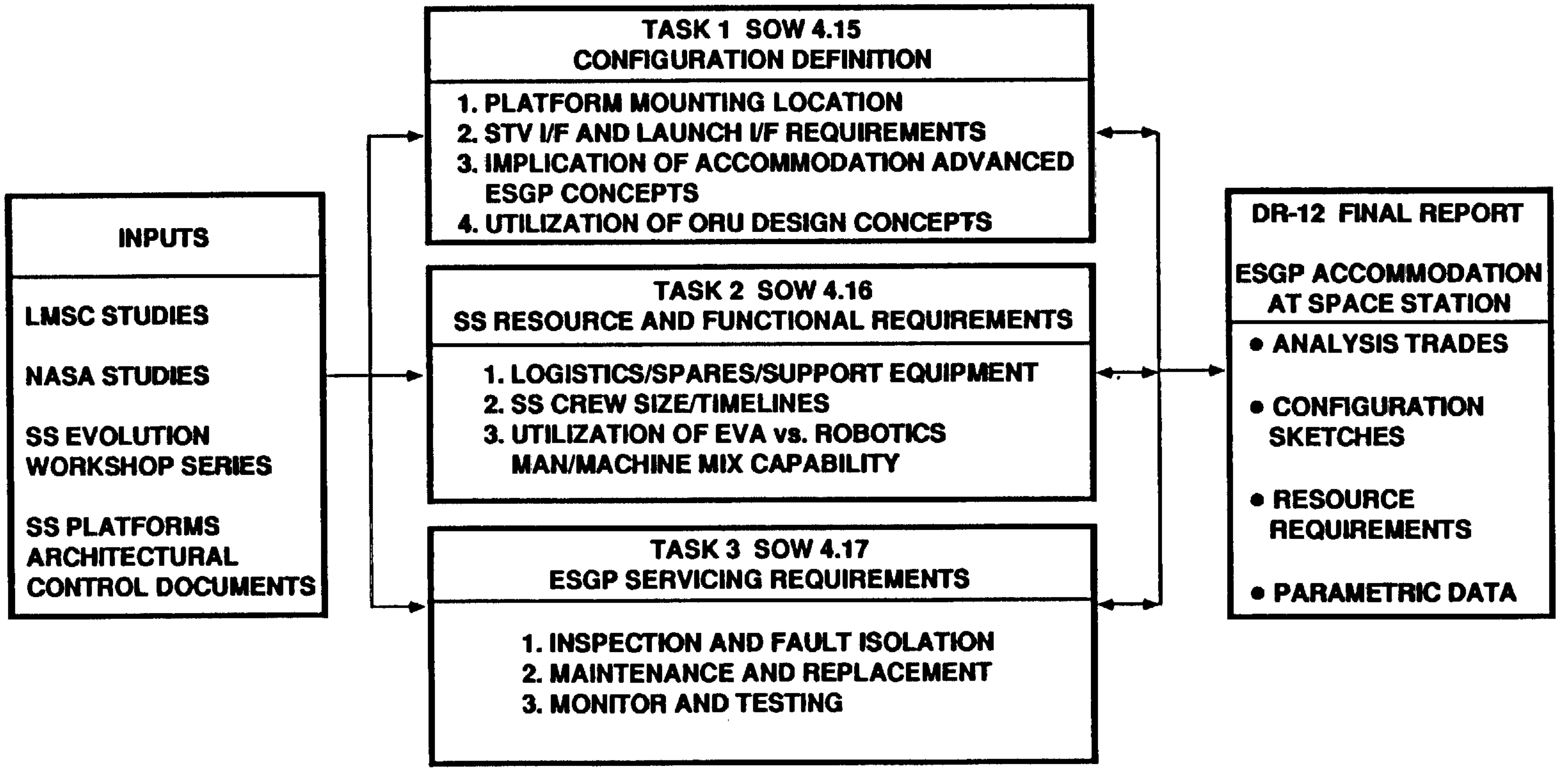
The objective of this task is to identify resource requirements at the SSF for advanced ESGP delivery, assembly, checkout, and preparation for launch into a Geostationary orbit. Three major areas shall be investigated: logistics / spares / and support equipment, SSF crew size / timeline / schedule requirements, and the utilization of EVA versus robotics and man / machine mix capabilities.

Task 3. ESGP Servicing Requirements

The objective of this task is to identify the preliminary requirements for ESGP servicing at the SSF.

All analysis trades, configuration sketches, resource requirements and parametric data developed as a result of these tasks will be documented and included in the Study Final Report (DR-12).

STUDY LOGIC FLOW DIAGRAM



INPUTS

- LMSC STUDIES
- NASA STUDIES
- SS EVOLUTION WORKSHOP SERIES
- SS PLATFORMS ARCHITECTURAL CONTROL DOCUMENTS

TASK 1 SOW 4.15
CONFIGURATION DEFINITION

1. PLATFORM MOUNTING LOCATION
2. STV I/F AND LAUNCH I/F REQUIREMENTS
3. IMPLICATION OF ACCOMMODATION ADVANCED ESGP CONCEPTS
4. UTILIZATION OF ORU DESIGN CONCEPTS

TASK 2 SOW 4.16
SS RESOURCE AND FUNCTIONAL REQUIREMENTS

1. LOGISTICS/SPARES/SUPPORT EQUIPMENT
2. SS CREW SIZE/TIMELINES
3. UTILIZATION OF EVA vs. ROBOTICS MAN/MACHINE MIX CAPABILITY

TASK 3 SOW 4.17
ESGP SERVICING REQUIREMENTS

1. INSPECTION AND FAULT ISOLATION
2. MAINTENANCE AND REPLACEMENT
3. MONITOR AND TESTING

DR-12 FINAL REPORT

ESGP ACCOMMODATION AT SPACE STATION

- ANALYSIS TRADES
- CONFIGURATION SKETCHES
- RESOURCE REQUIREMENTS
- PARAMETRIC DATA

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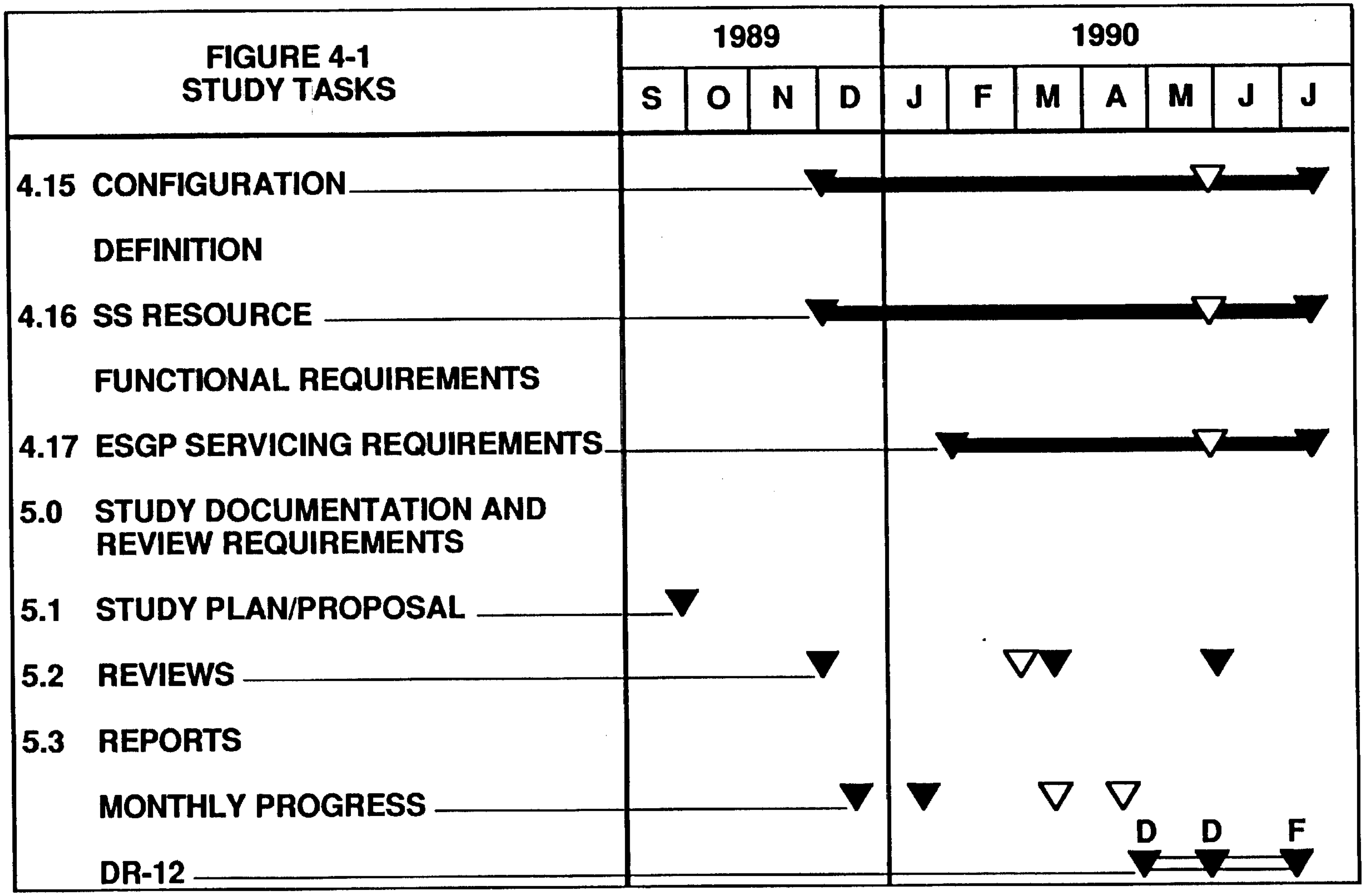
STUDY SCHEDULE

The schedule for the study is shown in the accompanying figure. The schedule shows the time phasing of the configuration definition, the SSF resource functional requirements and the ESGP servicing requirements tasks.

STUDY SCHEDULE



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STUDY REFERENCE DOCUMENTATION

The following two figures present a listing of the documentation used as reference material during the study. Reference documentation used in the material contained within this report is cited by a numerical designator corresponding to the reference documentation list contained in these two figures.

STUDY
REFERENCE DOCUMENTATION

(1) PROCEEDINGS OF THE SPACE STATION EVOLUTION SYMPOSIUM, SOUTH SHORE HARBOUR, LEAGUE CITY, TX FEB 6-8, 1990

(2) SSF ACCOMMODATION OF THE HEI, NASA/LARC OCT 1989

(3) EVOLUTIONARY SSF GEOMETRIC DATABASE SYSTEM ASSEMBLY, NASA/LARC FEB 1990

(4) SSF ROBOTIC SYSTEMS INTEGRATION STANDARDS, NASA/JSC OCT 1989 (ORU ENGINEERING DEVLOPMENT STUDY - OCEAN SYSTEMS ENGINEERING OCT 1989)

(5) GEOSTATIONARY PLATFORM BUS STUDY, LMSC DEC 10, 1986

(6) AUTOMATED SERVICING STUDY - AXAF DR-15, LMSC MAR 1987

(7) FLIGHT TELEROBOTIC SERVICER, LMSC PROPOSAL TO NASA/GSFC, JUL 1988

(8) SSP DEFINITION AND REQUIREMENTS DOCUMENT (SSP 30000, SEC 3)

(9) ARCHITECTURAL CONTROL DOCUMENT, THERMAL CONTROL SYSTEM (SSP 30258)

(10) ARCHITECTURAL CONTROL DOCUMENT, GUIDANCE, NAVIGATION AND CONTROL SYSTEM (SSP 30259)

(11) ARCHITECTURAL CONTROL DOCUMENT, COMMUNICATIONS AND TRACKING SYSTEM (SSP 30260)

(12) ARCHITECTURAL CONTROL DOCUMENT, DATA MANAGEMENT SYSTEM (SSP 30261)

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STUDY REFERENCE DOCUMENTATION (2)

(13) SS EXTERNAL CONTAMINATION CONTROL REQUIREMENTS (JSC 30426)

(14) ARCHITECTURAL CONTROL DOCUMENT, ELECTRICAL POWER SYSTEM (SSP 30263)

(15) SERVICING SCENARIO DATABASE SYSTEM SCENARIO ANALYSIS, COMPUTER TECHNOLOGY ASSOCIATES (CTA), NOV 1989

(16) OPERATIONS CONCEPT FOR THE ON-ORBIT ASSEMBLY, VERIFICATION, FUELING AND LAUNCH OF PLANETARY VEHICLES, CTA, JAN 1989

(17) SPACE OPERATIONS & ANALYSIS SYSTEM (SODAS) USER'S MANUAL, CTA, MAY 1990

(18) ADVANCED AUTOMATION FOR IN-SPACE VEHICLE PROCESSING, MSDSSC-KSC, LTV ASSEM, NOV 1989

(19) LUNAR MARS OUTPOST, IR#1, MARTIN MARIETTA, LTV DESIGN CONCEPT DEC 1989

(20) SERVICING SCENARIO DATABASE SYSTEM SCENARIO ANALYSIS, CTA, NOV 1989

(21) SS STAGE SUMMARY DATABOOK, SSFPO, DEC 1989

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SECTION 1

CONFIGURATION DEFINITION

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SSF EVOLUTION OPERATIONS OVERVIEW - EXAMPLE -

The figure depicts a possible evolution operations configuration overview. This figure is shown to emphasize that SSF evolution is not only concerned with the orbiting SSF but with all infrastructure with which SSF is associated, including Earth-based segments.

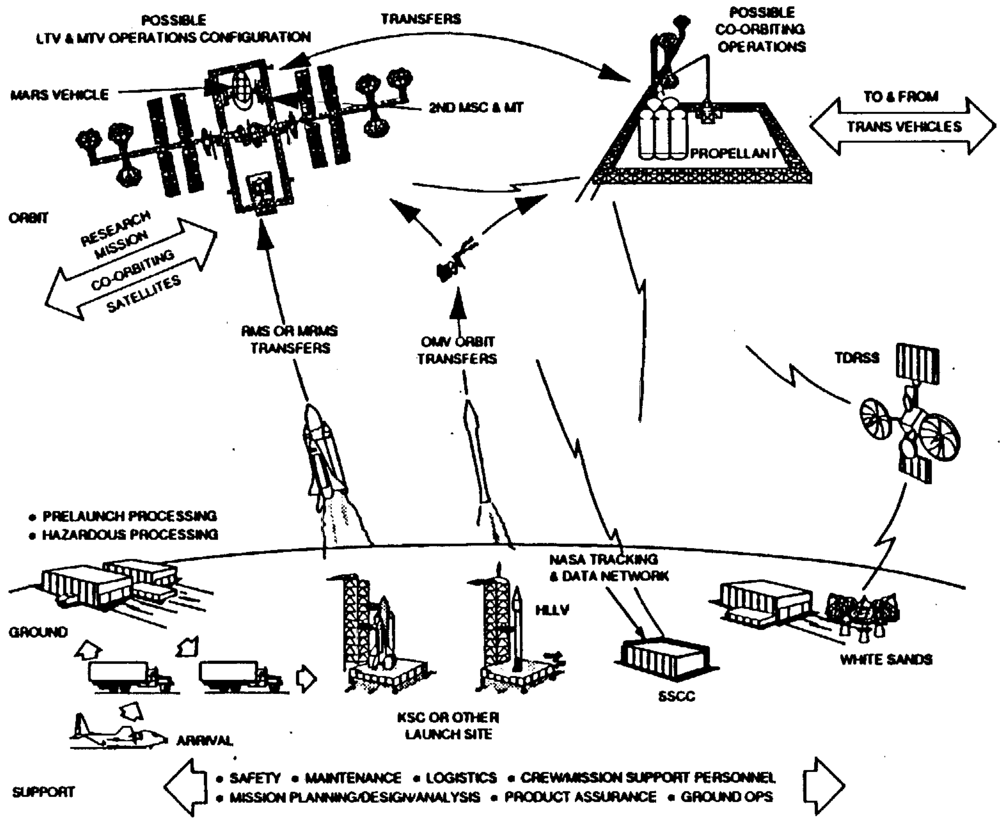
Gross requirements will be used to drive the operations analyses, functional analyses, trade studies and finally the initial utilization and operations architectures for SSF Evolution. Gross requirements that are expected to be crucial to initiating SSF evolution operations architecture are: (1) mass, size and function of euqipments and vehicles to be received and processed, (2) processing, servicing and maintenance needed to be performed, (3) infrastructure resources necessary to process items, and (4) operations necessary to be performed.

On-orbit operations studies will be guided by the following:

- Minimize/eliminate operations that can be performed on Earth
- Operations should be as automated as possible
- Avoid or minimize EVAs
- Simplify essential EVAs
- Avoid propellent transfers on SSF (safety)
  Alternate: use nearby co-orbiting platform
- Follow recommendations of the recent Utilization and Operations Task Force

Critical issues for on-orbit operation are: EVA; communications links; Shuttle and STV rendezvous; maintenance; timeline management; and control of logistics and other critical assets.

SSF EVOLUTION OPERATIONS OVERVIEW
- EXAMPLE -



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ADVANCED ESGP

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ADVANCED ESGP ORBITAL CONFIGURATION

A full three-dimensional view of the Advanced ESGP is shown in its deployed on-orbit configuration.

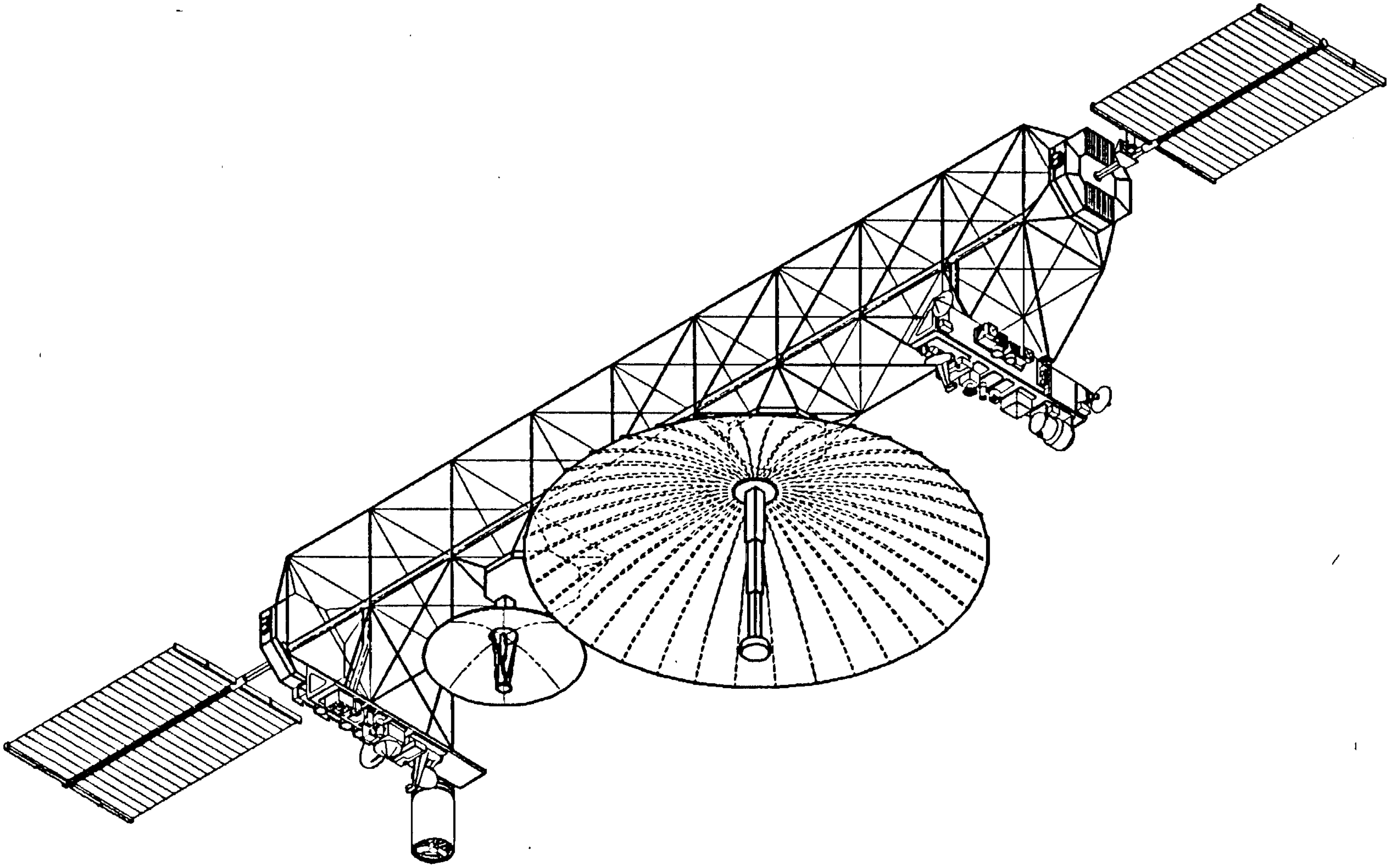
This configuration weighs 32116 lb and accommodates 19 instruments with a total collective weight of 10004 lb. Separate modules attached to both ends of the Platform are used for the scientific payloads and the bus subsystem equipment items.

Major subsystem design considerations are as follows:

- The use of graphite/aluminum struts provides a low coefficient of thermal expansion structural frame
- Propellant capacity is sized for a 10 year life
- The power subsystem is also sized for a 10 year life. Beginning of life (BOL) power provided by the solar arrays is 10 Kw.

ADVANCED ESGP ORBITAL CONFIGURATION

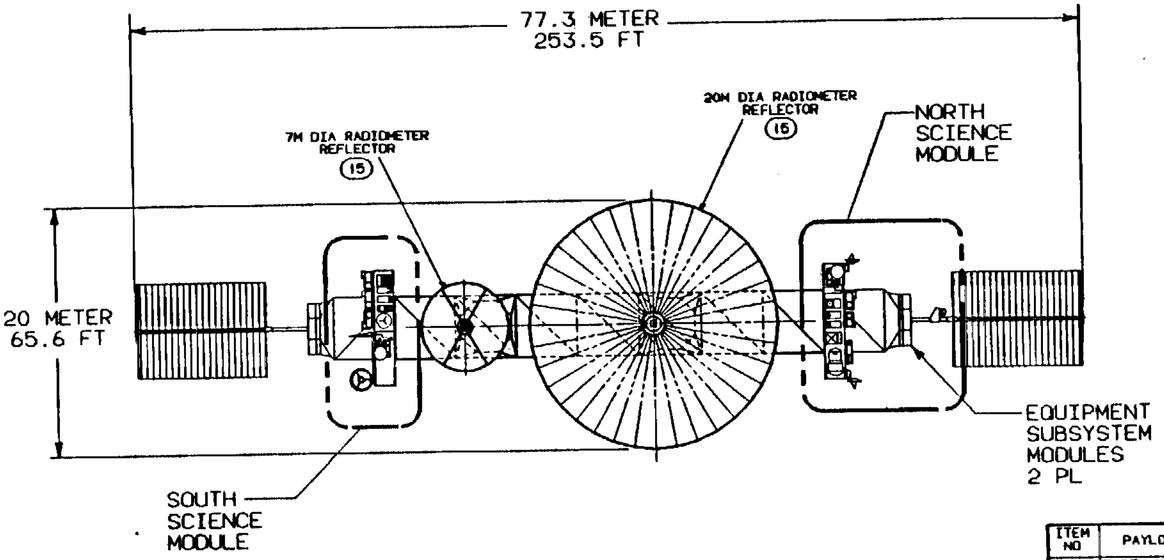
ORBITAL CONFIGURATION 3D VIEW

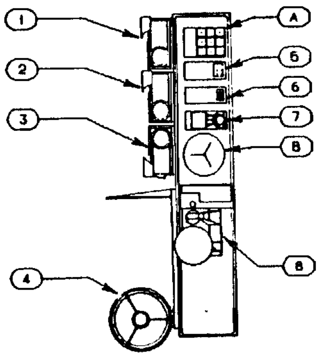


ADVANCED ESGP BUS AND PAYLOAD ARRANGEMENT

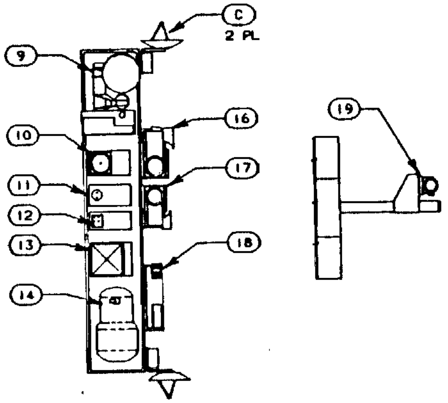
The plan view of the deployed configuration of the Advanced ESGP shows the platform dimensions and the location and size of the 7 and 20 meter radiometer antennas. The solar arrays and the north and south wing science instrument platforms are also illustrated and identified.

ADVANCED ESGP BUS AND PAYLOAD ARRANGEMENT





SOUTH MODULE



NORTH MODULE

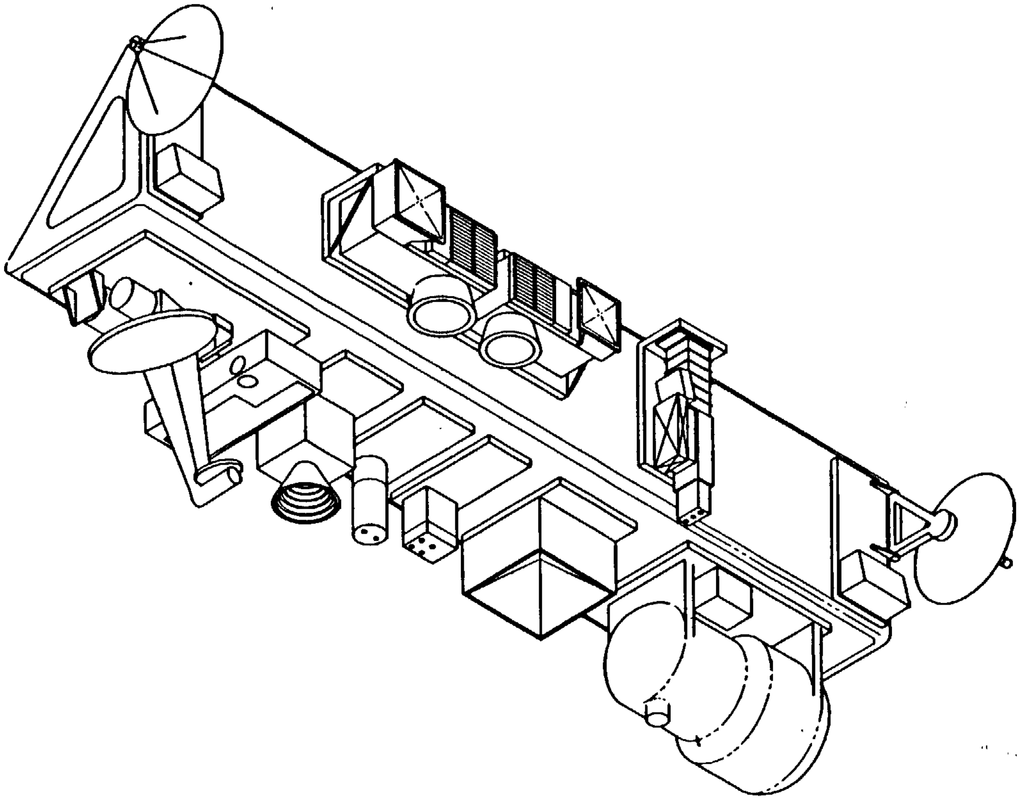
ITEM NO	PAYLOAD - STRAWMAN C-A
1	EARTH X-RAY IMAGER
2	1D/2D ARRAY IMAGING SPECTROMETER
3	GEO-MICROWAVE SOUNDING UNIT
4	ADVANCED HIGH-RESOLUTION IMAGER
5	ACTIVE CAVITY RADIOMETER
6	PARTICLE ENVIRONMENT MONITOR
7	HIGH-RESOLUTION DOPPLER IMAGER
8	MICROWAVE SOUNDER/IMAGER
9	MICROWAVE PRECIPTATION IMAGER
10	LIGHTNING MAPPER
11	SOLAR UV MONITOR
12	TOTAL OZONE MAPPER
13	GEODYNAMICS LASER RANGING SENSOR
14	CLAES
15	L/H FREQUENCY MICROWAVE ANTENNA
16	OPERATIONAL INFRARED SOUNDER
17	ADVANCED EARTH PROCESSES SPECTROMETER
18	SOLAR/STELLAR INTERCOMPARISON EXPERIMENT
19	SOLAR X-RAY IMAGER

A	ENVIRONMENTAL INSTRUMENTS
B	DOWN LINK
C	ISL

ADVANCED ESGP NORTH SCIENCE MODULE

The figure shows a 3-D view of the individual payloads and communication equipment mounted on the north science module.

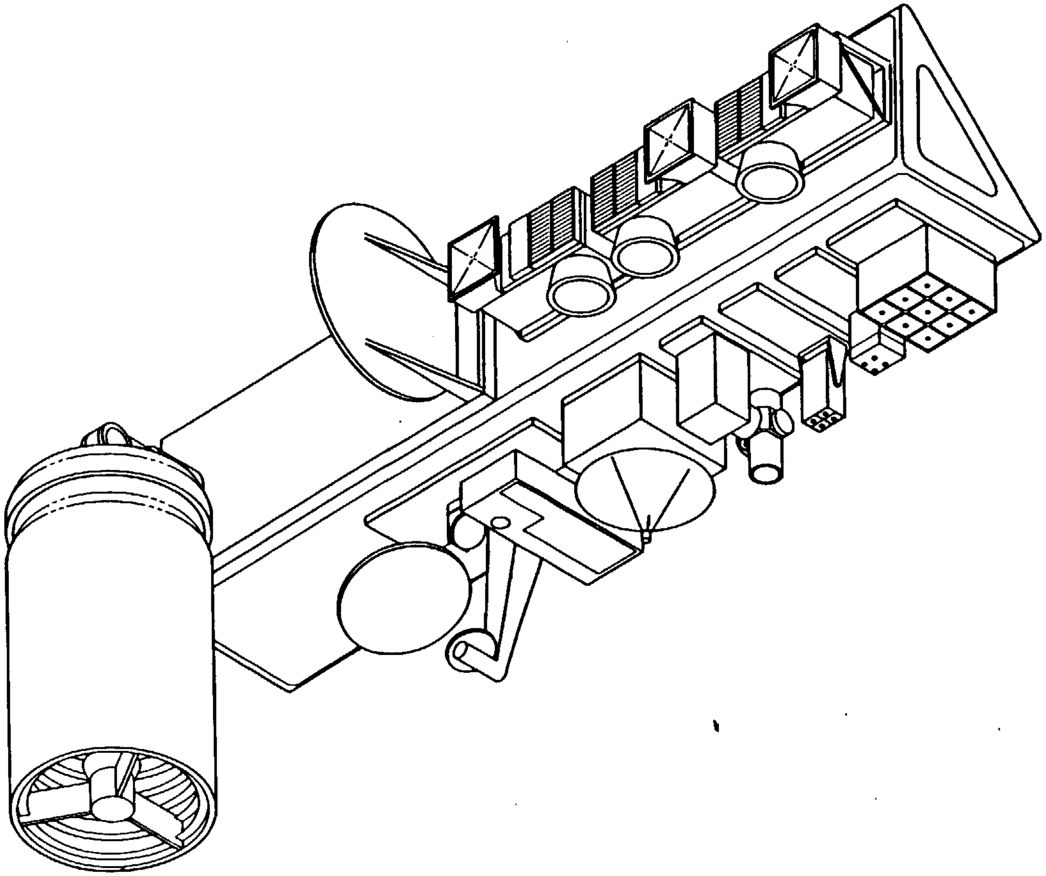
ADVANCED ESGP
NORTH SCIENCE MODULE



ADVANCED ESGP SOUTH SCIENCE MODULE

The figure shows a 3-D view of the individual payloads and communication equipment mounted on the south science module.

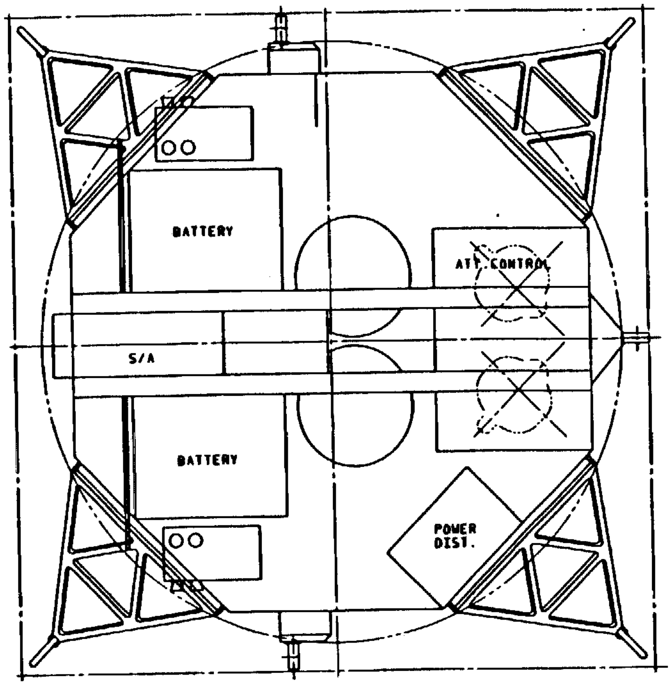
ADVANCED ESGP
SOUTH SCIENCE MODULE

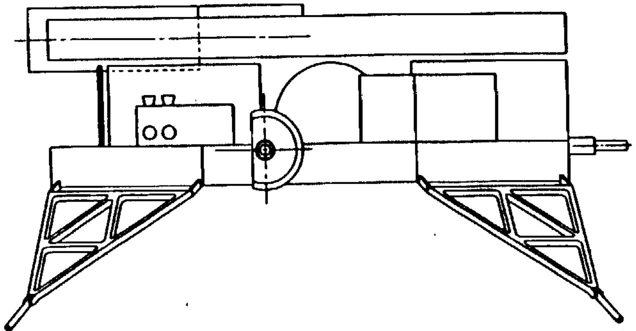


ADVANCED ESGP BUS MODULE ARRANGEMENT

A plan view of the bus subsystem module arrangement is shown in the figure. The bus modules are located at both ends of the truss platform. Individual equipment items are identified in the figure.

ADVANCED ESGP BUS MODULE ARRANGEMENT





ADVANCED ESGP WEIGHT ESTIMATE

The weight estimate for the Advanced ESGP is 32116 lb and includes a bus weight contingency of 30%. Individual bus subsystem weights, total payload weight, and total propellant weight for a 10 year life are listed. The total payload weight as a percentage of total platform dry weight is 39%.

ADVANCED ESGP
- WEIGHT ESTIMATE -

CONCEPT 4C-A WEIGHT ESTIMATE (10 YEAR LIFE)		
PLATFORM BUS SUBSYSTEM	LBS.	Kg
STRUCTURE & MECHANISMS	6529	2961
ATTITUDE CONTROL	610	276
ELECTRICAL POWER	3742	1697
DATA MANAGEMENT	400	181
COMMAND/CONTROL/TELEMETRY	107	49
THERMAL CONTROL	413	187
PROPULSION (DRY)	209	95
BUS SUBSYSTEM TOTAL=	12009	5447
CONTINGENCY (30 %)=	3603	1634
PLATFORM BUS	**15612**	**7081**
PAYLOAD	10004	4538
TOTAL PLATFORM (DRY)	25616	11619
PROPELLANT (DV=1900)	6500	2948
TOTAL PLATFORM AT BOL	**32116**	**14567**

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ADVANCED ESGP
SCIENCE INSTRUMENT
REQUIREMENTS

INTRODUCTION

In order to provide a realistic detailing of the requirements imposed on the Space Station Freedom by an Advanced Earth Science Geostationary Platform (ESGP), it is necessary to properly define the nature of the Advanced Platform.

As is true with any science-oriented spacecraft, the overall design of the Platform and the necessary support requirements are driven by the Science Instruments (SIs). In other words, to properly study the support required of the evolutionary Space Station for the ESGP, it is necessary to define the top-level SI requirements for the Platform. This allows the identification of instrument requirements that are drivers and that critically influence and govern the ESGP support requirements. A realistic determination of these requirements allows the derivation of a reasonable and viable Advanced ESGP, which, in turn, allows the identification of realistic requirements imposed on the evolutionary Space Station by the Advanced ESGP.

INTRODUCTION

PURPOSE: DEFINE TOP - LEVEL SCIENCE INSTRUMENT REQUIREMENTS FOR ADVANCED ESGP

- o ALLOWS IDENTIFICATION OF INSTRUMENT DRIVERS THAT GOVERN PLATFORM SUPPORT REQUIREMENTS
- o PROVIDES REALISTIC BASIS FOR SPACE STATION SUPPORT OF ADVANCED ESGP

STRAWMAN PAYLOAD

Earlier phases of the LMSC ESGP contract (1987 - 1988) investigated the nature of Advanced ESGPs, and included the identification of a candidate strawman SI payload for next-generation Platforms. The list is shown on the accompanying page.

The list represents a logical extrapolation of current technology, instrumentation and performance and extends these into the time-frame of the Advanced ESGP. Although much of the instrumentation currently exists in various stages of maturity, the primary distinction is that the Advanced ESGP will feature SIs with higher resolution, higher sensitivity and better overall performance as compared to earlier generations of SIs.

STRAWMAN PAYLOAD

1. X - RAY IMAGER (EARTH)
2. 10/20 ARRAY IMAGING SPECTROMETER
3. MICROWAVE SOUNDING UNIT
4. ADVANCED HIGH - RESOLUTION IMAGER
5. ACTIVE CAVITY RADIOMETER
6. PARTICLE ENVIRONMENT MONITOR
7. HIGH - RESOLUTION DOPPLER IMAGER
8. MICROWAVE SOUNDER / IMAGER
9. MICROWAVE PRECIPITATION IMAGER
10. LIGHTNING MAPPER
11. SOLAR ULTRAVIOLET MONITOR
12. TOTAL OZONE MAPPER
13. GEODYNAMICS LASER RANGER
14. GEOCLAES
15. LOW FREQUENCY MICROWAVE RADIOMETER
16. INFRARED SOUNDER
17. ADVANCED EARTH PROCESSES SPECTROMETER
18. SOLAR / STELLAR INTERCOMPARATOR
19. SOLAR X - RAY IMAGER

INSTRUMENT DRIVERS_
- CATEGORIES -

Review of the strawman payload list and the general instrument characteristics has led to the identification of three categories of SI drivers.

The desire for higher spatial resolution and the likely desire for extended spectral bandwidth combined with the presence of microwave radiometers in the strawman payload results in the size of the microwave radiometers as being a critical issue. The presence of a 4.4 meter microwave radiometer on the first ESGP is driving both the platform and instrument design, and the possibility of larger radiometers of a similar nature is expected to exacerbate the problem.

Along the same lines, the desire for higher spatial resolution for imagers can only be achieved through the use of larger mirrors. These larger mirrors will result in an increase both in instrument size and weight, two factors that influence overall platform design.

The third category is the issue of cryogen consumables. Although the current ESGP is not expected to carry any cryogenically cooled instruments, higher performance requirements in the long wavelength infrared spectral region dictate detector temperature requirements that can not be achieved on a purely passive basis. As the utilization of mechanical coolers/refrigerators is likely to induce pointing stability disturbances on the Platform, the alternative is to use cryogens to cool the detectors, in spite of their inherently limited lifetime.

INSTRUMENT DRIVERS
- CATEGORIES -

- o MICROWAVE RADIOMETER SIZE
- o IMAGER MIRROR SIZE
- o CRYOGEN CONSUMABLES

SUMMARY

A summary of the major science instrument requirements that are expected to drive the support of the Advanced ESGP at the Space Station is presented on the accompanying chart.

The estimated total payload weight and power requirements were derived based on data developed during the earlier phases of the ESGP study.

With a description of the major driving science instrument requirements, it is now possible to shape the developmental concept of an Advanced ESGP and use that to derive and study the requirements imposed by the Advanced Platform on the evolutionary Space Station.

SUMMARY

- o 20m DIAMETER LOW FREQUENCY MICROWAVE RADIOMETER (MESH)
- o 7m DIAMETER MICROWAVE SOUNDER / IMAGER (SOLID)
- o IMAGER MIRROR DIAMETERS UP TO 2.1m
- o HIGH SPATIAL RESOLUTION REQUIRED WITH HIGH POINTING STABILITY
- o LARGE DIAMETER IMAGERS LIKELY TO REQUIRE INSTRUMENT - SPECIFIC POINTING SYSTEM
- o CRYOGEN TOP-OFF AT SSF PRIOR TO GEO TRANSFER
- o ESTIMATED TOTAL PAYLOAD WEIGHT: 10000 lb
- o ESTIMATED TOTAL PAYLOAD POWER: 6.0 kW

ADVANCED ESGP SI USAGE OF SSF

Staging of an Advanced ESGP at the SSF results in three distinct benefits to the Science Instruments that comprise the ESGP payload.

The primary benefit is a relaxation of the size constraints imposed on the SIs. With the ESGP assembled in large sections at the SSF, the size of an SI can be larger as there is less of a concern of violating strict launch vehicle constraints as there would be if the Advanced ESGP was launched as one vehicle. This results in the possibility of larger mirrors for the imagers and larger antenna diameters for the microwave radiometers, which, in turn, results in a performance enhancement for the SIs.

Launch weight of any vehicle is always of great concern, and staging the Advanced ESGP at the SSF relaxes this concern. Advanced SIs are likely to carry cryogens to allow their detectors to be cooled to sufficient level to permit long-wavelength infrared observations. As cryogens are heavy, their use on Earth-launch platforms is typically discouraged unless absolutely necessary. However, use of the SSF as a top-off point for cryogens, allows those SIs that use cryogens to launch with a minimum amount of the coolant with the dewar being filled once the SI reaches SSF.

A final benefit for SI usage of SSF is the possibility of checkout of the SIs prior to transfer to the operational geostationary orbit. Such checkout is likely to be limited to basic activities such as low-voltage turn on, activation of monitoring and housekeeping systems etc., This is due to the possibility of contamination of exposed SI optical surfaces while in proximity to the SSF, as well as the required time to allow outgassing which could harm systems that utilize high voltage.

ADVANCED ESGP SI USAGE OF SSF

- o SSF STAGING RELIEVES SI SIZE CONSTRAINTS
  - LARGER IMAGER MIRRORS
  - LARGER MICROWAVE RADIOMETERS
- o ALLOWS CRYOGEN TOP-OFF OF SIs
  - REDUCES SI LAUNCH WEIGHT
- o PERMITS LIMITED SI CHECKOUT PRIOR TO GEO - ORBIT TRANSFER

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EVOLUTIONARY SSF

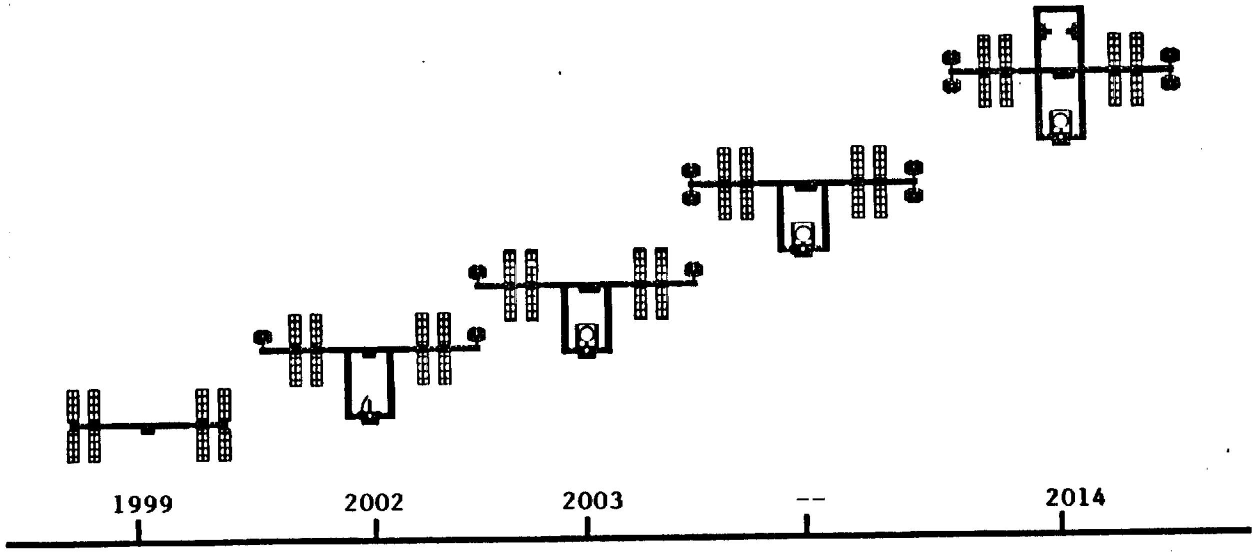
EVOLUTIONARY SSF

The SSF Evolutionary growth depicted in the figure was contained in the NASA/LARC final package briefing of October 1989 entitled SSF Accommodation of the HEI and was based on two years of systems studies sponsored by the Official Space Station Transition Definition Program including Transportation Node studies sponsored by OEXP. The dates shown on the bottom of the figure were included in the Option 5; SSF Deployment Option schedule. Ideally, the assembly and launch of the Advanced ESGP would occur sometime prior to the start of LTV and MTV Operations in 2014 during the period of Reusable LTV Operations which included two SSRMS and MSC operational capability.

EVOLUTIONARY SSF

Transportation Node Configuration Analysis

Space Station Freedom Evolution - October 1989



1999	2002	2003	--	2014
Baseline Assembly Complete	LTV Verification Flight	Expendable LTV Operations	Reusable LTV Operations	LTV and MTV Operations

Office of Space Station

LaRC SSFO

LARC R&D AND TRANSPORTATION NODE COMPARISONS

The figure shows a growth comparison for the multidiscipline R&D and transportation node options of the evolutionary SSF. The vehicle assembly design requirements of the Advanced ESGP are optimally satisfied by the transportation node option which provides a 2 MSC capability operating in the vicinity of the assembly hangar facility. Additionally, the STV assembly facility is larger on the transportation node option and is better suited for the Advanced ESGP mission requirements.

Data for the growth comparison was contained in a NASA/LARC briefing package dated June 1989.

LARC R&D AND TRANSPORTATION NODE COMPARISONS

GROWTH ELEMENTS	RD	TN	COMPARISON REMARKS
HAB MODULES	✓	✓	2 ADDITIONAL HABS IN BOTH CASES
LAB MODULES	✓	✓	2 FULL LABS FOR RD, 1-2 FOR TN; POCKET LABS FOR BOTH BUT NO MATERIAL PROD. FOR MATURE TN; TN REQUIRES LAB APART FROM MODULE PATTERN
LOG MODULES	✓	✓	TN LIKELY TO REQUIRE ULC CAPABILITY BEYOND BASELINE
AIRLOCKS		✓	NO REQT IDENTIFIED FOR RD AIRLOCK GROWTH; TN REQUIRES AIRLOCK ATTACHED TO PRESS MODULES WITHIN STV ASSEMBLY HANGER
STRUCTURE, KEELS & BOOM	✓	✓	DUAL KEEL FOR TN & RD BUT TN REQUIRES MORE STRUCTURE TO SUPPORT LARGER/MULTIPLE STV'S
POWER/THERMAL	✓	✓	RD PAYLOADS DRIVE POWER/THERMAL REQTS.
APAE	✓	✓	RD & TN WILL SUPPORT ADDED ATTACHED PAYLOADS BUT TN OPERATIONAL CONFLICTS ARE CONSTRAINING FOR VIEWERS
MSC		✓	TN MAY REQUIRE 2 DEDICATED MSC'S WITHIN ASSEMBLY HANGER
SERVICING FAC.	✓	✓	SERVICING OF GREAT OBSERVATORIES IS A COMMON REQUIREMENT; OMV ACCOMMODATIONS INCLUDED
STV HANGER/ ASSEMBLY FAC.	✓	✓	RD ACCOMMS. FOR STV SUPPORTS GEO PAYLOADS; RD FACILITY IS SMALLER THAN TN ASSEMBLY HANGER

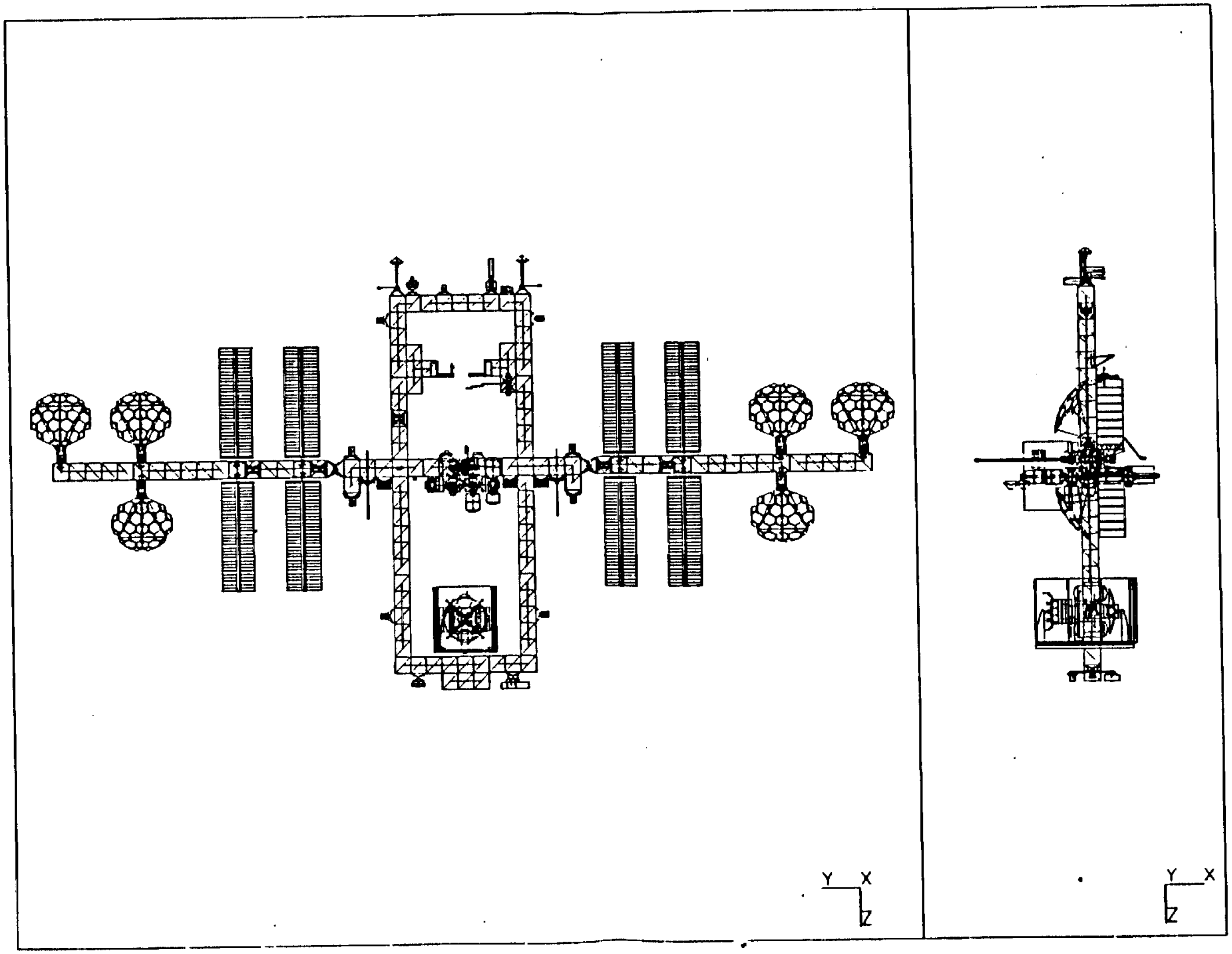
RD = R&D GROWTH EMPHASIS
TN = TRANSP. NODE EMPHASIS

EVOLUTIONARY SSF TRANSPORTATION NODE

The evolutionary SSF transportation node configuration used as a baseline design in this study is shown in the figure. The configuration is represented by the geometric database titled: SS02: [WAS] REFERENCE and was obtained from NASA/LARC and generated on the NASA IDEAS**2 SDRC L4.1 LARC 6.1 System Assembly in February 1990.

The transfer of data from the NASA/LARC project relational database (IDEAS**2) to the Lockheed IDEAS**2 system was done through the use of universal files and is discussed in detail in the Automated Analysis Tools section of the report. The IDEAS**2 geometric database allows various organizations to access and evaluate a common geometric definition of a design concept such as the transportation node option.

TRANSPORTATION NODE CONFIGURATION - LaRC



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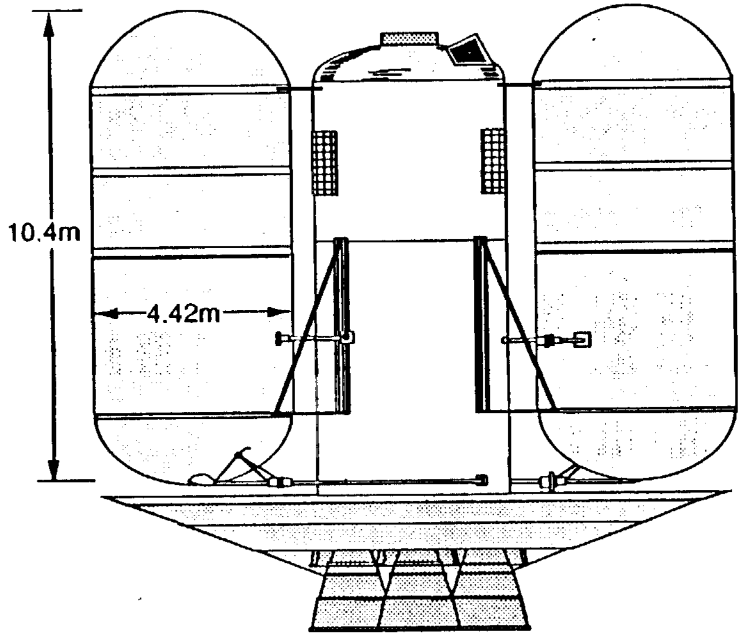
SPACE TRANSFER VEHICLE

Lockheed

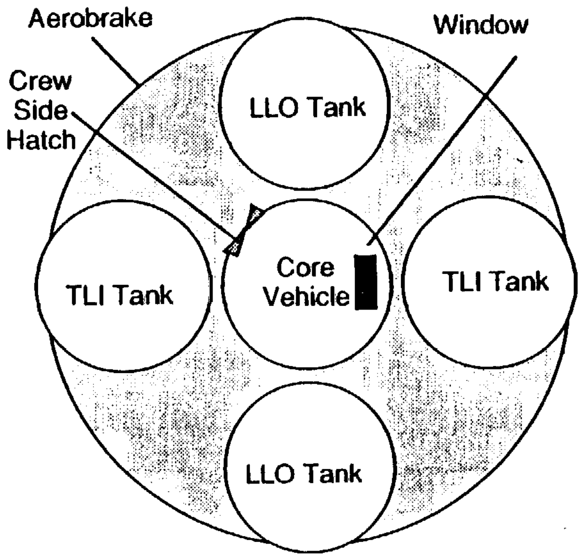
LTV/STV CONFIGURATION

The basic LTV/STV configuration used in the study is shown in the figure. The LTV core configuration consists of a rigid 13.7m aerobrake, four ASE engines, propulsion module, and a lunar transit crew cab which is not utilized as part of the GEO transfer scenario, but is an integral part of the LTV core vehicle. Two TLI and two LLO drop tanks are positioned as shown around the core vehicle. The drop tank attach structures and feedlines are mounted to the core vehicle.

LTV / STV CONFIGURATION



Plan View



MARTIN MARIETTA
MANNED SPACE SYSTEMS

LTV/ESGP ATTACHMENT DESIGN

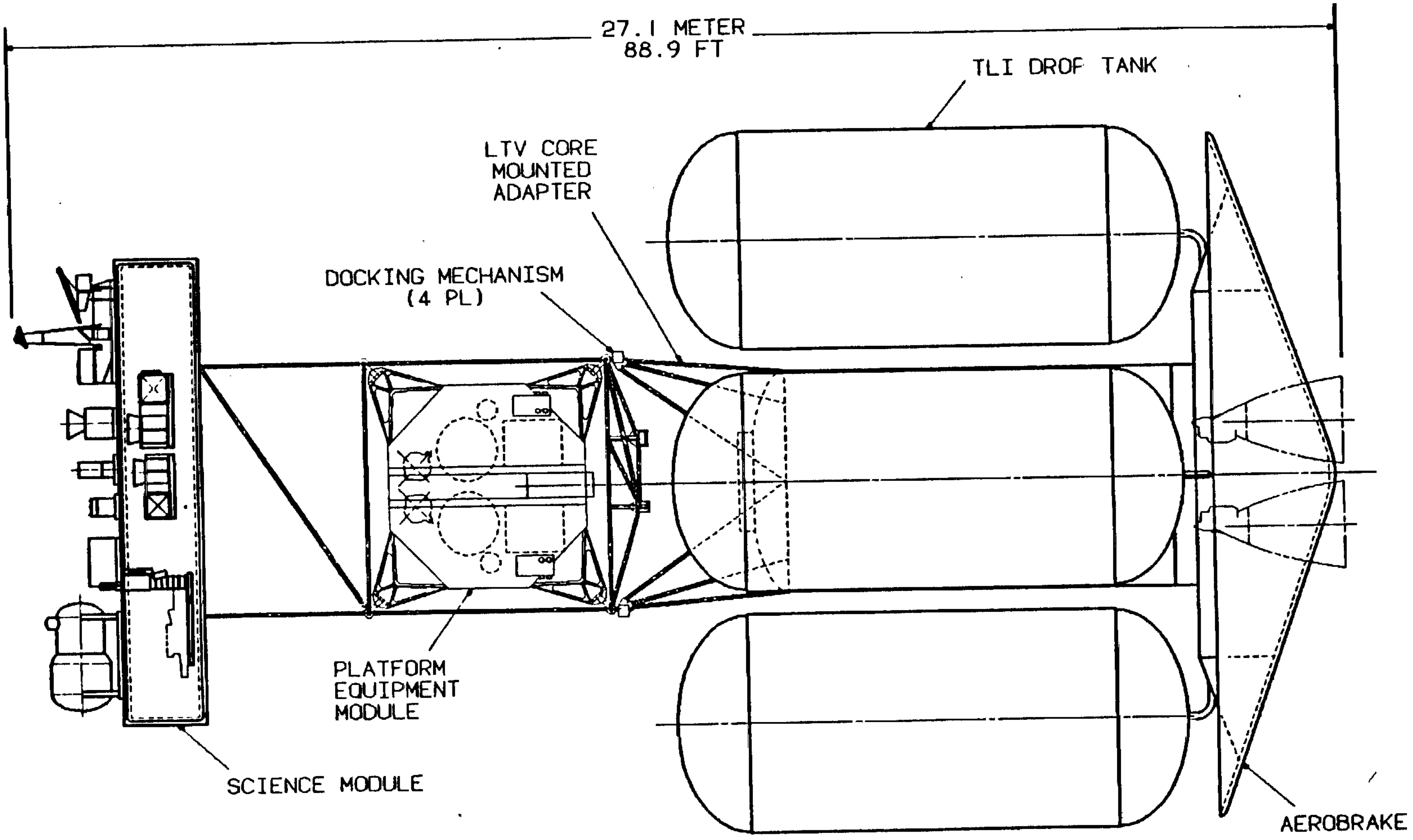
The LTV/ESGP attachment interface is shown in the figure. The LTV core-mounted adapter and docking mechanism design are identified with respect to the ESGP end-view configuration.

NASA SPACE FLIGHT

LTV / ESGP ATTACHMENT DESIGN

Lockheed

GEO TRANSFER CONFIGURATION



GEO PLATFORM END VIEW **LTV/TLI CONFIGURATION**

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SECTION 2

RESOURCE & FUNCTIONAL REQUIREMENTS

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MECHANICAL INTERFACES

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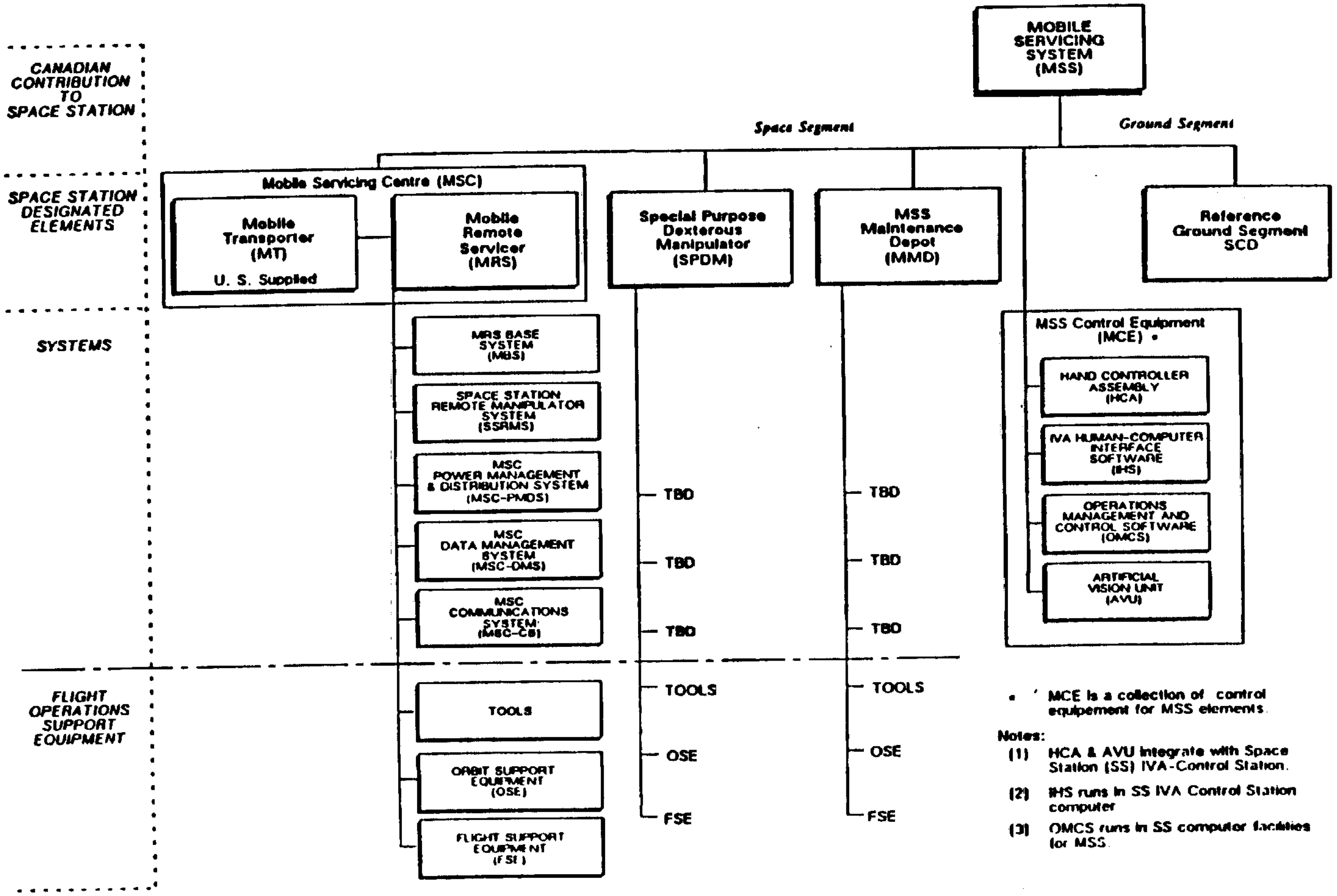
MOBILE SERVICING SYSTEM OVERVIEW



CANADIAN CONTRIBUTION TO SPACE STATION

SPACE STATION DESIGNATED ELEMENTS

SYSTEMS

FLIGHT OPERATIONS SUPPORT EQUIPMENT

MOBILE SERVICING SYSTEM (MSS)

Space Segment

Ground Segment

Mobile Servicing Centre (MSC)

Mobile Transporter (MT)
U. S. Supplied

Mobile Remote Servicer (MRS)

MRS BASE SYSTEM (MBS)

SPACE STATION REMOTE MANIPULATOR SYSTEM (SSRMS)

MSC POWER MANAGEMENT & DISTRIBUTION SYSTEM (MSC-PMDS)

MSC DATA MANAGEMENT SYSTEM (MSC-DMS)

MSC COMMUNICATIONS SYSTEM (MSC-CS)

TOOLS

ORBIT SUPPORT EQUIPMENT (OSE)

FLIGHT SUPPORT EQUIPMENT (FSE)

Special Purpose Dexterous Manipulator (SPDM)

- TBD
- TBD
- TBD
- TOOLS
- OSE
- FSE

MSS Maintenance Depot (MMD)

- TBD
- TBD
- TBD
- TOOLS
- OSE
- FSE

Reference Ground Segment SCD

MSS Control Equipment (MCE) •

HAND CONTROLLER ASSEMBLY (HCA)

IVA HUMAN-COMPUTER INTERFACE SOFTWARE (IHS)

OPERATIONS MANAGEMENT AND CONTROL SOFTWARE (OMCS)

ARTIFICIAL VISION UNIT (AVU)

• MCE is a collection of control equipement for MSS elements.

Notes:

(1) HCA & AVU integrate with Space Station (SS) IVA-Control Station.

(2) IHS runs in SS IVA Control Station computer

(3) OMCS runs in SS computer facilities for MSS.

MOBILE SERVICING CENTRE CHARACTERISTICS

The MSC is the mobile portion of the MSS, and provides transport and positioning function on the SSF. It consists of the MRS, which provides accommodation and positioning for payloads ranging from ORUs to complete modules, and the MT, which provides mobility for the MSC along the SSF truss.

The MRS consists of the MBS; the SSRMS; hardware for power, data and communications sub-systems; tools; locations for the FTS, SPDM, and EVA work station; and two attachment interfaces for payloads such as ORUs and pallets. Four sets of video cameras (two with pan and tilt units) and lights will be mounted on the MBS.

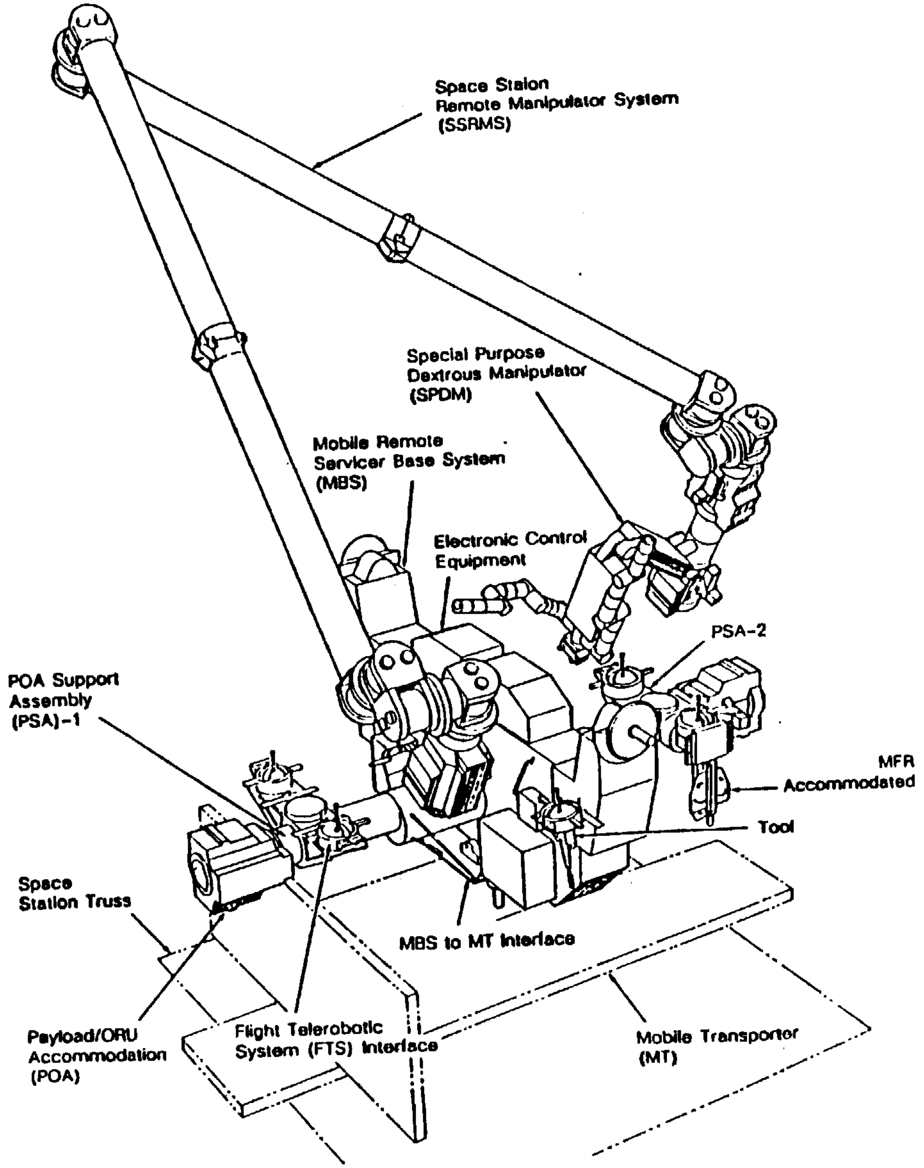
The SSRMS is a robotic device used primarily for handling large objects on the SSF. The large manipulator arm with 7 DOF has the capability for capturing, manipulating, and releasing large payloads. Each end of the arm is terminated in an end effector which function as an interface mechanism with the external systems. Force-moment sensors will be incorporated at the manipulator tip to provide operational load information. The SSRMS is symmetrical about the elbow joint and can operate from any PDGF as well as the MBS. It has the ability to move from PDGF to PDGF, although it cannot transport a payload in this mode. The SSRMS will have control electronics and processors to operate and control the joints, end effectors, force-moment sensors, and other equipment in the SSRMS. Four sets of video cameras (two with pan and tilt) and lights will be mounted on the SSRMS to provide television coverage of the arm operation.

The MT, which is developed and provided by NASA WP-2, provides the MRS with translation mobility along the SSF truss as well as plane change and turning capabilities on the truss. The MT interfaces with the SSF power system at utility ports on the truss and provides that utility power to the MT/MRS interface for the MRS.

NASA SPACE FLIGHT

MOBILE SERVICING CENTRE
- CHARCTERISTICS -

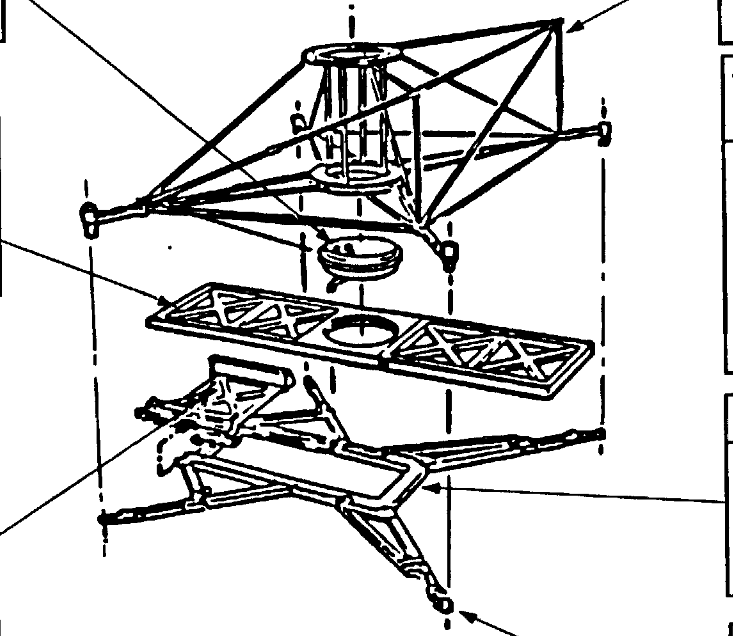
Lockheed



SPACE STATION REMOTE MANIPULATOR SYSTEM MOBILE TRANSPORTER

The mobile transporter shown in the figure is required to transport the MSC and its payloads of up to 46000 lbs along the Space Station truss. Such payloads may include pallets, modules (ESGP elements), EVA crewmembers, FTS, and other associated equipment. The MT translation capability for a mass of 20000 lbs is equal to an average rate of 0.018 m/sec. The MT rotation capability for a similar mass is equal to an average rate of 0.47 deg/sec.

SPACE STATION REMOTE MANIPULATOR SYSTEM MOBILE TRANSPORTER



TURNTABLE ASSEMBLY

- FULLY REDUNDANT DRIVE AND BEARING SYSTEM
- ON-ORBIT REPLACEABLE

TRACK BASE

- UNFOLDABLE GRAPHITE TRACK STRUCTURE FOR TRANSLATION

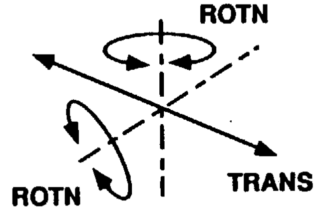
DRIVE HINGE

- FULLY REDUNDANT RELIEVER AND TRANSLATION DRIVE AND BEARING SYSTEM
- ON-ORBIT REPLACEABLE

UPPER BASE

- DEPLOYABLE GRAPHITE TRUSS STRUCTURE
- SUPPORTS MRS AND PAYLOADS

TRANSPORTER DEGREES OF FREEDOM



LOWER BASE

- UNFOLDABLE GRAPHITE STRUCTURE
- SUPPORTS TRANSPORTER DURING MOVEMENT

NODE PIN LATCH

- ELECTRICALLY REDUNDANT
- ANY THREE LATCHES WILL SUPPORT A BASE

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MOBILE SERVICING CENTRE
ESGP INTERFACES

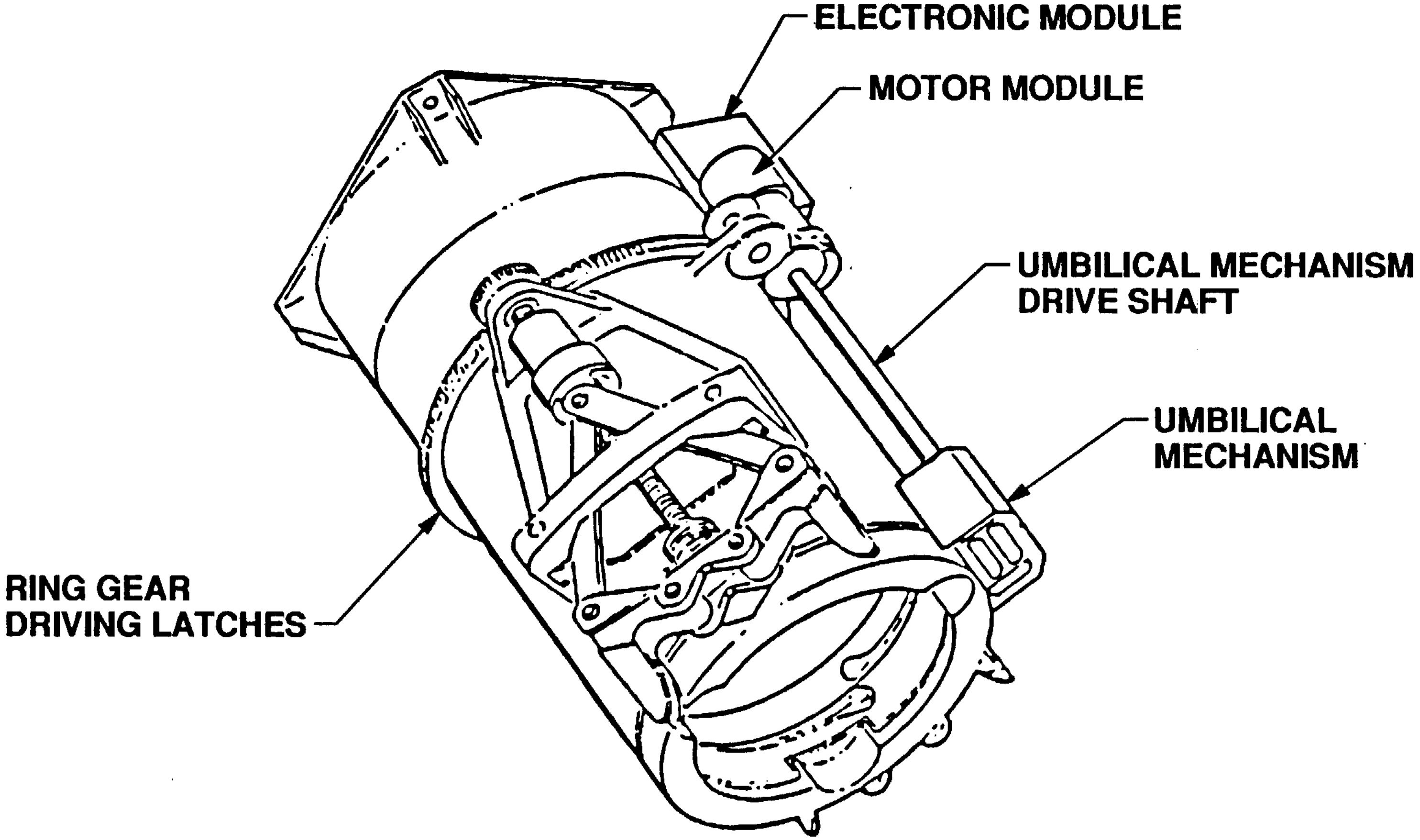
The MSC uses the Latching End Effector LEE/PDGP interface to join payloads to the MRS, and to join the SSRMS to payloads and/or the MRS.

Both end of the SSRMS are equipped with a LEE, which can serve as either the attachment to the MRS (or suitable truss-mounted) PDGF or to a payload.

Two LEEs are also furnished on the MRS Payload/ORU Accommodations Support Assembly (PSA) to support PDGF-equipped payloads.

MOBILE SERVICING CENTRE (Cont)

ESGP INTERFACES



MOBILE SERVICING CENTRE - ESGP INTERFACES -

The Power and Data Grapple Fixture (PDGF) shown in the figure is used for utility transfer to the ESGP. The overall utility transfer capabilities are included below. The SSRMS has utility transfer capabilities to support the FTS or SPDM, and to provide keep-alive and diagnostic utilities for any payload attached to its LEE.

Power

a. The MT is capable of transferring up to TBD (10 kW) of power to the MRS during stationary operations, and up to TBD (5 kW) of power to the MRS while the MT is translating, via a hard-wired connection.

b. The MRS is capable of transferring the following power:

   1. Up to 0.9 kW of power back to the MT.

   2. 1.8 kW for SSRMS, SPDM, and payloads mounted on the MRS, via the PDGF/LEE interfaces.

   3. 2.0 kW for the FTS mounted on the MRS.

Data/Video

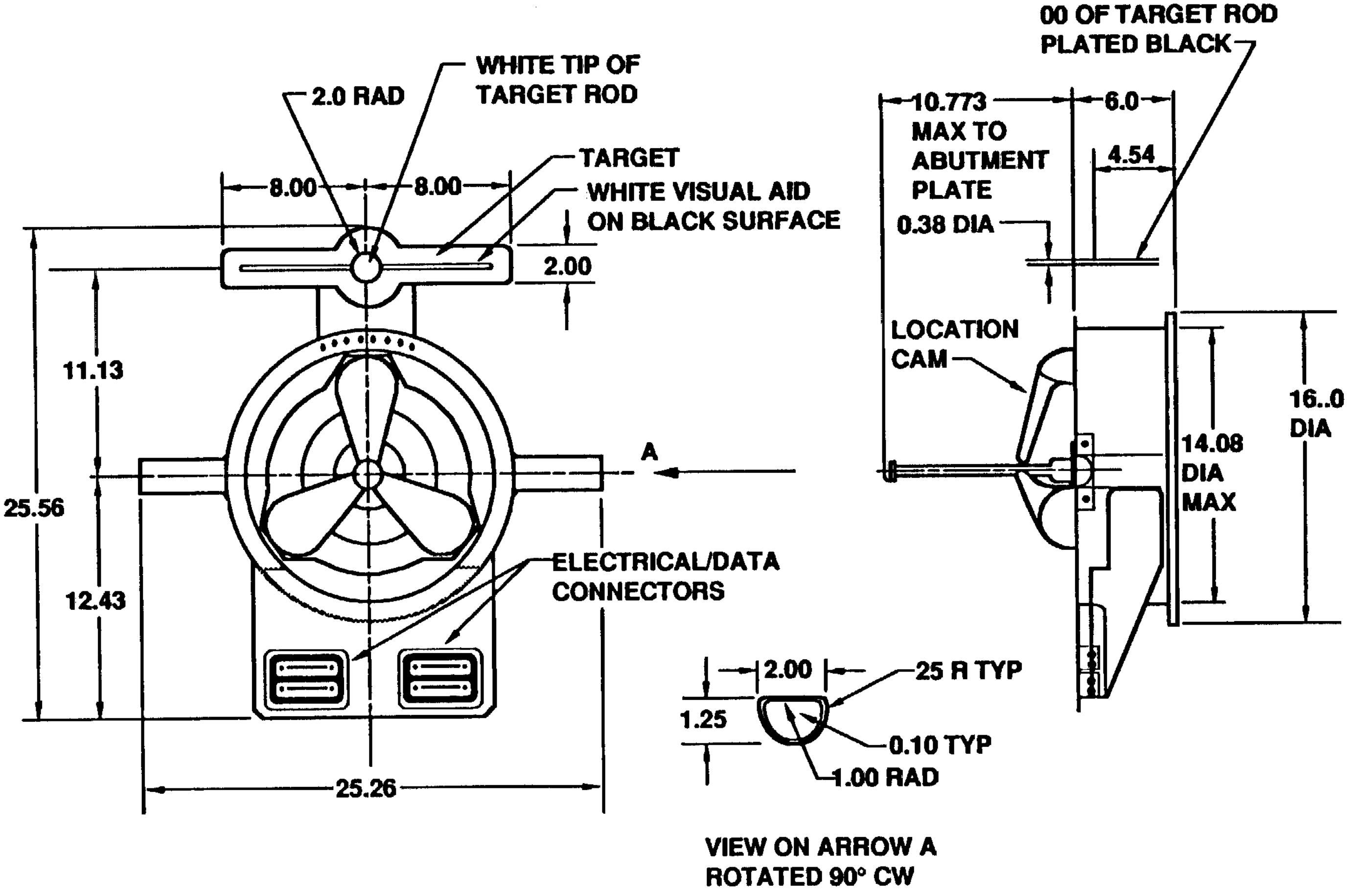
a. Data is transferred among the various MSC components at TBD rates. Up to 3 video channels are supported.

b. Data is transferred between the various MSC components (MRS, SSRMS) and payloads at a rate of 16 kbps. Up to 3 video channels are supported.

c. Data rates to support FTS operations are TBD. Up to 3 video channels are supported.

MOBILE SERVICING CENTRE (Cont)

ESGP INTERFACES

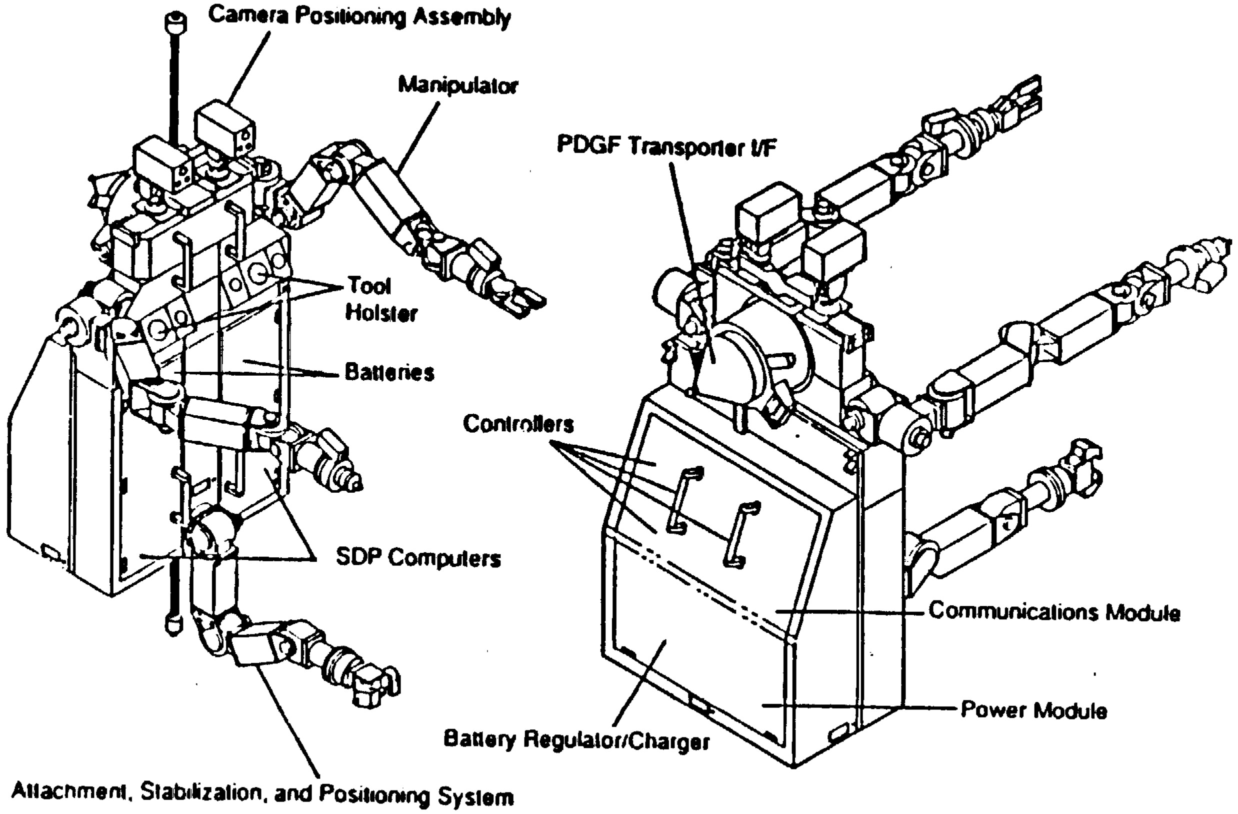


FLIGHT TELEROBOTIC SERVICER CHARACTERISTICS

The FTS has two manipulators; an Attachment, Stabilization, and Positioning Subsystem (ASPS) for stabilization and worksite attachment; two pan and tilt body cameras; a wrist camera on each manipulator; and body attachment point for tools and interchangeable end effectors as shown in the figure. The manipulators are equipped for force feedback and are capable of simultaneous coordinated control.

The FTS manipulators are 59 inches long and have 7 DOF. The manipulators provide 6 fully-controllable degrees of freedom (shoulder yaw and pitch, elbow pitch, wrist pitch, yaw and roll) with a single indexed roll DOF at the shoulder.

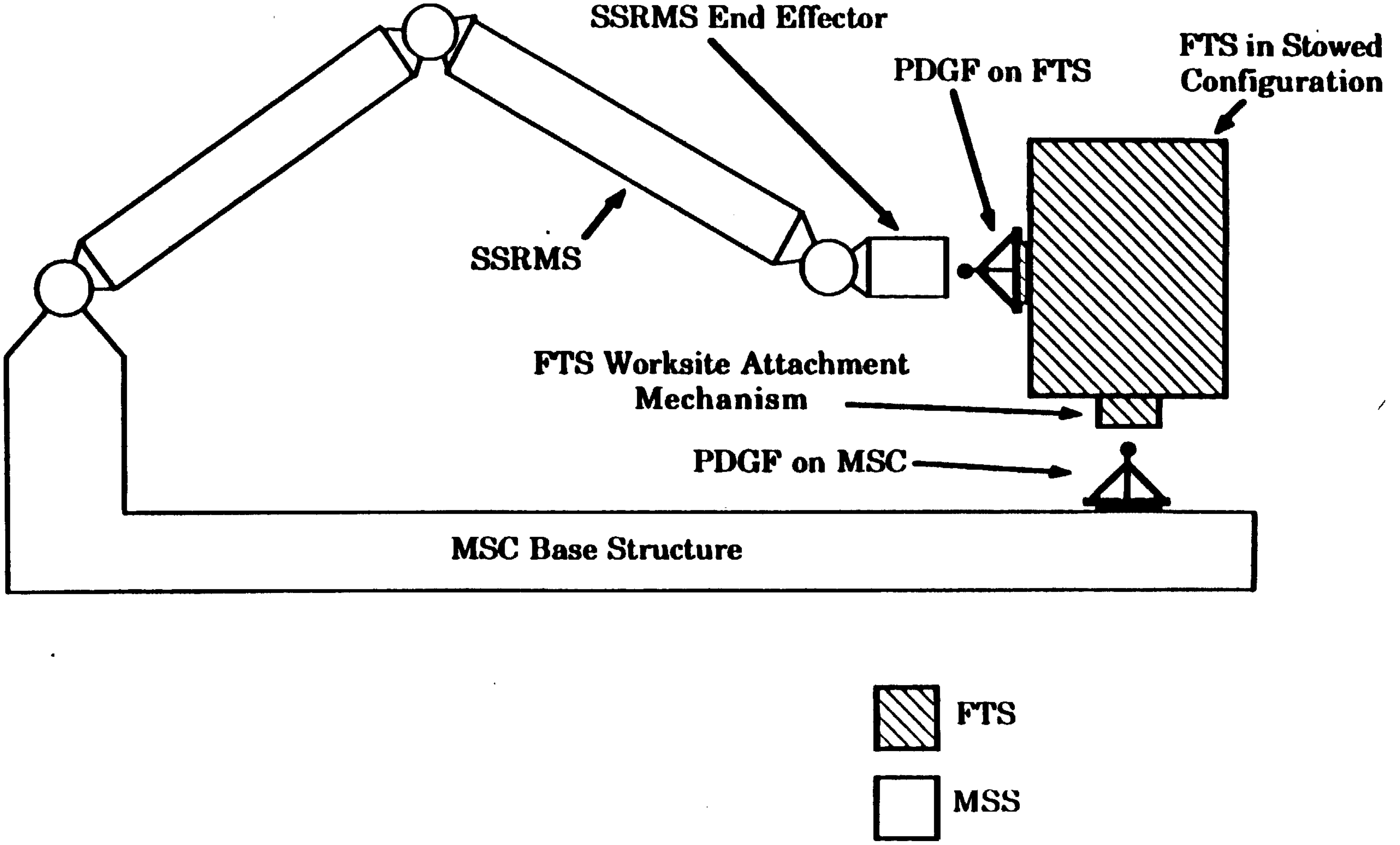
FLIGHT TELEROBOTIC SERVICER CHARACTERISTICS



FLIGHT TELEROBOTIC SERVICER - ESGP INTERFACES

The major interface between the FTS and the SSRMS of the MSC base structure is shown in the figure. There are two PDGF interface locations identified for the FTS.

FLIGHT TELEROBOTIC SERVICER
- ESGP INTERFACES -



FLIGHT TELEROBOTIC SERVICE - ESGP INTERFACES -

FTS/ESGP INTERFACE(s)

FTS primarily interfaces with payloads thorugh end effectors mounted on its two manipulators. The figure shows FTS/ESGP interfaces. Structural and utility resource interfaces are identified below:

Structural

FTS can grasp/attach to many objects with its standard end effectors and tools, including EVA handrails.

Power

Power is provided via the end-of-arm tooling/payload interface.

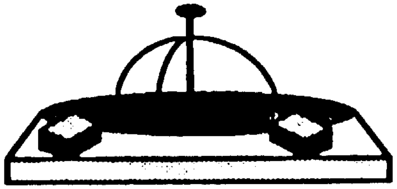
Data/Video

Data/video is provided via the end-of-arm tooling/payload interface.

Thermal

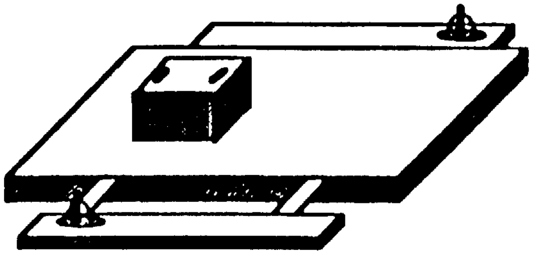
FTS has no active thermal interface to payloads.

FLIGHT TELEROBOTIC SERVICER
- ESGP INTERFACES -



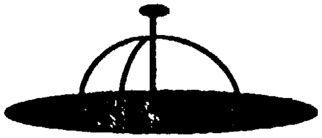
POWER & DATA GRAPPLE FIXTURE
- O POWER
- O DATA
- O VIDEO
- O SAFETY

MT/MSC/TRUSS/STORAGE/CETA



PERMANENT RAILS AT TWO ATTACHED PAYLOAD LOCATIONS

END-EFFECTORS ON:
- O SHUTTLE RMS
- O MSC SRMS
- O SFM



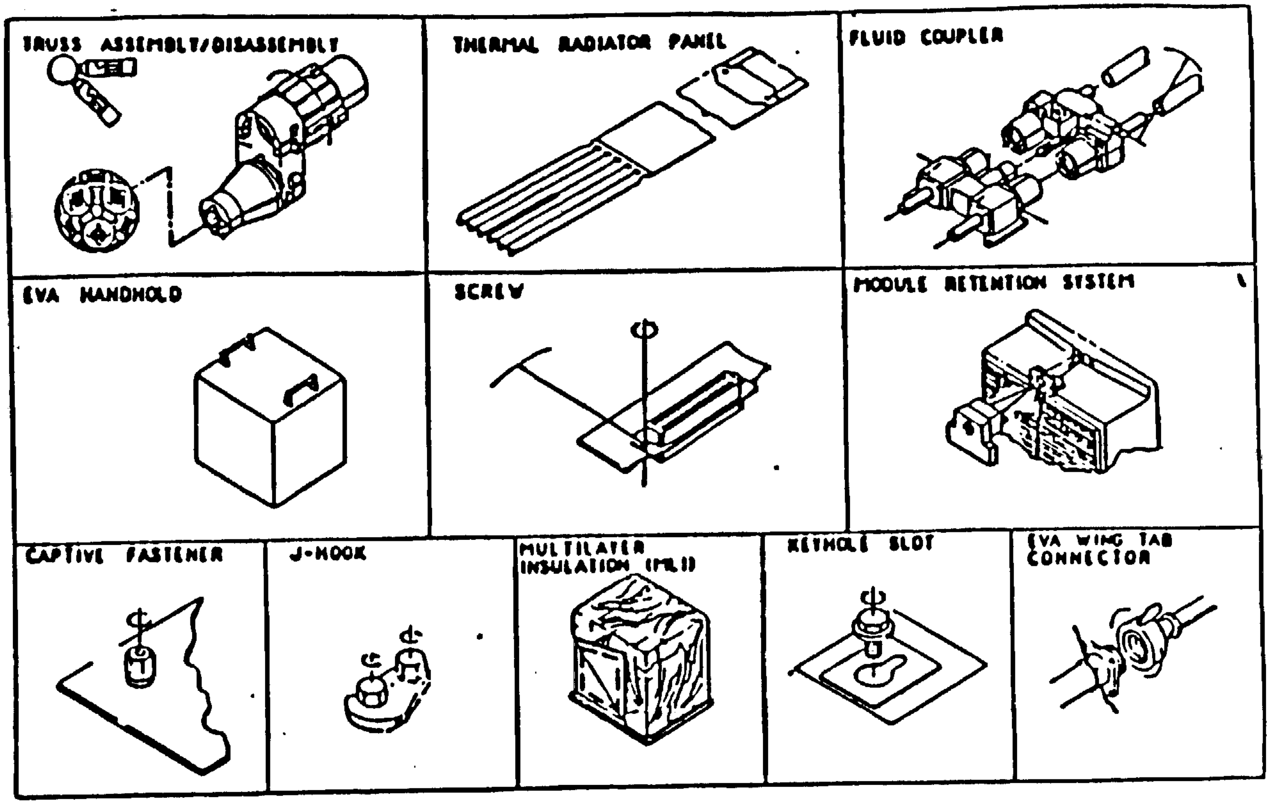
MECHANICAL GRAPPLE FIXTURE

FLIGHT TELEROBOTIC SERVICER - ESGP INTERFACES

Individual end effector interfaces for the FTS are shown in the figure. The end effectors for truss assembly, module retention system, and fluid coupler functions represent major ESGP interface requirements.

FLIGHT TELEROBOTIC SERVICER
- ESGP INTERFACES -

Lockheed



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SSF
SYSTEM
INTERFACE
REQUIREMENTS

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SSF SYSTEM OPERATIONS REQUIREMENTS

SSF systems operations requirements for the Advanced ESGP consist of the following elements: Cupola and Multipurpose Application Console.

Systems control requirements while viewing ESGP assembly operations from a cupola include:

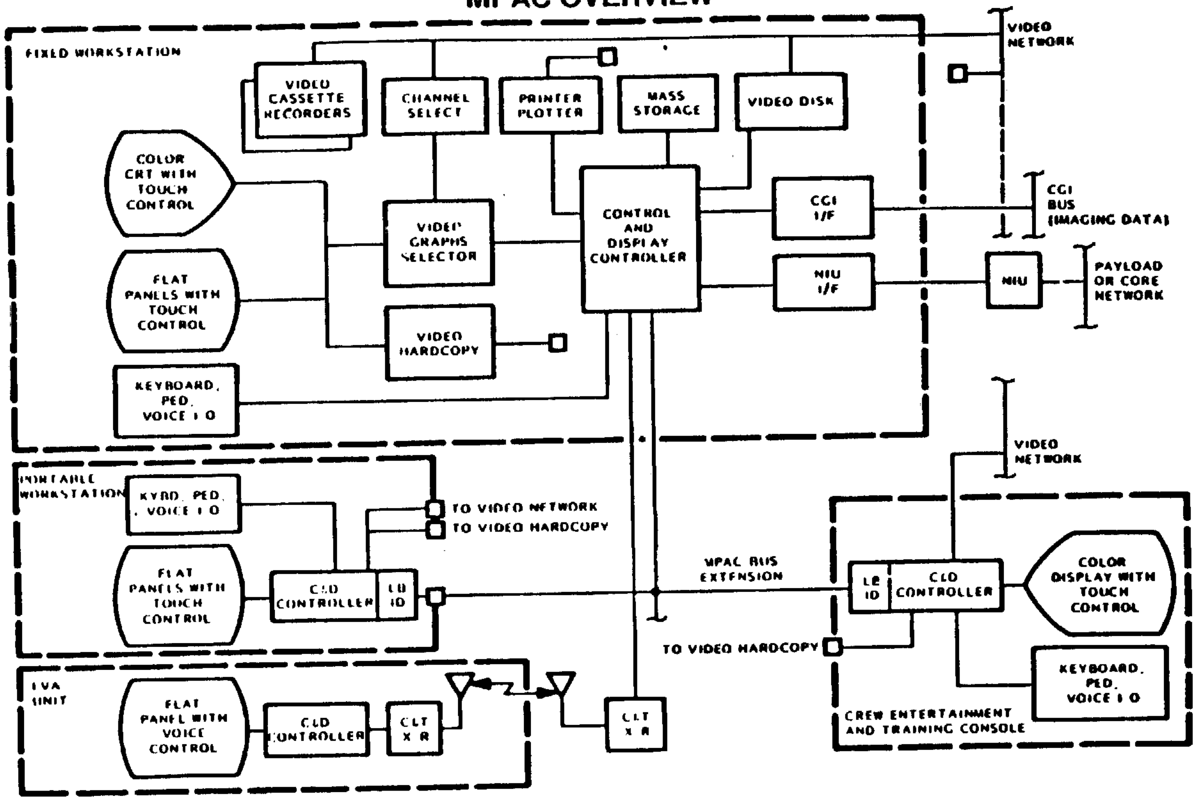
- Station manipulators
- Station manipulator transporter
- FTS
- Piloting of any unmanned commandable vehicle within the Command and Control Zone (CCZ)
- External video cameras and lights and internal (cupola) video monitors
- Any visual alignment, range, or angle sighting devices
- Internal and external voice communications
- Systems control funtions available through DMS access

Systems control requirements from a Multipurpose Application Console (MPAC) for ESGP assembly operations include:

- Safety critical payload safing
- Element-unique payload safing
- Element-unique systems operations
- Test and checkout of element-unique systems
- Element-hosted payload operations (a designated MPAC) will serve attached payloads)
- Access to all appropriate and authorized Operations Management Systems (OMS) functions
- Internal voice, video, and recorder operations

SSF SYSTEM OPERATIONS REQUIREMENTS

MPAC OVERVIEW

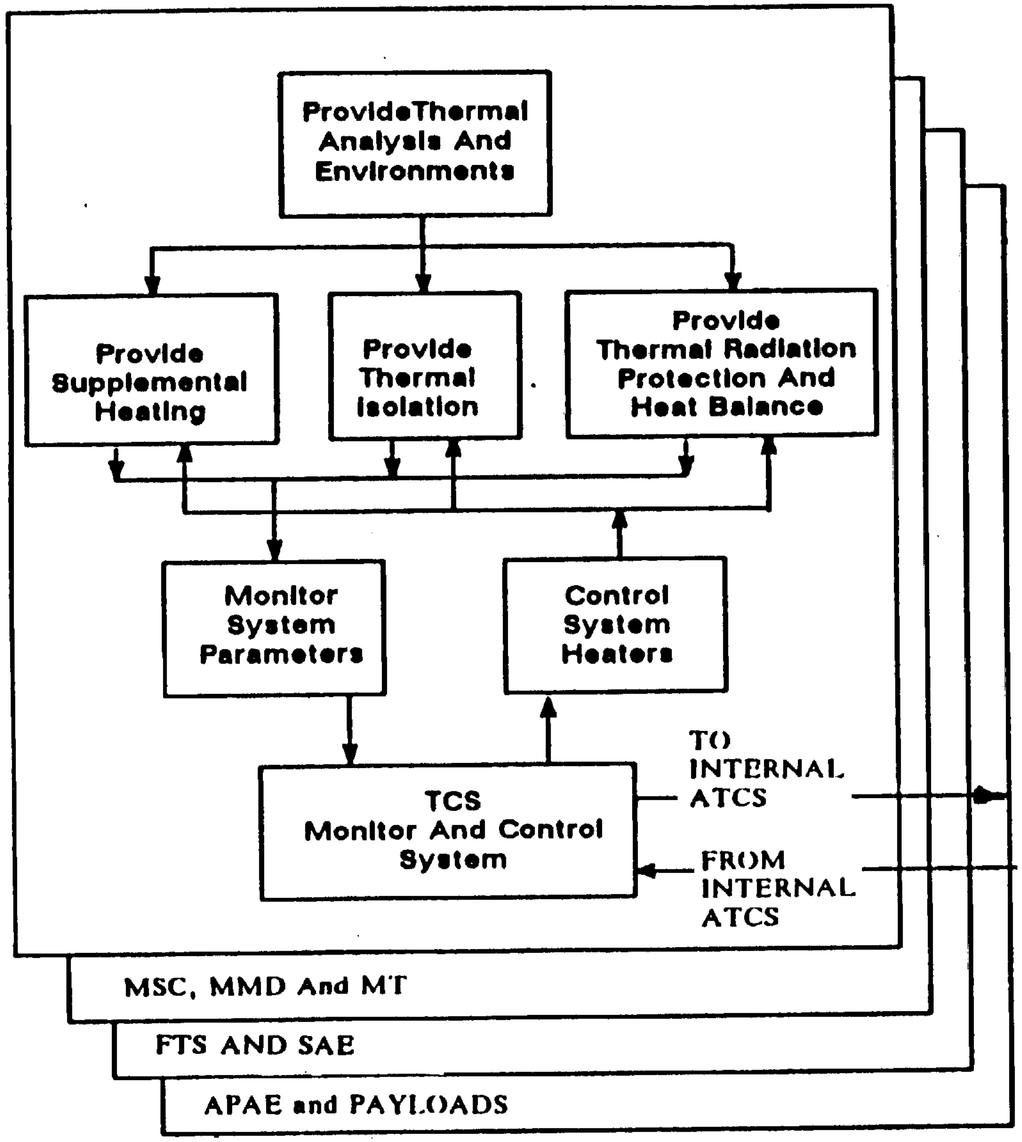


PASSIVE THERMAL CONTROL SYSTEM - MOBILE SERVICING SYSTEM -

The passive thermal control system requirements for the MSS and other elements are shown in the figure.

Selective surface coatings, heaters, heat pipes, insulation and isolators are provided for environmental protection and to control structural and externally mounted equipment temperatures. Pallet mounted equipment will be thermally controlled using passive thermal control when practical from a location and available passive radiator surface standpoint. The heat rejection on each resource pallet will be limited to a maximum steady state value of 1.2 kW with a short term peak not to exceed 1.5 kW based on a maximum heat rejection temeprature of 85 degrees F and a radiator direct space viewing of at least 80 percent. The pallet design shall provide sufficient area to meet the net heat rejection requirements, and shall be located to provide adequate heat rejection capability. The ORU equipment baseplate temperature for any Space Station distributed systems which are located on the resource pallets are <= 85 degrees F for nominal operations. Peak power excursions will be limited to 122 degrees F.

PASSIVE THERMAL CONTROL SYSTEM - MOBILE SERVICING SYSTEM -



Provide Thermal Analysis And Environments

Provide Supplemental Heating

Provide Thermal Isolation

Provide Thermal Radiation Protection And Heat Balance

Monitor System Parameters

Control System Heaters

TCS Monitor And Control System

TO INTERNAL ATCS

FROM INTERNAL ATCS

MSC, MMD And MT

FTS AND SAE

APAE and PAYLOADS

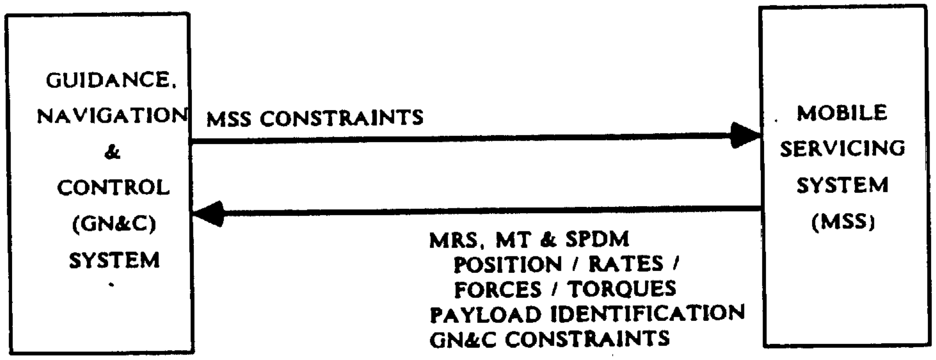
GUIDANCE, NAVIGATION & CONTROL - MOBILE SERVICING SYSTEM -

The GN&C to MSS interface requirements are shown in the figure.

The core GN&C subsystem interfaces with the MSS to provide for coordinated operations of the MSS within GN&C prescribed constraint envelopes. These constraint envelopes on the MSS shall consist of point-of-resolution displacement, rate, and force and torque limits relative to TBD reference frame. To support adaptation of attitude state maintenance to the operation to the MSS, the MSS must provide point-of-resolution displacement, rate, and forces and torques relative to the TBD reference frame to the GN&C system. In addition, the MSS will provide payload identification for the payload which it is maneuvering. These data are required by the GN&C system to perform mass properties extraction and momentum management.

GUIDANCE, NAVIGATION AND CONTROL

- MOBILE SERVICING SYSTEM -



GUIDANCE, NAVIGATION & CONTROL (GN&C) SYSTEM

MSS CONSTRAINTS

MOBILE SERVICING SYSTEM (MSS)

MRS, MT & SPDM
POSITION / RATES /
FORCES / TORQUES
PAYLOAD IDENTIFICATION
GN&C CONSTRAINTS

ELECTRICAL POWER SYSTEM - MOBILE SERVICING SYSTEM -

The EPS/MSS interface requirements are shown in the figure.

Interface A is defined as the output of the DC-to-DC converter unit (DDCU).

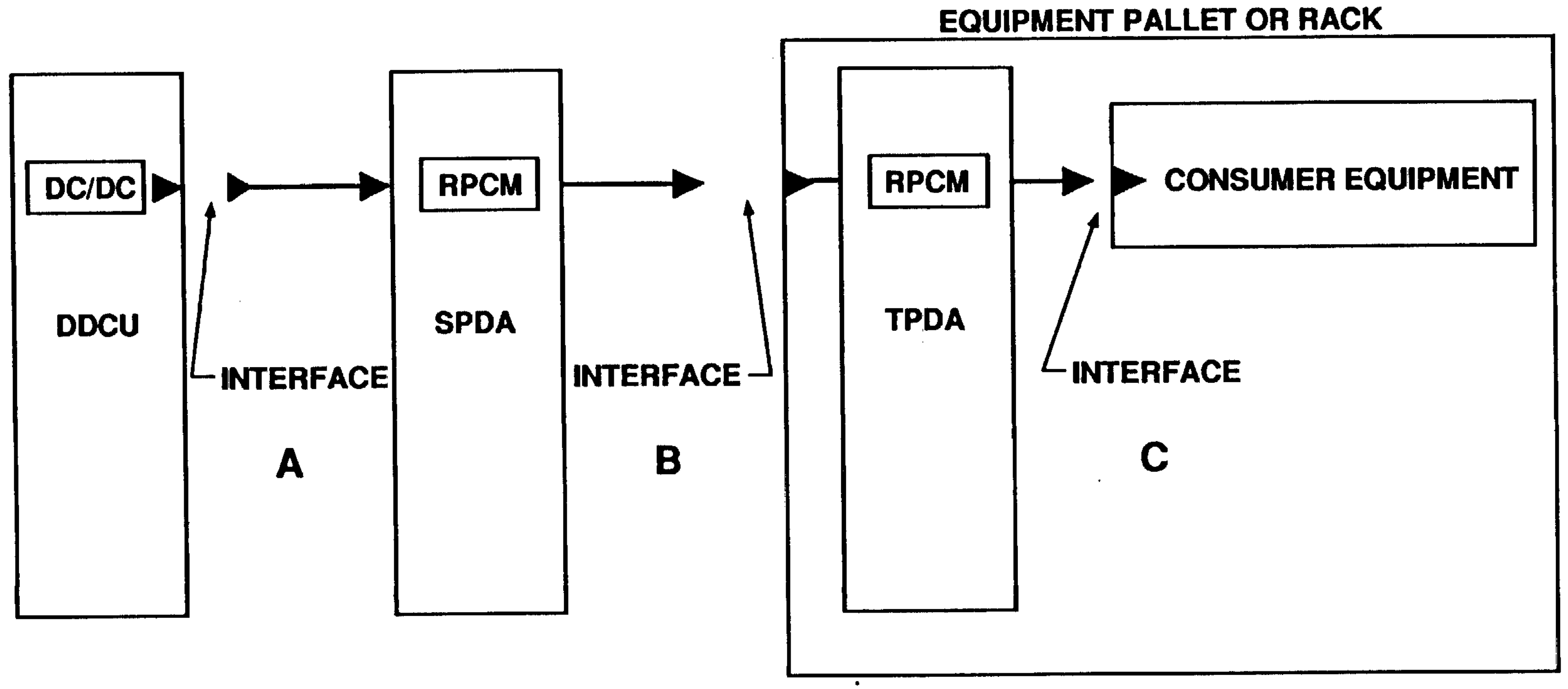
Interface B is at the end of the power cable connecting the secondary power distribution assembly (SPDA) to the pallet, utility port, rack or other secondary power unit. The SPDA is an assembly consisting of Remote Power Controller Modules (RPCM), a central utility rail wich provides power and data connections, and a cold plate. The utility rail and cold plate are element unique.

Interface C is at the input to the consumers equipment or at the end of the power cable connecting the tertiary power distribution assembly (TPDA) to the consumer equipment, if applicable.

The TPDA is an assembly consisting of RPCMs, power and data connections, and a cold plate. TPDA cold plate and mounting structure are element unique.

The EPS architecture of the MSS consists of two DDCUs, SPDAs and associated cables as shown in the figure. The DDCUs provide voltage regulation and ensure element isolation for a single-point ground. DC distribution power is provided to the MSS from two independent MBSU power feeders (one port and one starboard), one to each of the DDCUs. Each feeder is rated at 6.25 kW peak. The outputs of the DDCU transformers are tied together at the MSC single-point ground and then connected to the Station single-point ground.

MOBILE SERVICING SYSTEM



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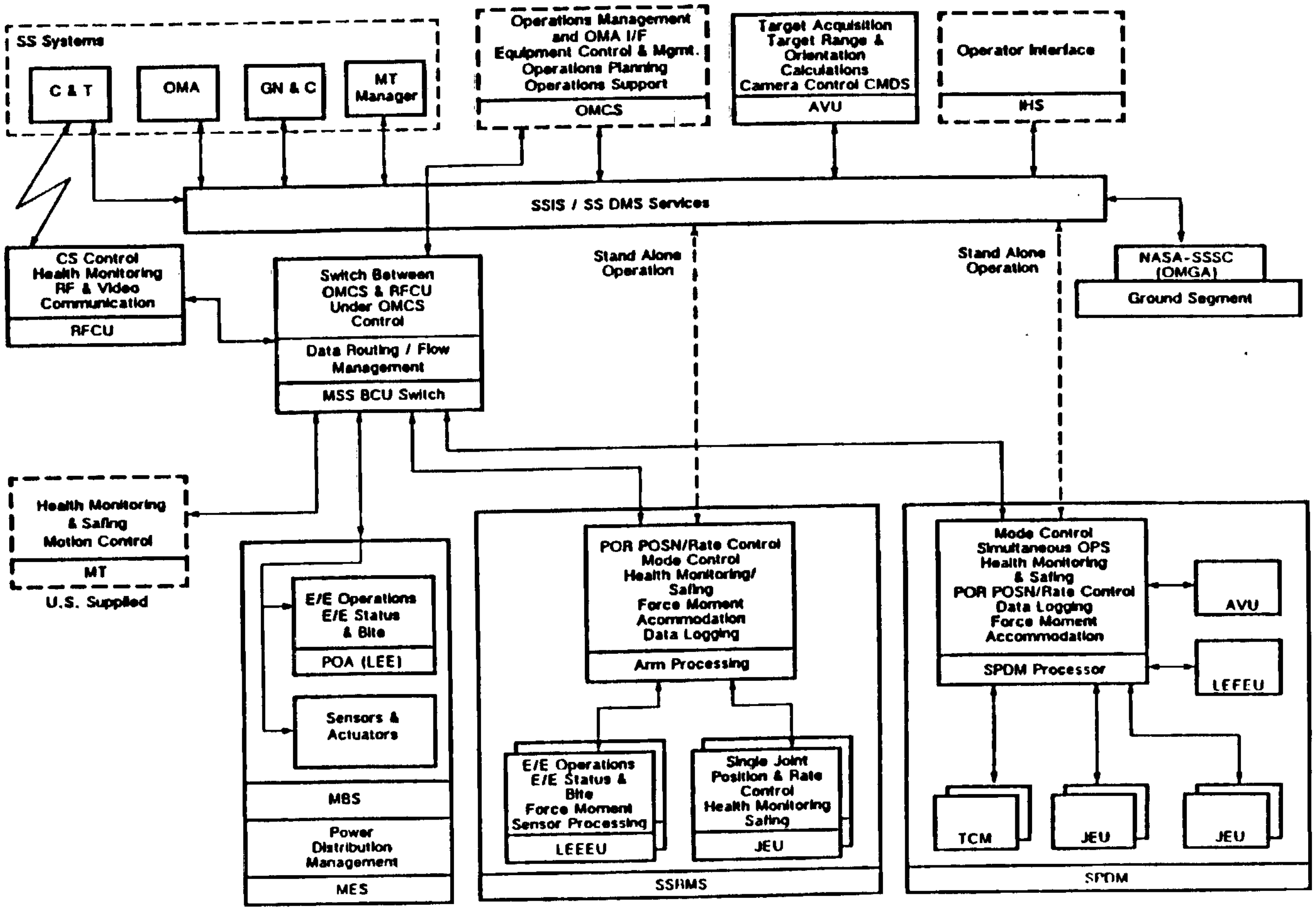
NASA SPACE FLIGHT

DATA MANAGEMENT SYSTEM
- MOBILE SERVICING SYSTEM -

Lockheed



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COMMUNICATIONS & TRACKING SYSTEM - MOBILE SERVICING SYSTEM -

The space-to-space subsystem provides RF communications between the space station and compatible interoperating elements operating within the space station proximity zone and command and control zone. A functional block diagram of the space-to-space subsystem is shown in the figure.

The MSS communications function is implemented solely on the MSC and provides an RF link interface to exchange data with the space station via the space-to-space subsystem. The following functions are provided by the MSS:

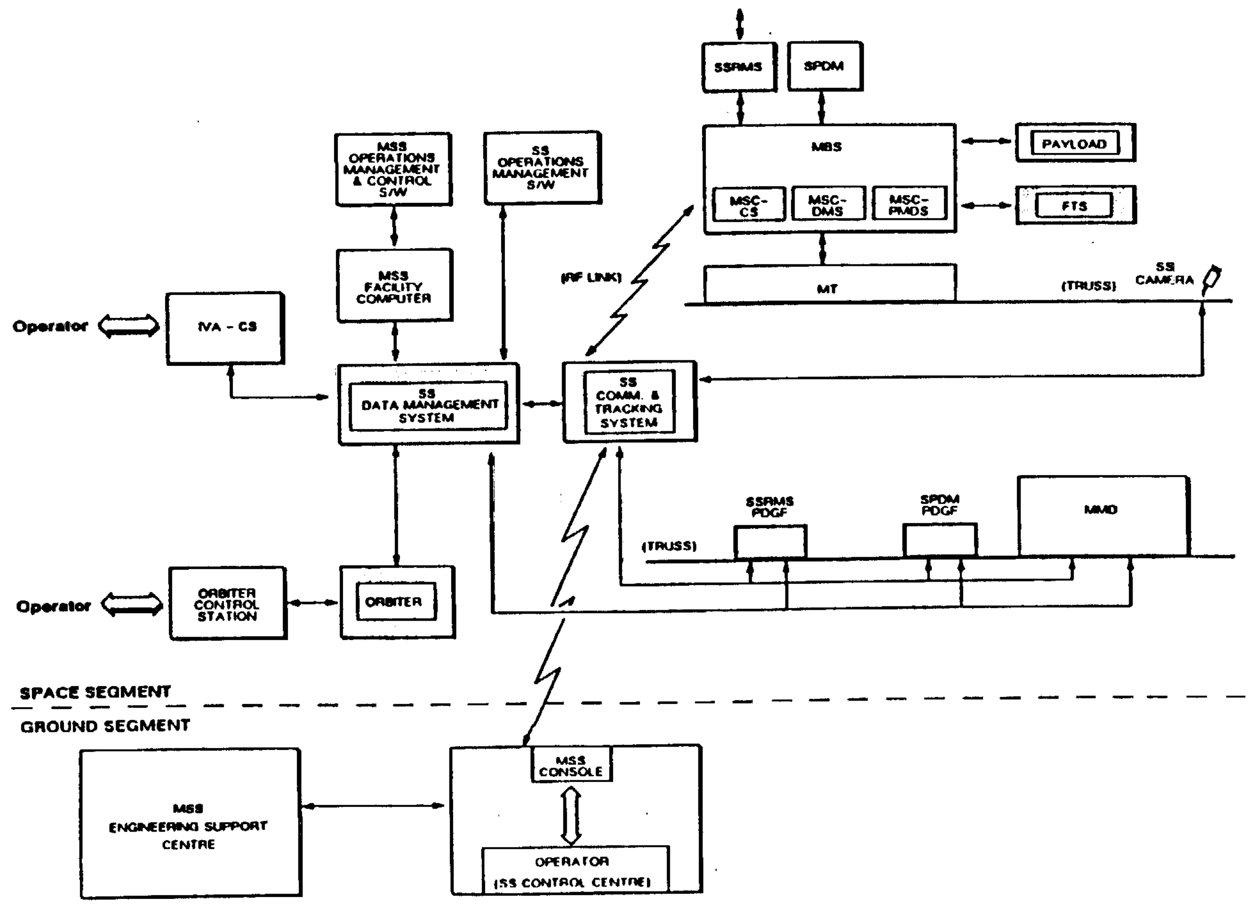
A. Transmission of 3 simultaneous color television signals originated by MSC-mounted television cameras.

B. RF reception of digital data and space station time reference transmitted from the space station to the MSC for control of the MSC.

C. RF transmission of telemetry data from the MSC to the space station.

D. Reception of orderwire data from the space station for MSC RF-terminal control and transmission of RF-terminal status and performance data to the space station C&T system.

COMMUNICATIONS AND TRACKING SYSTEM - MOBILE SERVICING SYSTEM -



SSF CONTAMINATION CONTROL REQUIREMENTS

The detailed implementation methods, controls, and responsibilities which are necessary to ensure external contamination requirements are met will be included in the Space Station Contamination Control Plan.

Some preliminary requirements associated with payloads such as the Advanced ESGP are summarized in the figure.

Requirements associated with vehicle processing in the assembly or servicing area include particulate deposition and molecular deposition as measured on a 300 K surface with an acceptance angle of 2 pi steradians.

During transfer of payload elements, component cleanliness levels will be maintained.

It is assumed that contamination covers and shields will be in place on all elements with optical sensors from shuttle launch until the final launch readiness sequence at SSF.

SSF CONTAMINATION CONTROL REQUIREMENTS

o SHUTTLE DELIVERY OF ESGP ELEMENTS
  CLEANED TO STD LEVEL DEFINED IN JSC-SN-C-0005

o MAIN CLUSTER SPACE STATION AND ESGP ELEMENTS

BACKGROUND SPECTRAL IRRADIANCE

ULTRAVIOLET (UV) MAX: 1.0 E -10 W/M**2/SR/NM
INFRARED (IR) MAX: 1.1 E -13 W/M**2/SR/NM

MOLECULAR COLUMN DENSITY

IR MOLECULES MAX: 3 E 11 MOLECULES/CM**2
UV MOLECULES MAX: 5 E 13 MOLECULES/CM**2

PARTICULATE BACKGROUND AND DEPOSITION

ONE PARTICLE 5 MICRONS/ORBIT/1 E 5 SR FOV
FOR 1 M DIA APERTURE TELESCOPE

MOLECULAR DEPOSITION

MASS DEPOSITION RATE: 1 E -14 G/CM**2/SEC
ON A 300K SURFACE WITH 2 PI SR ACCEPTANCE ANGLE

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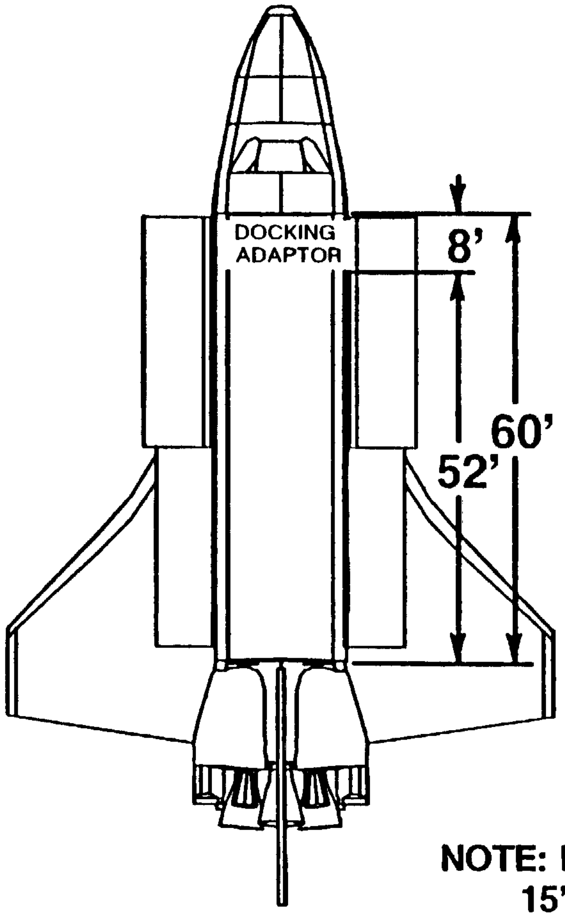
ESGP DELIVERY REQUIREMENTS

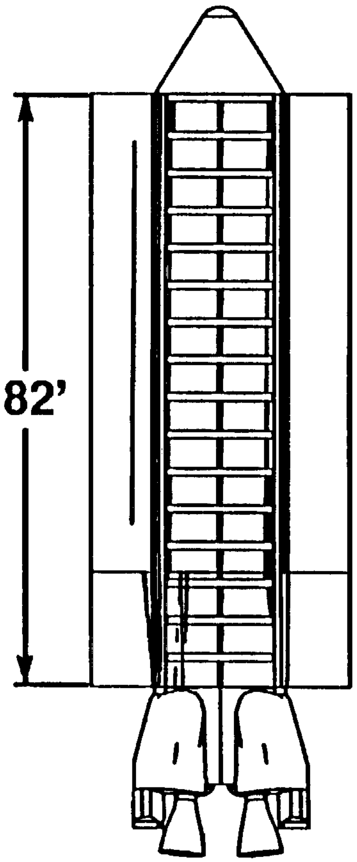
LAUNCH VEHICLE PAYLOAD BAY DIMENSIONS

The payload capabilities for both the Shuttle and Shuttle-C vehicles are shown in the figure. Both vehicles are capable of delivering the ESGP elements to the SSF orbit.

Two Shuttle launches are required to deliver all of the ESGP elements. All ESGP elements except for the truss assembly fixture can be accommodated in the Shuttle-C payload bay.

LAUNCH VEHICLE PAYLOAD BAY DIMENSIONS





NOTE: BOTH VEHICLES HAVE
15' DIAMETER BAYS

CAPABLE OF DELIVERING 41030 lbs
TO 220nm. ASRM's ADD 8000 lbs.

SHUTTLE

CAPABLE OF DELIVERING 88180
lbs TO 220nm.

SHUTTLE–C

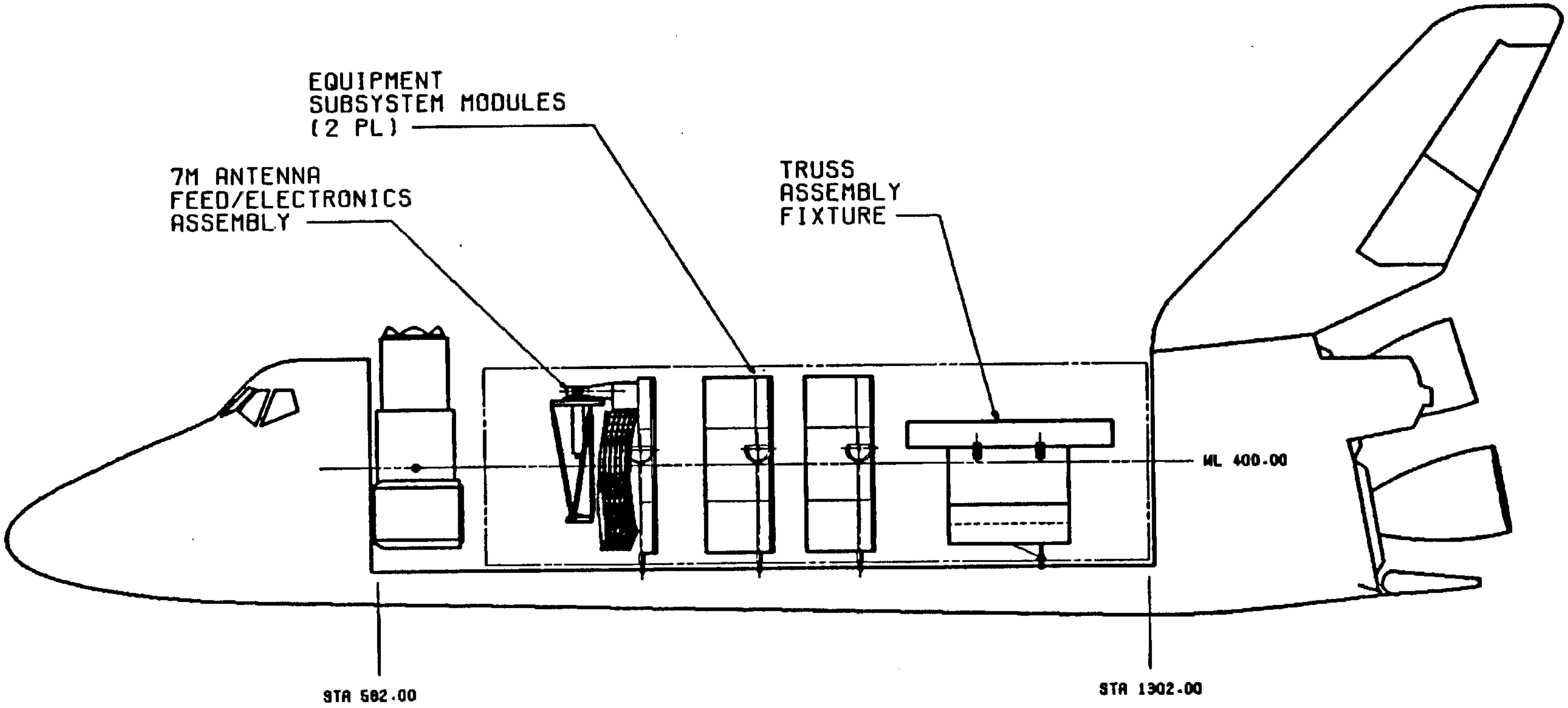
ADVANCED ESGP SHUTTLE LAUNCH ONE CONFIGURATION

The Shuttle was selected as the launch vehicle for the Advanced ESGP.

The figure shows the Shuttle launch one configuration for the Advanced ESGP and illustrates the stowed condition of the 7m antenna assembly, the two equipment subsystem modules, and the truss assembly fixture. The docking module assembly is shown at station 582.00.

ADVANCED ESGP
SHUTTLE LAUNCH ONE
- CONFIGURATION -

SHUTTLE LAUNCH ONE CONFIGURATION- INBOARD PROFILE

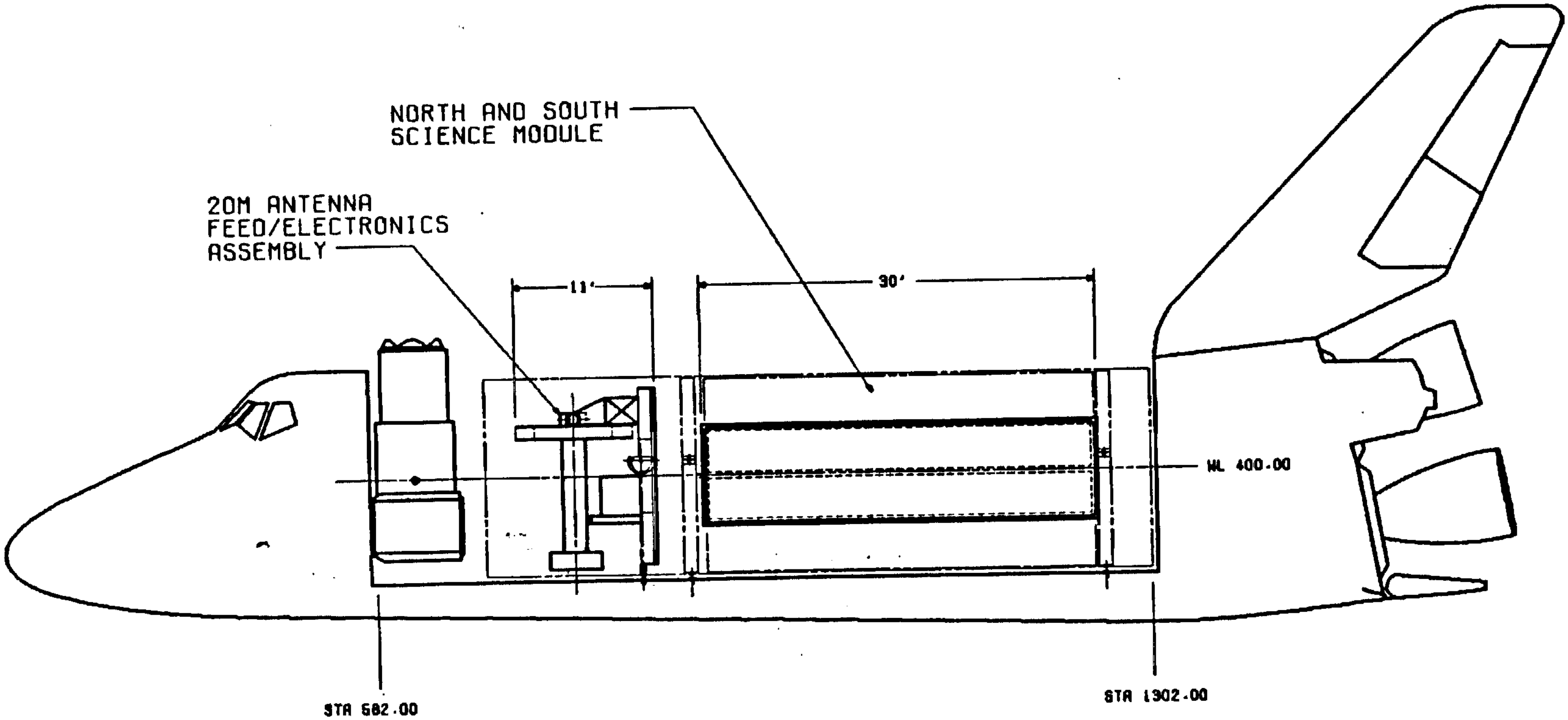


ADVANCED ESGP SHUTTLE LAUNCH TWO CONFIGURATION

The figure shows the Shuttle launch two configuration for the Advanced ESGP and illustrates the stowed condition of the 20m antenna assembly, and the north and south science module assemblies. The docking module assembly is shown at station 582.00.

ADVANCED ESGP
SHUTTLE LAUNCH TWO
- CONFIGURATION -

SHUTTLE LAUNCH TWO CONFIGURATION- INBOARD PROFILE

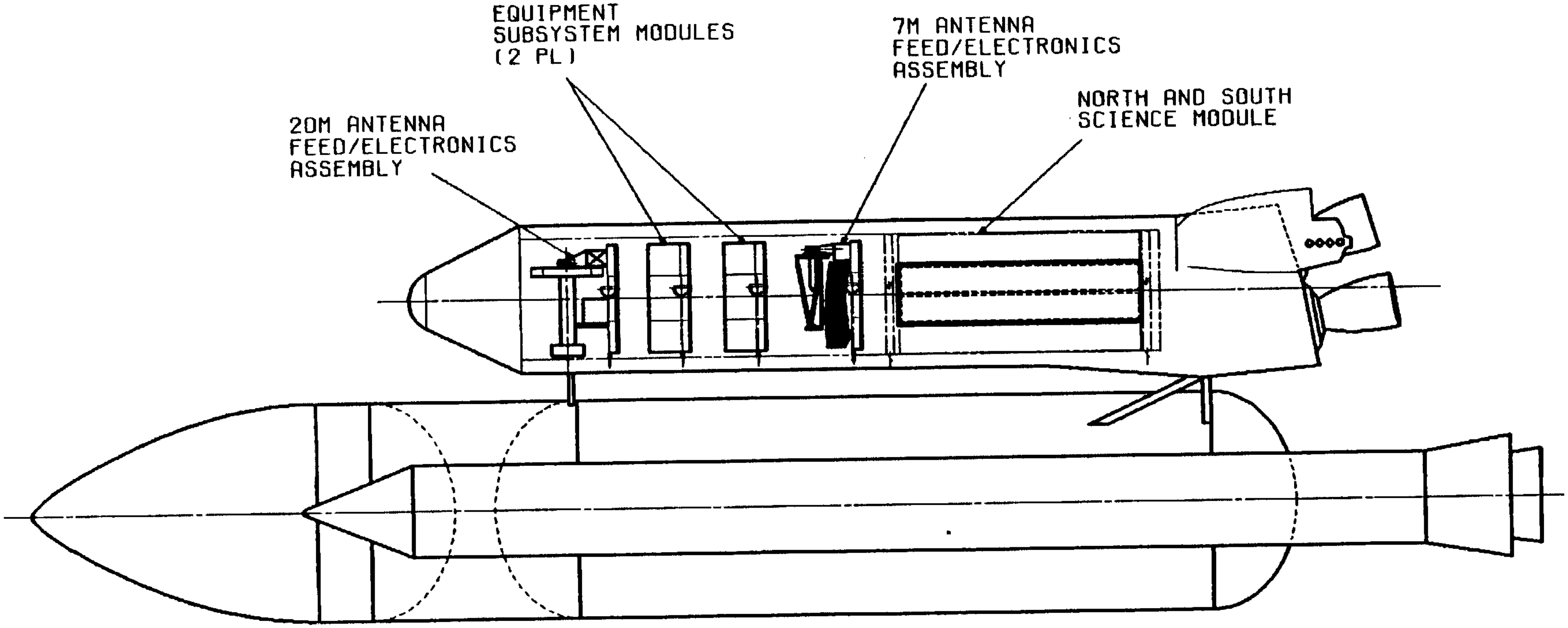


ADVANCED ESGP SHUTTLE-C LAUNCH CONFIGURATION

Although not selected as the baseline delivery launch vehicle, the configuration for a Shuttle-C launch is shown in the figure. All Advanced ESGP elements except for the platform truss assembly fixture can be accommodated in the Shuttle-C shroud.

ADVANCED ESGP
SHUTTLE C
- LAUNCH CONFIGURATION -

SHUTTLE C LAUNCH CONFIGURATION - INBOARD PROFILE

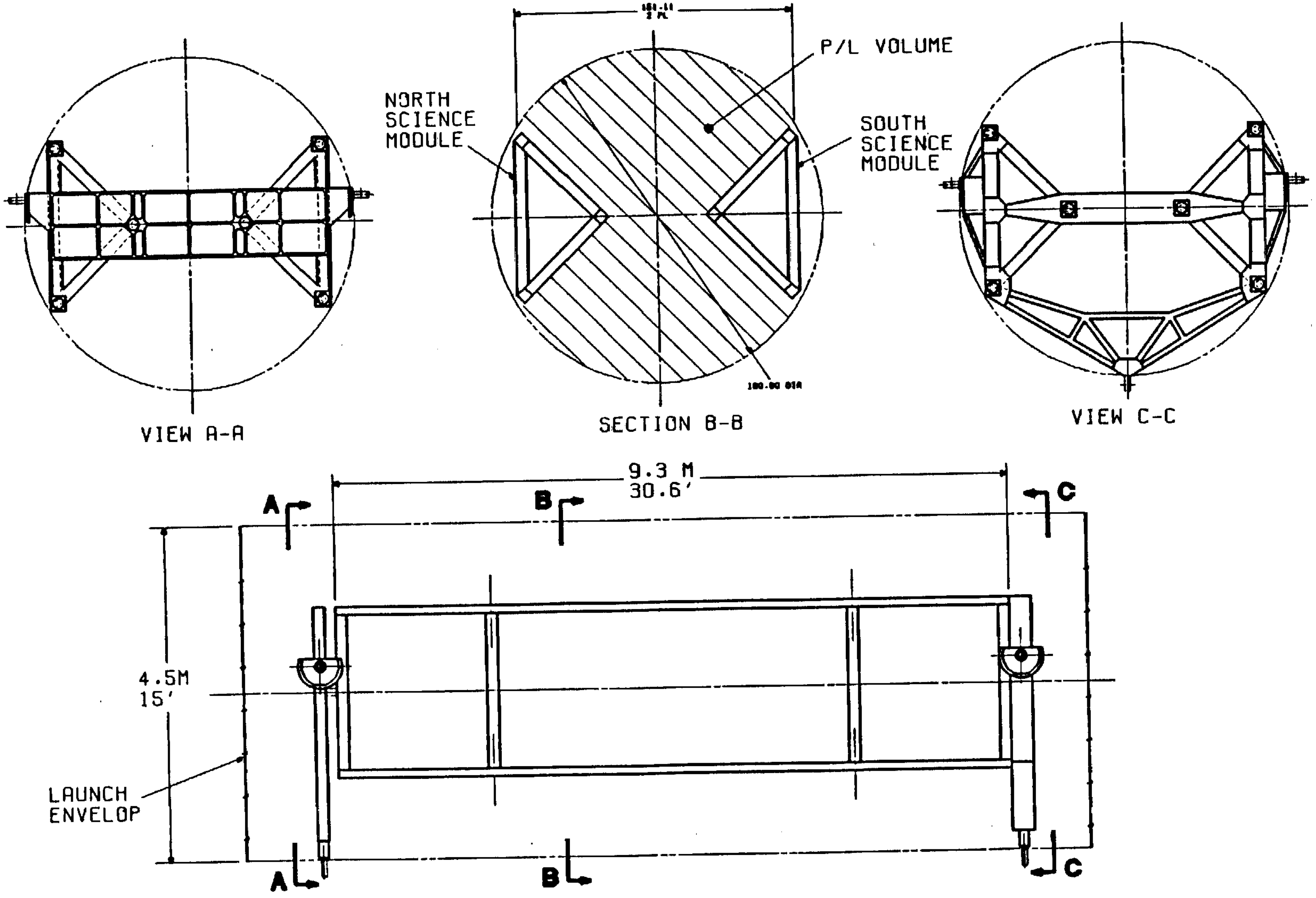


- THE TRUSS ASSEMBLY FIXTURE PRESUMED TO BE LOCATED AT SPACE STATION.
- THE TRUSS MEMBERS AND CABLE TRAYS ARE LOCATED ON THE SCIENCE MODULE.

ADVANCED ESGP SCIENCE MODULE LAUNCH CONFIGURATION

The configuration for launch of the Advanced ESGP science modules is shown in the figure. The shuttle cargo bay interfaces/attachment points are identified for structural support.

ADVANCED ESGP SCIENCE MODULE - LAUNCH CONFIGURATION -



STV VELOCITY REQUIREMENTS FOR ESGP DELIVERY

A two-impulse all-propulsive delivery is optimal, since energy requirement and hence propellant requirements, are minimized with this method. The plane change angle for delivery is 238.5 deg requiring a delta V of approximately 13800 ft/sec (fps). The impulse distribution is 7970 fps at GEO transfer orbit insertion and 5830 fps at GEO orbit insertion. Impulse transfer to GEO from the SSF in a 200 nm, 28.5 deg inclined orbit would begin with a large (8000 fps) POSIGRADE burn at the STV crosses the equator. This raises apogee to the GEO altitude of 19323 nm and makes 2.2 deg of the plane change. At apogee, a second burn of 6000 fps circularizes the orbit and provides the ramainder of the plane change (26.3 deg). The standard geosynchronous transfer orbit will be used in the platform delivery mission. The STV-ESGP will incur a 180 deg longitude change during the transfer while the Earth will rotate almost 80 deg during the 5.25 hour transfer. Minimization of costly orbit plane change maneuvers dictate that the STV inject the ESGP into the GEO transfer orbit at or near the equator. The time of the GEO transfer injection will be based on a nodal crossing opportunity which places the platform within 25 deg of the desired longitude.

STV VELOCITY REQUIREMENTS FOR ESGP DELIVERY

C2

	VELOCITY REQUIREMENT
OUTBOUND PHASE (ALL PROPULSIVE)	
1. OTV/SPACE STATION SEPARATION	20.0 fps
2. GEO SYNCHRONOUS TRANSFER ORBIT INSERTION	7,944.8 fps
3. GEO SYNCHRONOUS LONGITUDE DRIFT ORBIT INSERTION	5,589.7 fps
4. CIRCULARIZATION AT GEO SYNCHRONOUS ALTITUDE	262.3 fps
SUBTOTAL	13,816.8 fps
RETURN PHASE (OTV AEROBRAKING/AEROMANEUVERING RETURN)	
1. OTV /GEO PLATFORM SEPARATION	20.0 fps
2. LEO TRANSFER ORBIT INSERTION	5,924.4 fps
3. LEO PARKING ORBIT INSERTION	603.1 fps
4. OTV RENDEZVOUS PHASING MANEUVER	216.1 fps
5. OTV HEIGHT MAEUVER	319.5 fps
6. OTV STABLE ORBIT MANEUVER	99.9 fps
7. OTV TERMINAL RENDEZVOUS MANEUVERS	17.2 fps
SUBTOTAL	7,199.0 fps
TOTAL MISSION VELOCITY REQUIREMENTS	21,016.7 fps

TIMELINE FOR ESGP DELIVERY TO GEO

The figure shows the event timeline, orbital parameters, and velocity requirements for ESGP delivery to GEO.

This phase of the ESGP delivery operations includes STV support operations to payload activation, checkout and the physical release of the platform from the STV. After release, the STV will perform a retrograde separation maneuver to move away from the platform. This separation maneuver should be initiated near the SSF orbit plane node to minimize performance requirements of the returning STV. A velocity requirement of 20 fps is assumed adequate for completion of this maneuver.

Although not included in the timeline, the space-based STVs aerobraking/aeromaneuvering capabilities will be employed in the return to SSF. The aerobraking substitutes dissipation of orbital energy for STV propulsion. The STV will be inserted into transfer orbit to LEO and then a LEO parking orbit prior to SSF rendezvous. The LEO transfer will bring the STV to 400,000 ft altitude to dissipate orbital energy and hence lower apogee from 19323 nm to 400 nm. As in GEO, the majority of the orbital plane change (26.3 deg) will occur in the transfer phase. The STV will coast to the 400 nm apogee an perform maneuvers to circularize this orbit.

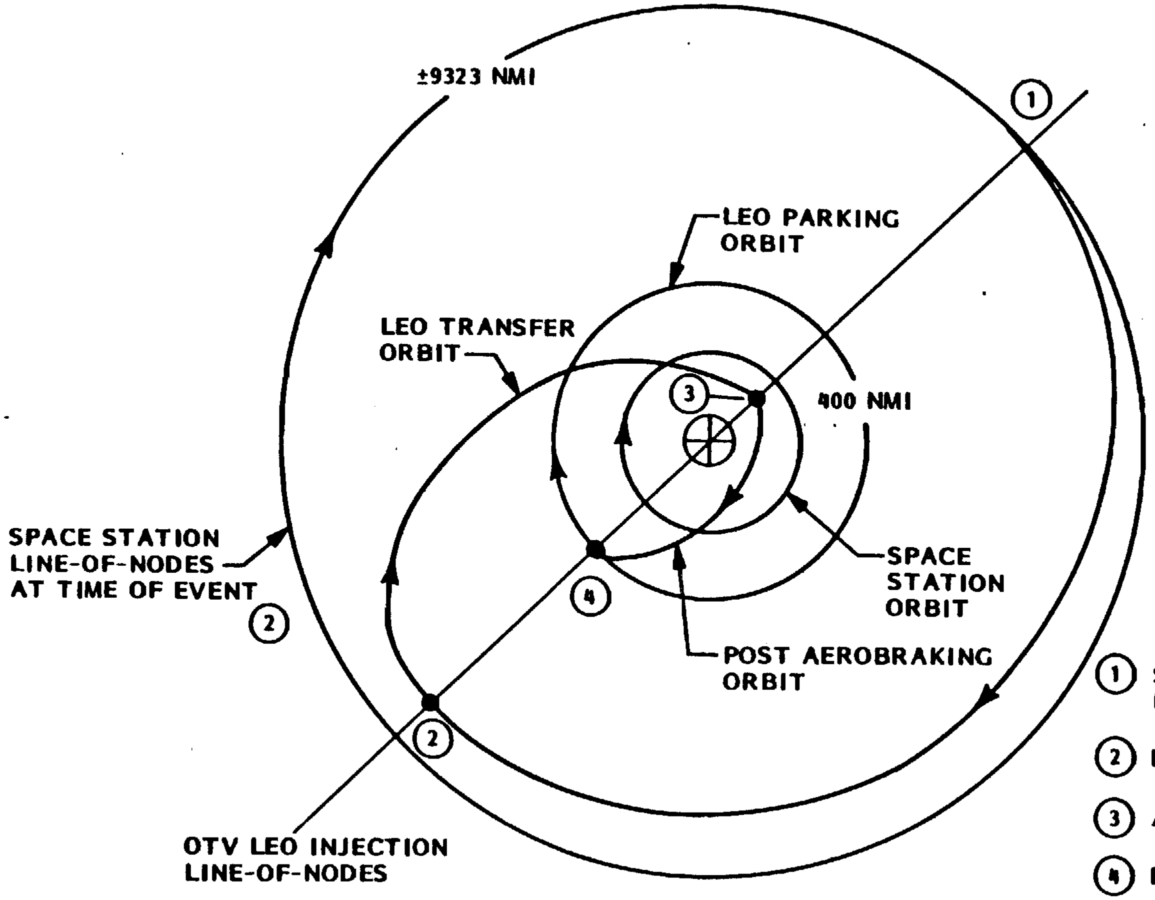
TIMELINE FOR ESGP DELIVERY TO GEO

EVENT NUMBER	EVENT	MISSION ELAPSED TIME (d:h:m:s)	DURATION (d:h:m:s)	Ha/Hp (nmi)	INCL (deg)	WEDGE ANGLE (deg)	DELTA V (fps)	COMMENTS
0	INITIAL SPACE STATION ORBIT			200/200	28.5			
1	OTV SEPARATION	0:00:00:00		210/200	28.5	0	20	OTV PERFORMS SEPARATION MANEUVER FROM SSF AT NODAL CROSSING
2	COAST FOR 4 ORBITAL PERIODS		0:06:08:05	210/200	28.5			COAST DURATION IS ASSUMED FOR ANY POSTDEPLOYMENT CHECK etc
3	OTV INSERTION TO GEO TRANSFER ORBIT	0:06:08:05		19323/210	26.3	2.2	7944.8	OPTIMUM HEIGHT AND PLANE CHANGE MANEUVER
4	COAST TO EQUATOR		0:05:16:36					COAST 1/2 REVOLUTION
5	INSERT INTO LONGITUDE DRIFT ORBIT	0:11:24:41		19323/17174	0	28.5	5598.2	DELTA V DEPENDS ON AMOUNT OF LONGITUDE PHASING, ONE REV COAST FOR LONGITUDE PLACEMENT ASSUMED
6	COAST TO MIDCOURSE MANEUVER		0:11:07:53					COAST TO EQUATOR OR 1/2 REV AFTER INSERTING INTO LONGITUDE DRIFT ORBIT
7	PERFORM MIDCOURSE MANEUVER IF REQUIRED	0:22:32:34		19323/17174	0			ORBITAL DISPERSIONS REQUIRED MIDCOURSE MANEUVER
8	COAST TO GEO ALTITUDE		0:11:07:53					
9	CIRCULARIZE AT GEO	1:09:40:27		19323/19323	0		262.3	OTV ATTAINS REQUIRED ALTITUDE AND LONGITUDE FOR GEO PLATFORM DEPLOYMENT
	WEDGE ANGLE: ANGLE BETWEEN OTV AND SSF ORBITS							

STV RETURN TO SPACE STATION

The STV will complete at least two orbital revolutions (200 min) in the LEO parking orbit prior to transferring to SSF at the 200 nm altitude. This will be required for data acquisition, processing and any required command activities associated with STV/SSF rendezvous. The STV will then be inserted into a phasing orbit and finally a height adjustment maneuver will be performed to place the STV 15 nm behind SSF.

STV RETURN PHASE TO LEO PARKING ORBIT



① SEPARATION FROM GEOSTATIONARY PLATFORM

② LEO TRANSFER ORBIT INSERTION

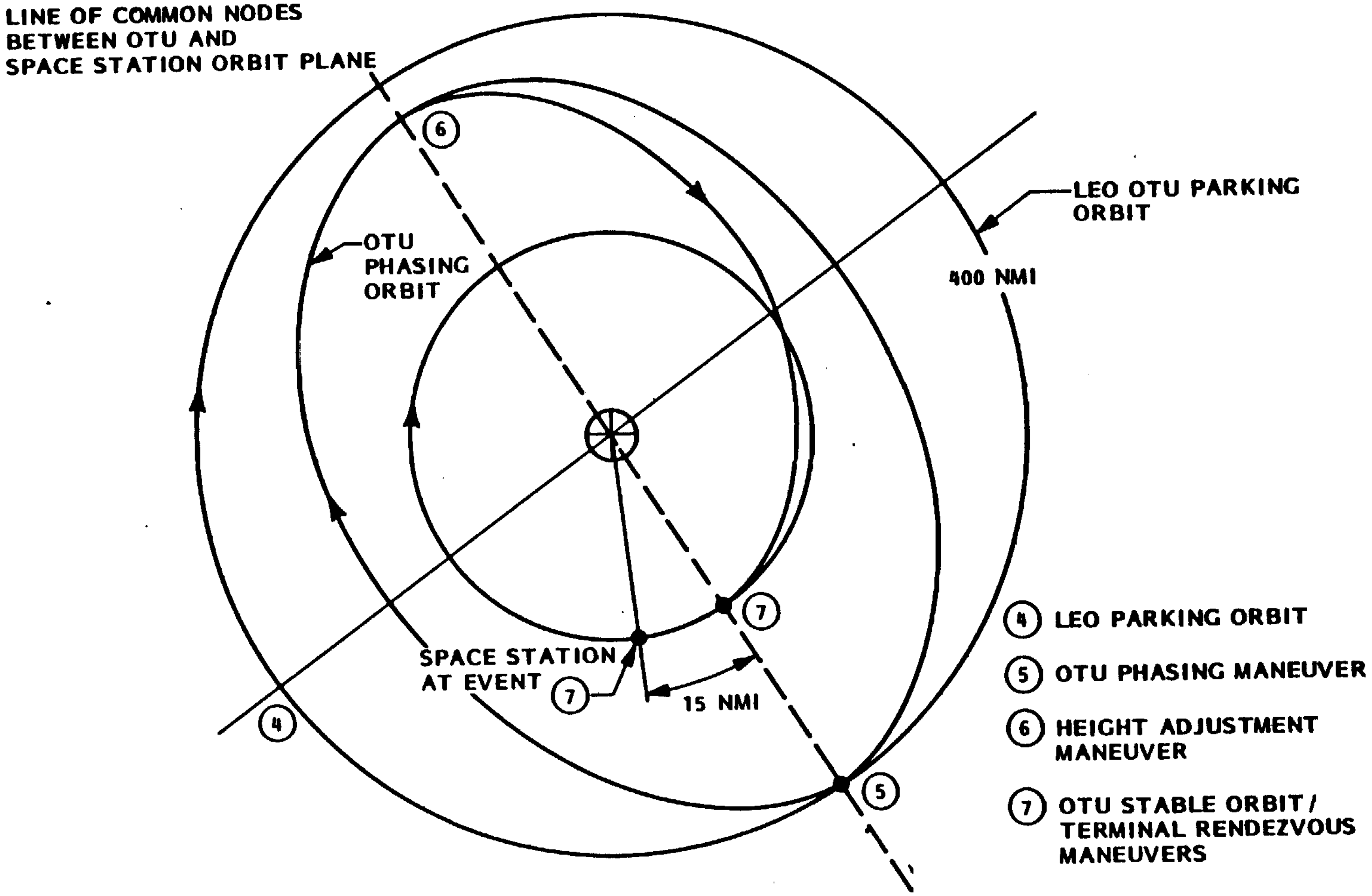
③ AEROBRAKING/AEROMANEUVER

④ LEO PARKING ORBIT INSERTION

STV/SSF RENDEZVOUS

The STV terminal rendezvous maneuvers will be performed for STV capture by SSF. The STV will trail SSF for at least two orbits. The provides an opportunity to complete any STV reconfiguration functions that may be required. After the STV has been prepared for rendezvous operations, maneuvers are performed to bring the STV to the SSF.

STV - SSF RENDEZVOUS



④ LEO PARKING ORBIT

⑤ OTU PHASING MANEUVER

⑥ HEIGHT ADJUSTMENT MANEUVER

⑦ OTU STABLE ORBIT / TERMINAL RENDEZVOUS MANEUVERS

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ESGP
VEHICLE ASSEMBLY REQUIREMENTS

FACILITY, EQUIPMENT & PROCESSES ASSUMPTIONS FOR ESGP ASSEMBLY

The following assumptions concerning facility, equipment, and processes were made for the analysis of assembly and processing of the ESGP vehicle.

The shuttle vehicle was selected as the Advanced ESGP launch vehicle and two shuttle launches are required to lift all ESGP elements to the SSF.

The hangar facility will be an enclosed structure to provide micrometeorite, thermal and sun-impingement protection. A section of the enclosed structure will be opened to enable transfer of equipment.

The ESGP platform truss assembly operations will take place on an assembly work platform located on the lower keel.

Two mobile servicing centers will be dedicated to the assembly and processing of the Advanced ESGP.

All fueling will be performed at a co-orbiting PTF. The fully assembled ESGP will be transported to the PTF using an OMV-like vehicle. The mating of the ESGP and LTV will take place on the PTF.

NASA SPACE FLIGHT

FACILITY, EQUIPMENT & PROCESSES ASSUMPTIONS FOR ESGP ASSEMBLY

Lockheed

- ESGP ELEMENTS LIFTED TO SSF IN TWO SHUTTLE LAUNCHES
- HANGAR FACILITY STORAGE & ENVIRONMENTAL PROTECTION AVAILABLE FOR ESGP ELEMENTS
- PLATFORM TRUSS ASSEMBLY PERFORMED ON ASSEMBLY WORK PLATFORM (AWP) ON LOWER KEEL
- TWO MOBILE SERVICING CENTERS AVAILABLE FOR ASSEMBLY / VERIFICATION & CHECKOUT TASKS
- FUELING & STV MATING OPERATIONS PERFORMED AT CO - ORBITING PROPELLANT TANK FARM

ESGP ASSEMBLY CONFIGURATION AT SSF

The assembly operation locations are identified on the figure. There are four specific locations involved in ESGP assembly and processing.

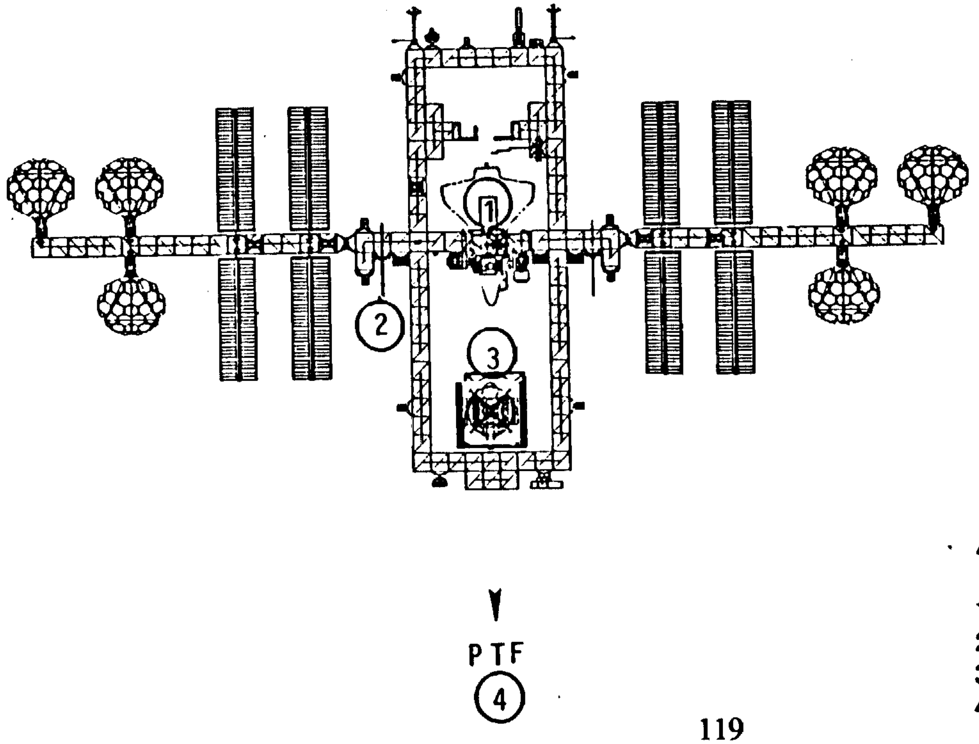
Area 1 is the shuttle docking area and payload bay where ESGP elements are removed from the shuttle.

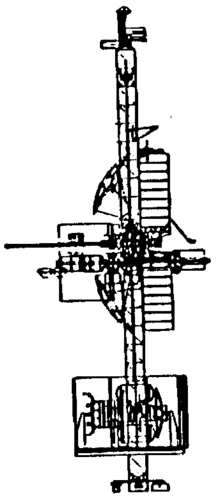
Area 2 is the ESGP platform assembly area on the lower keel and contains the Assembly Work Platform (AWP).

Area 3 is the hangar assembly and storage area which is used to store the ESGP elements and the FTS.

Area 4 is the propellant tank farm (PTF) where fueling operations are conducted. The PTF is in co-orbit with SSF.

ESGP ASSEMBLY CONFIGURATION AT SSF





- ASSEMBLY OPS LOCATIONS

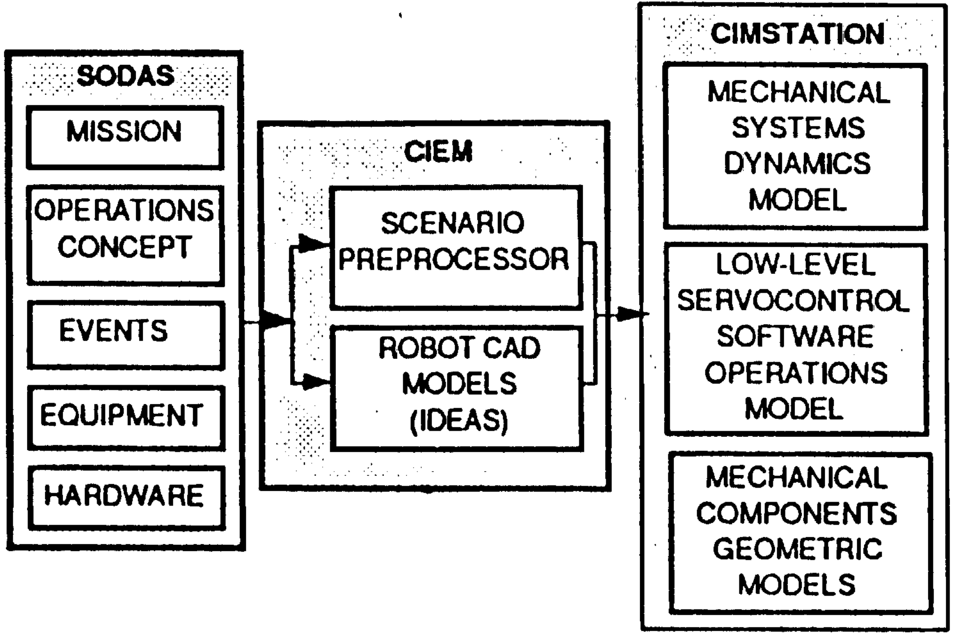
1. SHUTTLE DOCKING AREA - P / L BAY
2. PLATFORM ASSEMBLY AREA - LOWER KEEL
3. HANGAR ASSEMBLY & STORAGE AREA
4. PROPELLANT TANK FARM - CO-ORB PLATFORM

INTEGRATED SODAS, CIEM AND CIMSTATION SYSTEM INTERFACE

Specific representative events in the mission scnearios created by SODAS can be decomposed into FTS and MSC robotic primitives and used for time-motion studies. These primitives can be used to build three-dimensional solid models using the Lockheed-developed CIEM System. As shown in the figure, the CIEM-generated geometric solid models of the mechanical components are then used by the robotic simulator system CimStation. CimStation is used to integrate the geometric models with the dynamics models of the mechanical components and operations models of the low-level servocontrol software to produce three-dimensional animations of robotic manipulators.

EVA, IVA, and robotic work analyses, combined with the timelines, cost, and resources and crew requirements analyses can be used to detemine trade-offs between EVA, IVA, telerobotic, and robotic operations.

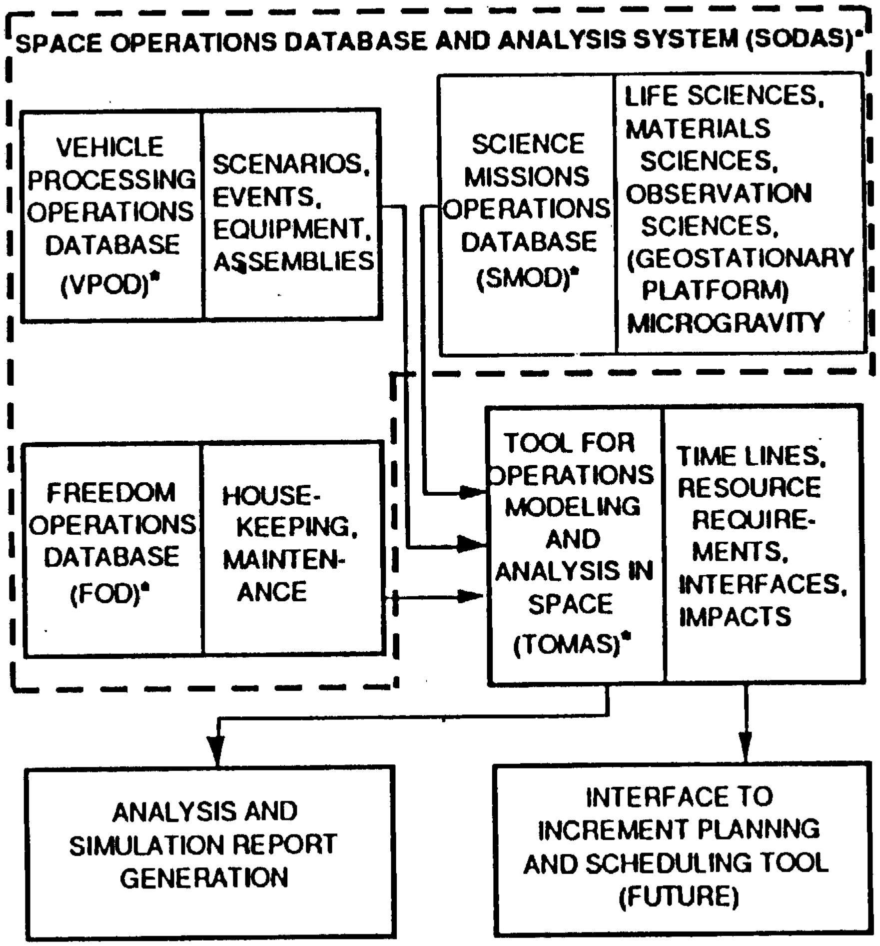
INTEGRATED SODAS, CIEM AND CIMSTATION SYSTEM INTERFACE



INTEGRATED SPACE OPERATIONS MODELING AND ANALYSIS SYSTEM

The figure shows the planned Integrated Space Operations Modeling and Analysis System that is required to complete a detailed on-orbit assembly/servicing study. Lockheed recognizes that vehicle and mission design is dynamic at the present stage of Advanced Geostationary Platform definition. To respond to evolving vehicle definition, automated analysis tools are needed. For NASA/LaRC, CTA developed the Space Operations Database and Analysis System (SODAS), which includes the Vehicle Processing Operations Database (VPOD), the Science Missions Operations Database (SMOD), and SSF Freedom Operations Database (FOD). The Tools for Operations Modeling and Analysis in Space (TOMAS) models on-orbit operations and SSF resources and physical conditions such as communications and viewing interfaces and impacts, and is used to assess integrated requirements at SSF.

INTEGRATED SPACE OPERATIONS MODELING & ANALYSIS SYSTEM



*DEVELOPED FOR LaRC BY CTA

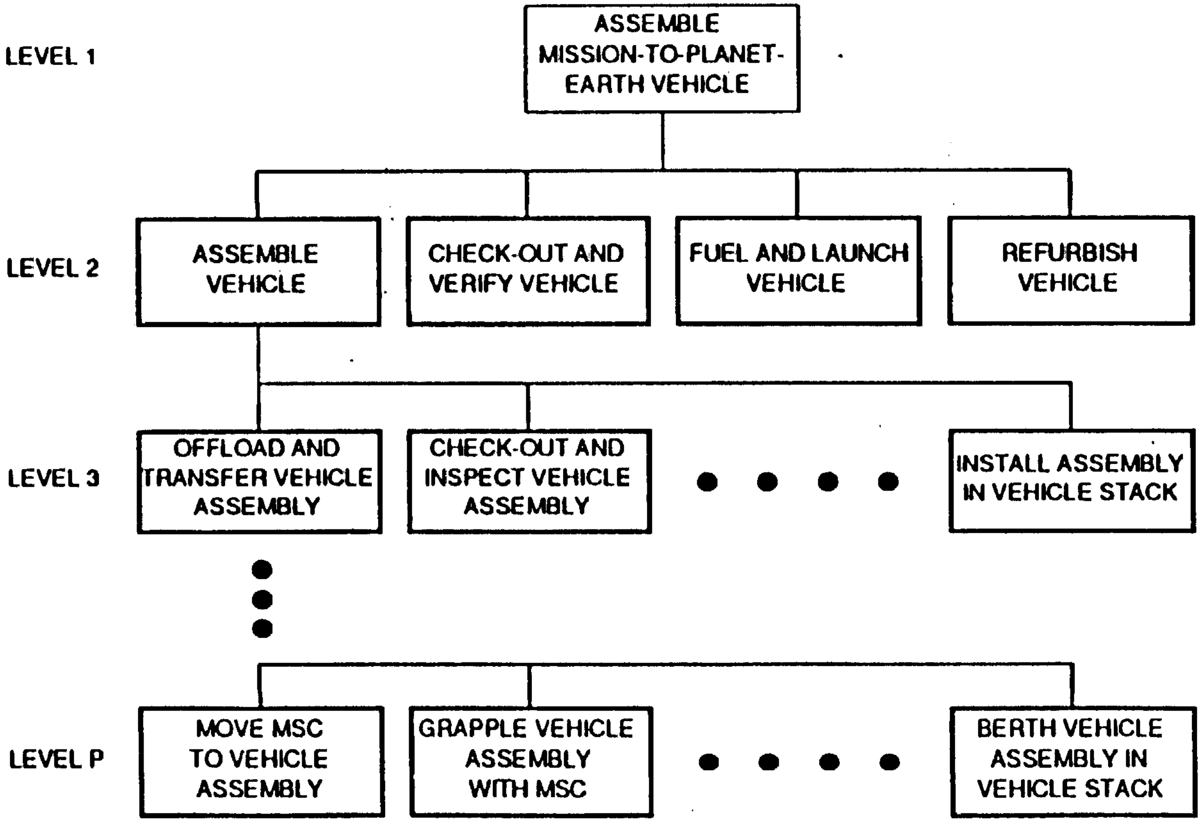
VPOD EVENTS HIERARCHY - EXAMPLE -

The Vehicle Processing Operations Database (VPOD) is an element of the Space Operations Database and Analysis System (SODAS) and was used in this analysis for the hierarchial decomposition and sequencing of events that need to be performed to assemble and process Advanced ESGP vehicles at the SSF.

Using the functional hierarchy, the events necessary to meet a goal or mission (e.g. Assembly of the ESGP) can be defined at several levels of detail, with lower levels providing greater resolution of the assembly process.

A complete description of VPOD and SODAS is included in Appendix C.

VPOD EVENTS HIERARCHY
- EXAMPLE -



LEVEL 1

ASSEMBLE MISSION-TO-PLANET-EARTH VEHICLE

LEVEL 2

ASSEMBLE VEHICLE

CHECK-OUT AND VERIFY VEHICLE

FUEL AND LAUNCH VEHICLE

REFURBISH VEHICLE

LEVEL 3

OFFLOAD AND TRANSFER VEHICLE ASSEMBLY

CHECK-OUT AND INSPECT VEHICLE ASSEMBLY

INSTALL ASSEMBLY IN VEHICLE STACK

LEVEL P

MOVE MSC TO VEHICLE ASSEMBLY

GRAPPLE VEHICLE ASSEMBLY WITH MSC

BERTH VEHICLE ASSEMBLY IN VEHICLE STACK

ASSEMBLY OPERATIONS FUNCTIONAL FLOWS

A top level functional flow of ESGP assembly operations is included in the figures. The functional flow includes the assembly task, the operations location, the crew operations (EVA/IVA) and equipment resource requirements.

The assembly tasks are described for four major event categories:

1: Assemble Geoplatform vehicle

2: Verify Geoplatform vehicle operation

3: Fueling of the Geostationary vehicle

4: Launching of the Geostationary vehicle

ASSEMBLY OPERATIONS FUNCTIONAL FLOWS

ASSEMBLY TASK	OPS LOCATION	CREW OPS	COMMENTS
1. **ASSEMBLE GEOPLATFORM VEHICLE (ESGP)**			
1.1 UNSTOW ESGP ELEMENTS	P/L BAY (1)	IVA	MSC USING 2 P/L SUPPORT ASSMs (PSA)
1.2 TRANSPORT ESGP ELEMENTS	HGR FAC (3)	IVA	MSC 6 HR / TRIP (ref #20)
			AVG PWR: 2.6 kW AVG THRM: 1.0 kW
1.3 CONFIGURE AWP FOR ASSEMBLY	LWR KEEL ASSM AREA (2)	IVA	MSC (3 HR)
		EVA	FTS
1.4 ASSEMBLE PLATFORM TRUSS	2	IVA	MSC (2 DAYS)
AND INSTALL UTILITY TRAYS			FTS (SEE TASK ANALYSIS)
		EVA	OPTIONAL EVA ASSM (2 hrs)
			see LMSC/SSAT
1.5 ASSEMBLE 7m RADIOMETER ANTENNA	3	IVA / EVA	MSC (2), FTS (12 hrs)
1.6 RETRIEVE ESGP ELEMENTS	3	IVA	MSC (3 hr / TRIP)
1.7 ATTACH ESGP ELEMENTS	2	IVA	MSC (2)
		EVA	FINAL ALIGNMENT MAY REQUIRE EVA
2. **VERIFY GEOPLATFORM VEHICLE**			GROUND OPER. DIRECTED TASKS
2.1 PERFORM VEHICLE INSPECTION	2	IVA	MSC w/CAMERA
2.2 TEST VEHICLE END-TO-END SYSTEM			SUBSYSTEM & MIN SI C/O & TEST (2 days)
			AVG POWER: 10 kW/hr
			AVG THERMAL: 3 kW/hr
			ENG DATA LINK < 1 Mbps
			CMD LINK 50 kbps
2.3 VERIFY LAUNCH / FUELING READINESS		IVA	32 hrs

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ASSEMBLY OPERATIONS FUNCTIONAL FLOWS

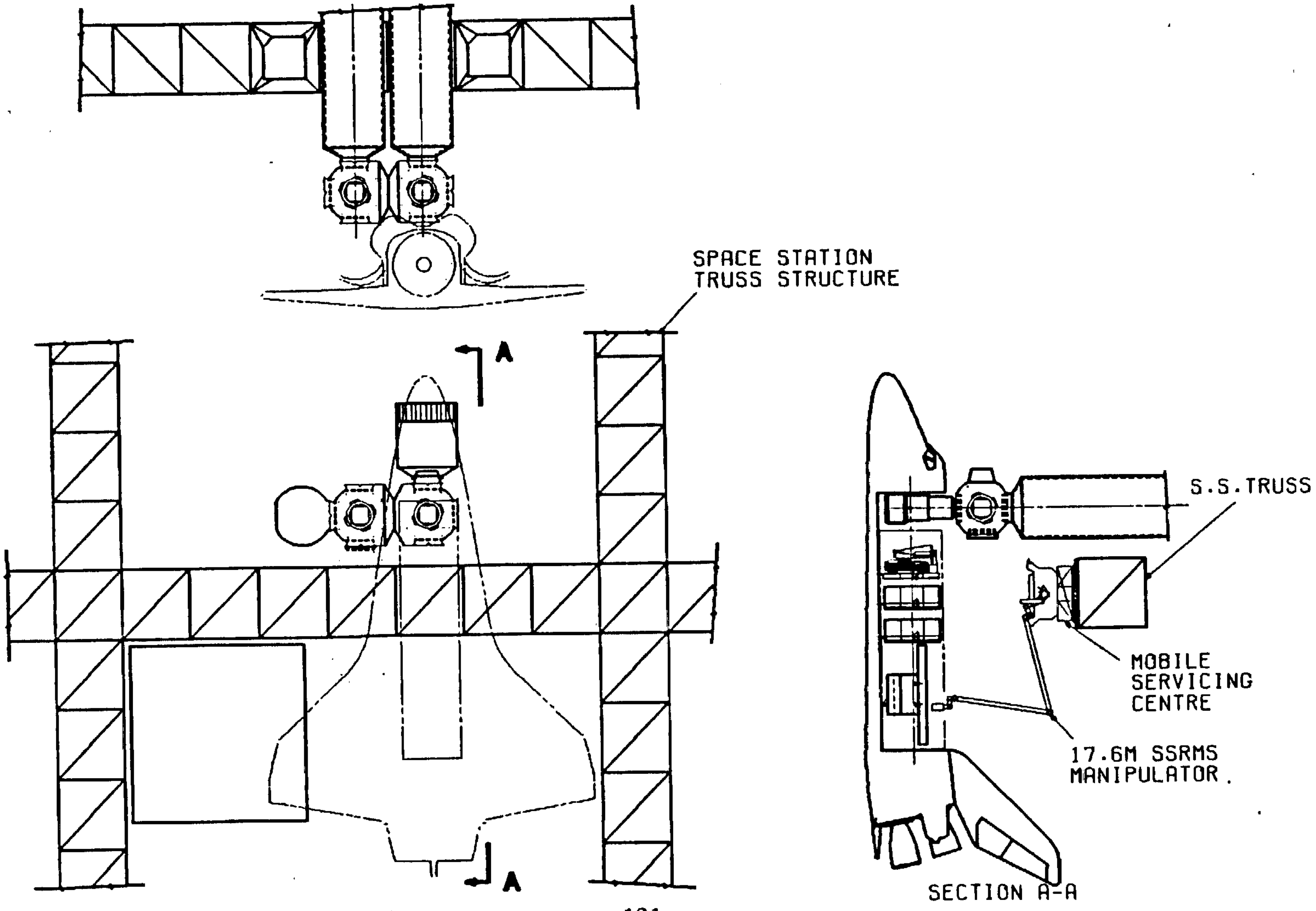
ASSEMBLY TASK	OPS LOCATION	CREW OPS	COMMENTS
3. FUELING GEOPLATFORM VEHICLE			GRD OPER DIRECTED TASKS
3.1 BERTH OMV TO VEHICLE	2	IVA	MSC (4 hrs)
3.2 EGRESS ASSEMBLY AREA	2	IVA	MSC
3.3 VERIFY VEHICLE CLEARANCE		IVA	MSC WITH CAMERA
3.4 TRANSPORT TO PTF WITH OMV		IVA	
3.5 BERTH VEHICLE TO PTF	PTF (4)	IVA	SPACE CRANE (4 hrs)
3.6 RETRIEVE LTV & MATE TO VEHICLE	4	IVA	SPACE CRANE
3.7 VERIFY VEHICLE LAUNCH READINESS			TOTAL LTV PROCESSING TIME = 121 SHIFTS
			(ref #18)
4. LAUNCHING GEOPLATFORM VEHICLE			GRD OPER DIRECTED TASKS
4.1 INITIATE COUNT-DOWN		IVA	1 DAY
4.2 LAUNCH PLATFORM			

ADVANCED ESGP TRANSFER FROM SHUTTLE TO SSF

The figure shows the docking location of the shuttle at SSF. The Advanced ESGP elements shown in the shuttle payload bay are transferred to the SSF by the SSRMS of the Mobile Servicing Centre.

ADVANCED ESGP TRANSFER FROM SHUTTLE TO SSF

COMPONENTS TRANSFER FROM SHUTTLE TO SPACE STATION

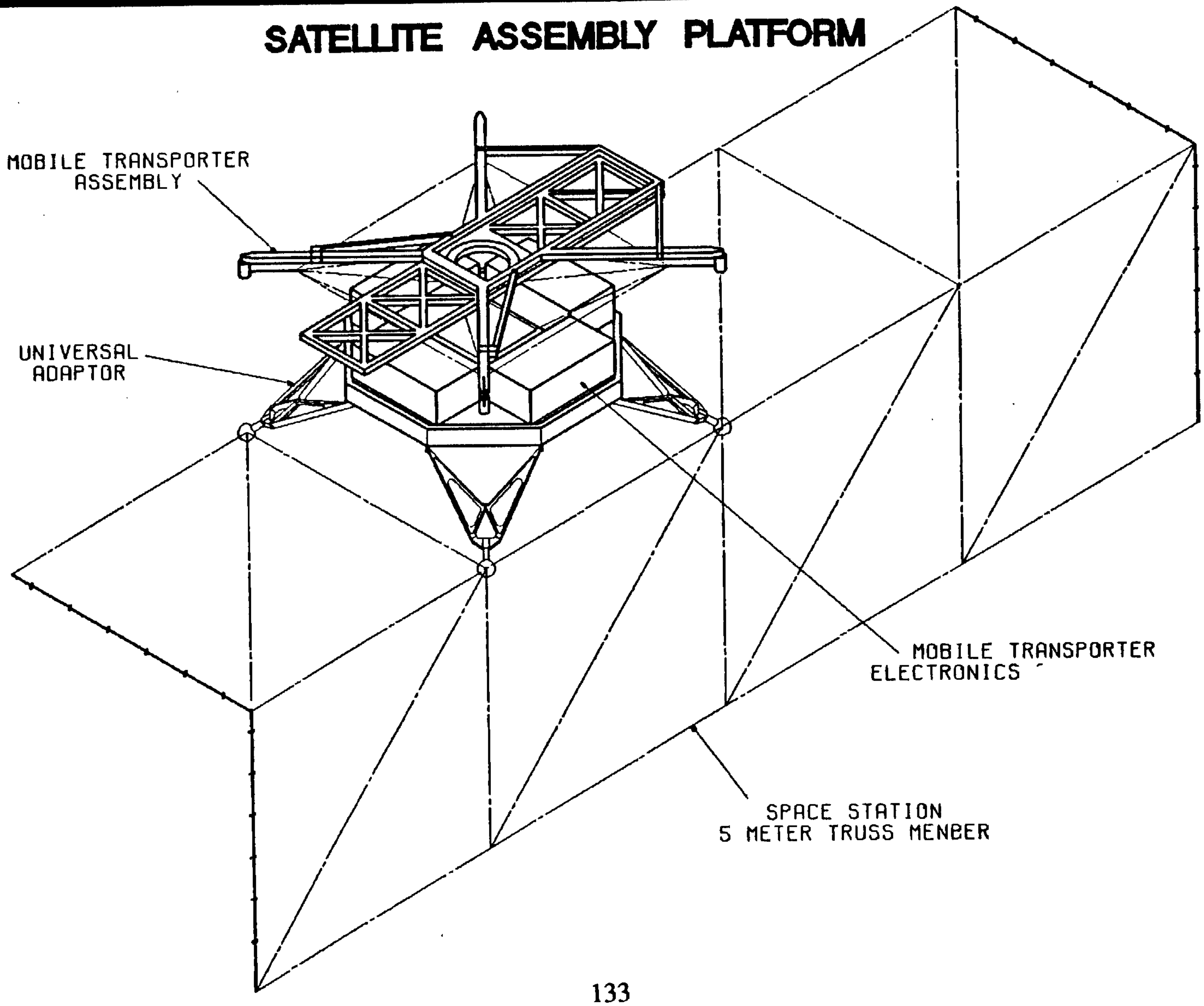


ADVANCED ESGP ASSEMBLY PLATFORM

The figure shows the first stage of the ESGP assembly process. A dedicated mobile transporter assembly is used to accommodate the ESGP Assembly Work Platform (AWP).

ADVANCED ESGP ASSEMBLY PLATFORM

SATELLITE ASSEMBLY PLATFORM

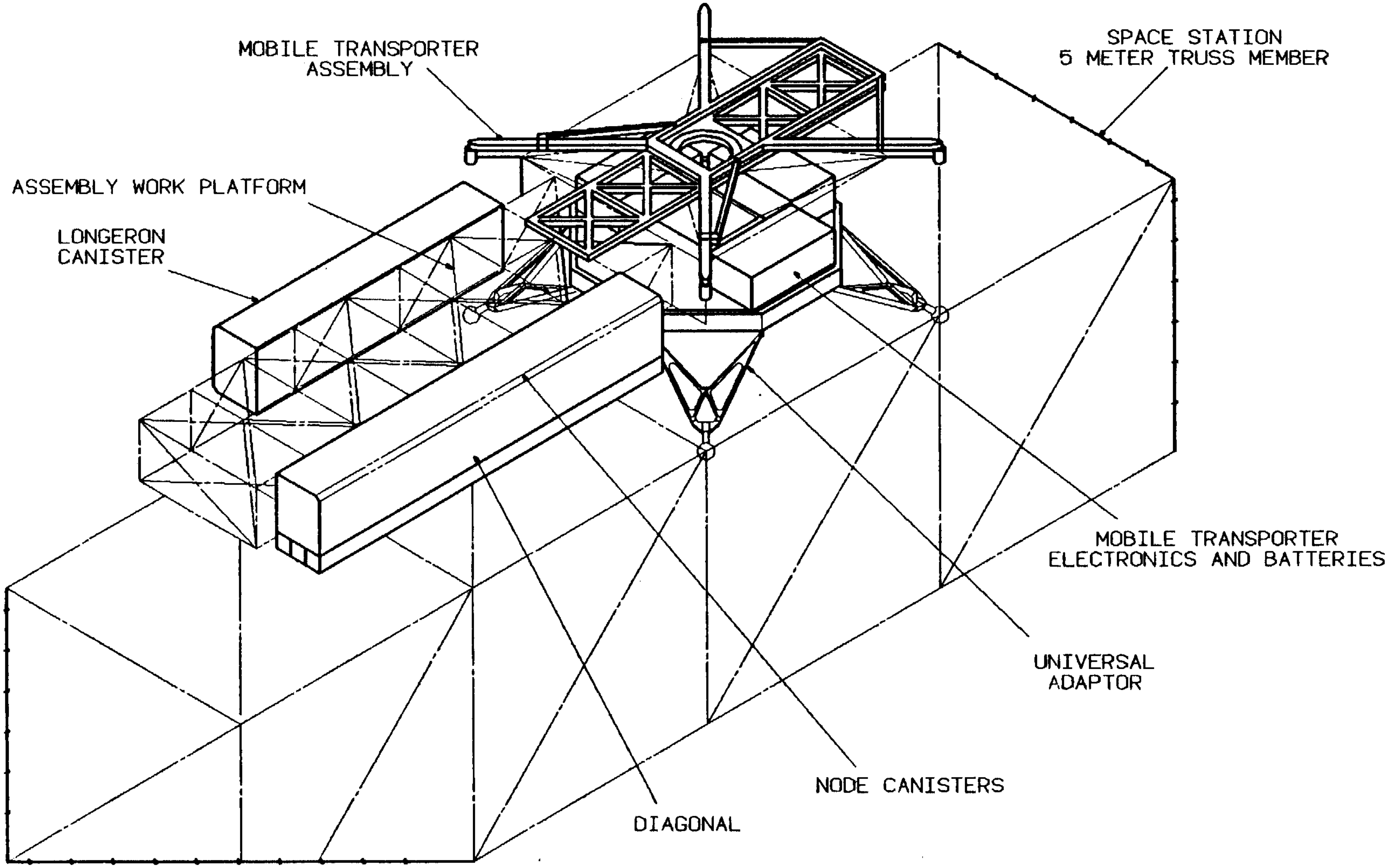


ADVANCED ESGP ASSEMBLY WORK PLATFORM

The Assembly Work Platform, shown in the figure, is similar to the one used during initial SSF assembly operations. The AWP is used to store the longeron, diagonal and node cannisters used to construct the ESGP platform.

ADVANCED ESGP ASSEMBLY WORK PLATFORM

SATELLITE ASSEMBLY PLATFORM

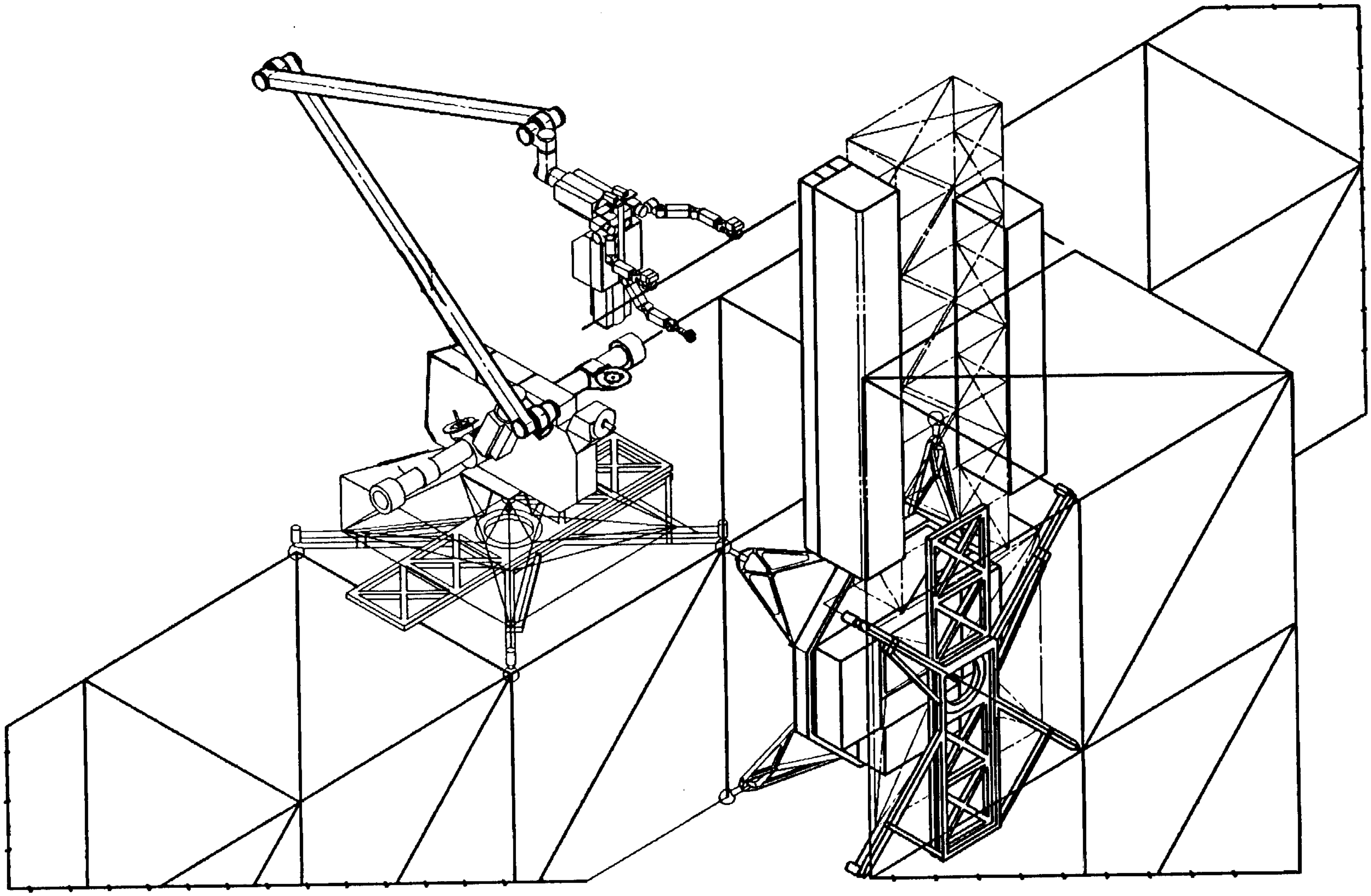


ADVANCED ESGP PLATFORM TRUSS ASSEMBLY

The figure shows the configuration used to construct the ESGP platform. Two SSRMS arms are used on the MSC. One SSRMS is mated with an FTS that is used to remove the individual truss elements from the canisters and install them on the platform assembly. A detailed task analysis of the FTS truss assembly sequence is included and is the basis for time estimates in the top-level functional flow analyses.

ADVANCED ESGP
PLATFORM TRUSS ASSEMBLY

PLATFORM TRUSS ASSEMBLY



MODULE TRANSFER CONSTRAINT TO ADVANCED ESGP

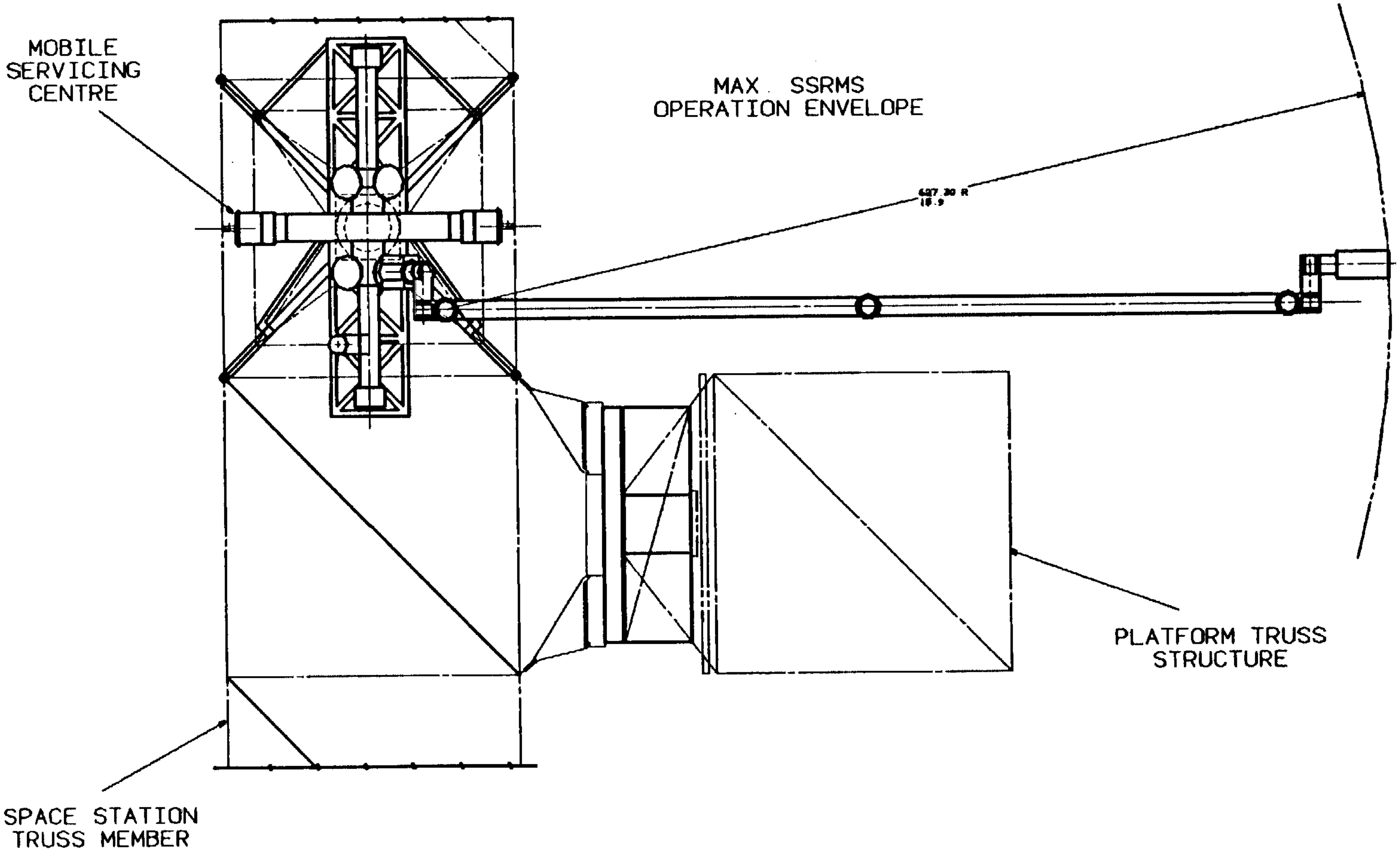
The maximum SSRMS operation envelope for ESGP assembly is shown in the figure. Details of the SSRMS characteristics are included in Appendix B.

NASA SPACE FLIGHT

MODULE TRANSFER CONSTRAINT TO ADVANCED ESGP

Lockheed

MODULE TRANSFER FROM MSS TO PLATFORM

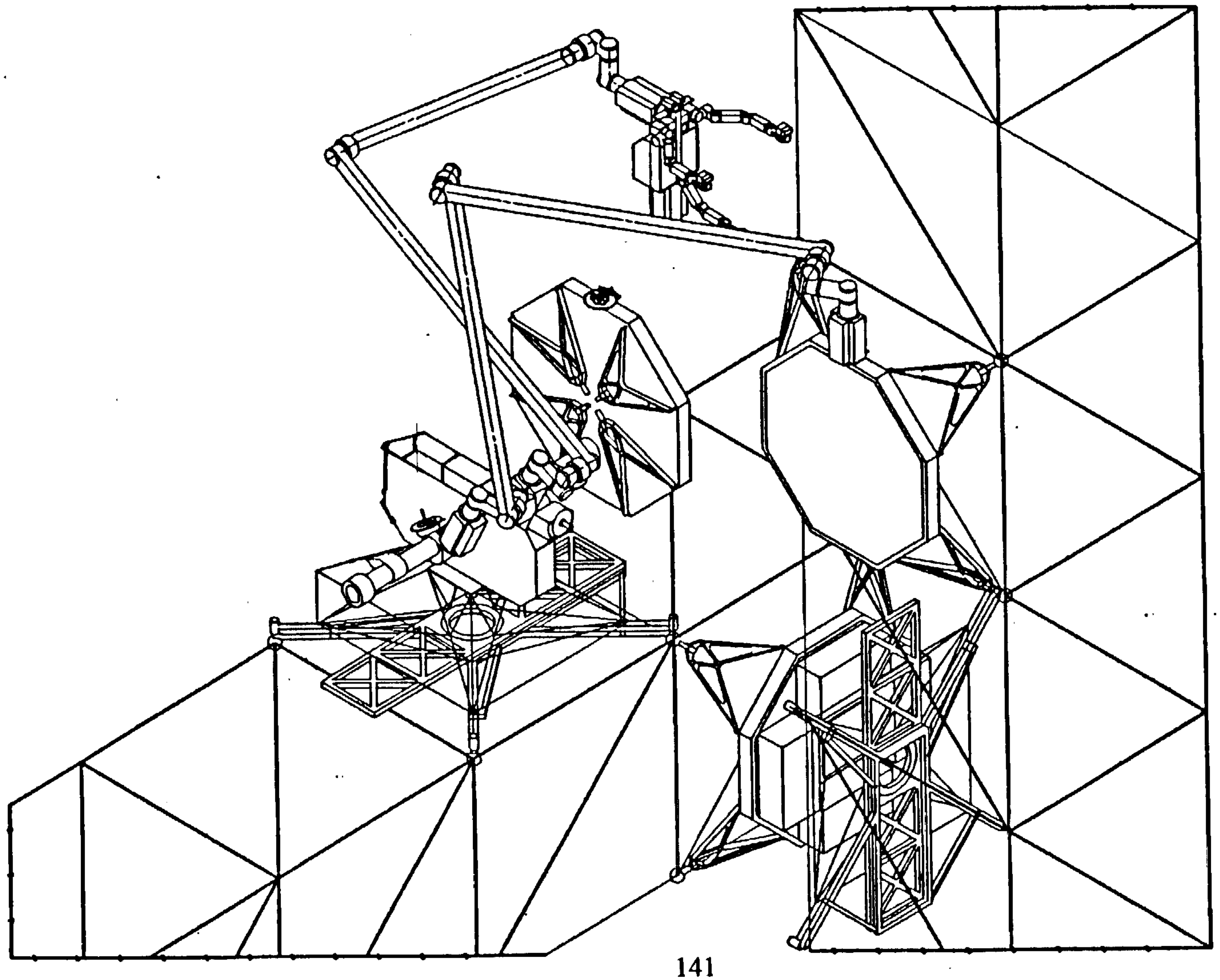


MODULE TRANSFER TO ADVANCED ESGP

The attachment of ESGP elements on the completed truss assembly is shown in the figure. The attachment is done on a standard interface assembly. Two MSC's are required to complete module transfer on the ESGP platform assembly.

MODULE TRANSFER
TO ADVANCED ESGP

MODULE TRANSFER FROM MSS TO PLATFORM



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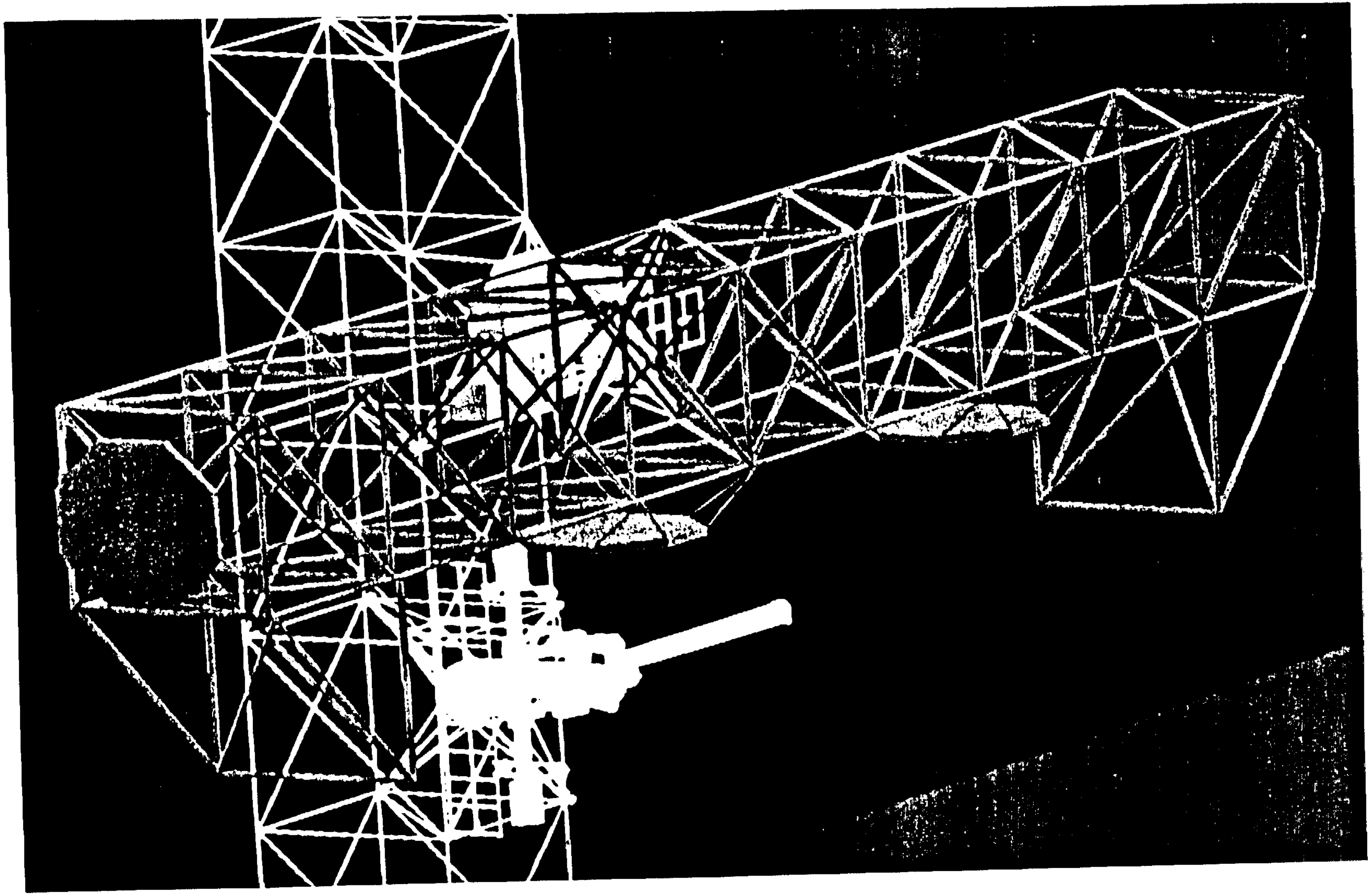
NASA SPACE FLIGHT

CIMSTATION
ADVANCED ESGP ERECTED STRUCTURE VIEW

Lockheed



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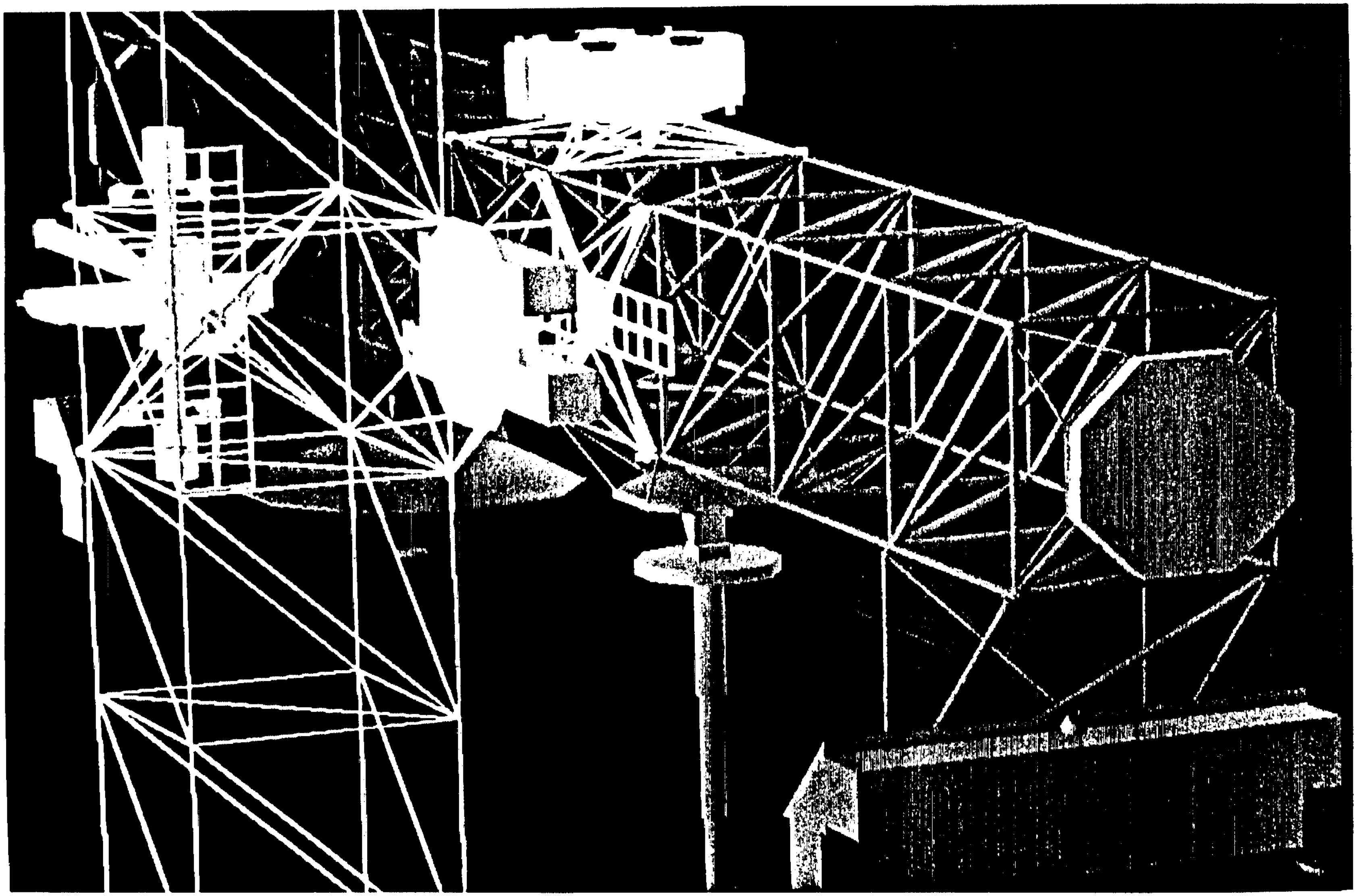
NASA SPACE FLIGHT

CIMSTATION
ADVANCED ESGP ERECTED STRUCTURE VIEW

Lockheed



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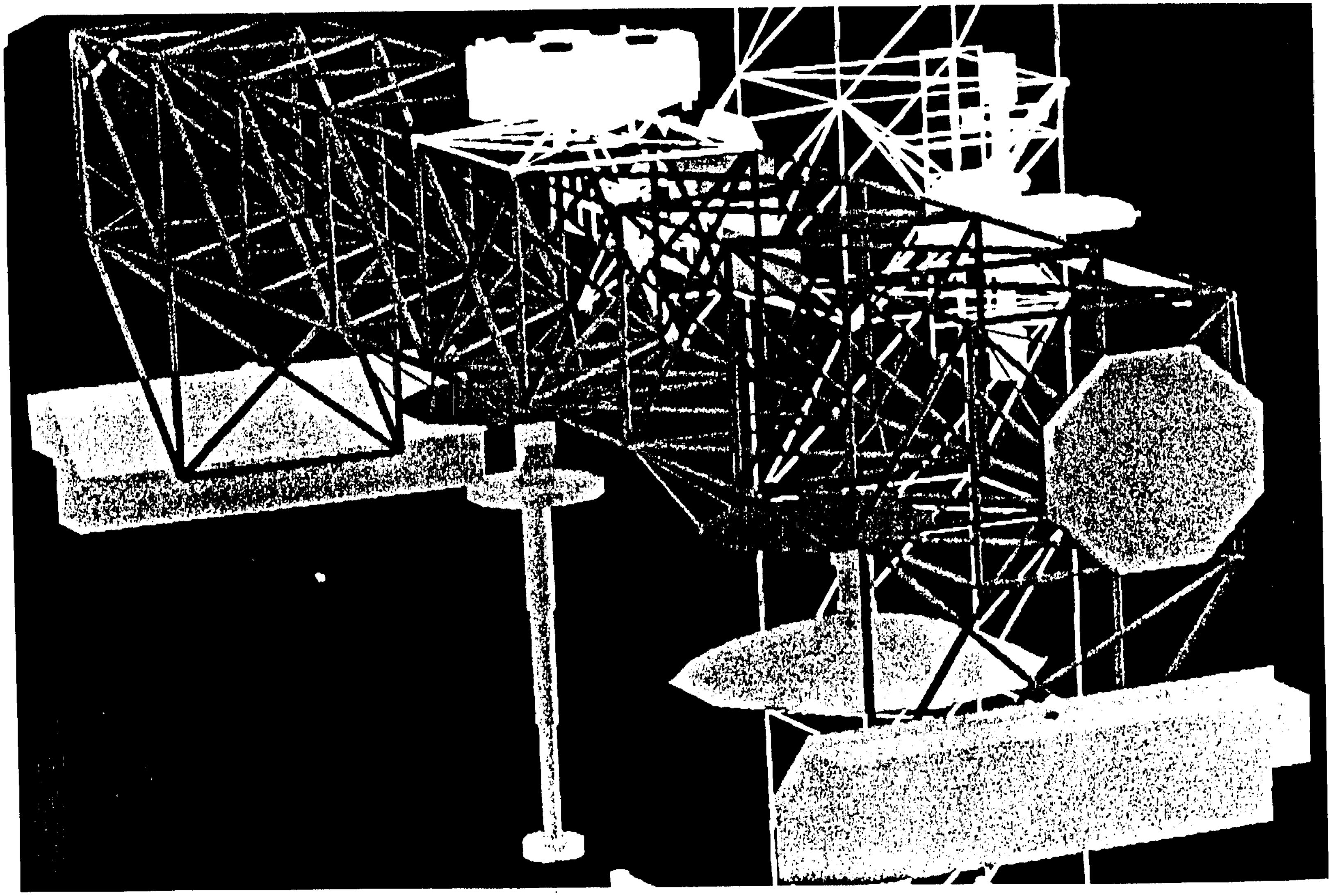
NASA SPACE FLIGHT

CIMSTATION
ADVANCED ESGP ERECTED STRUCTURE VIEW

Lockheed



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ADVANCED ESGP IN HANGAR ASSEMBLY - VOLUMETRIC REQUIREMENT -

The ESGP assembly assumptions indicated that the primary assembly area for the ESGP platform truss is the lower keel area. If the hangar facility area was used to construct the ESGP, it would require a significant increase in size and additional bottom truss support as indicated in the figure.

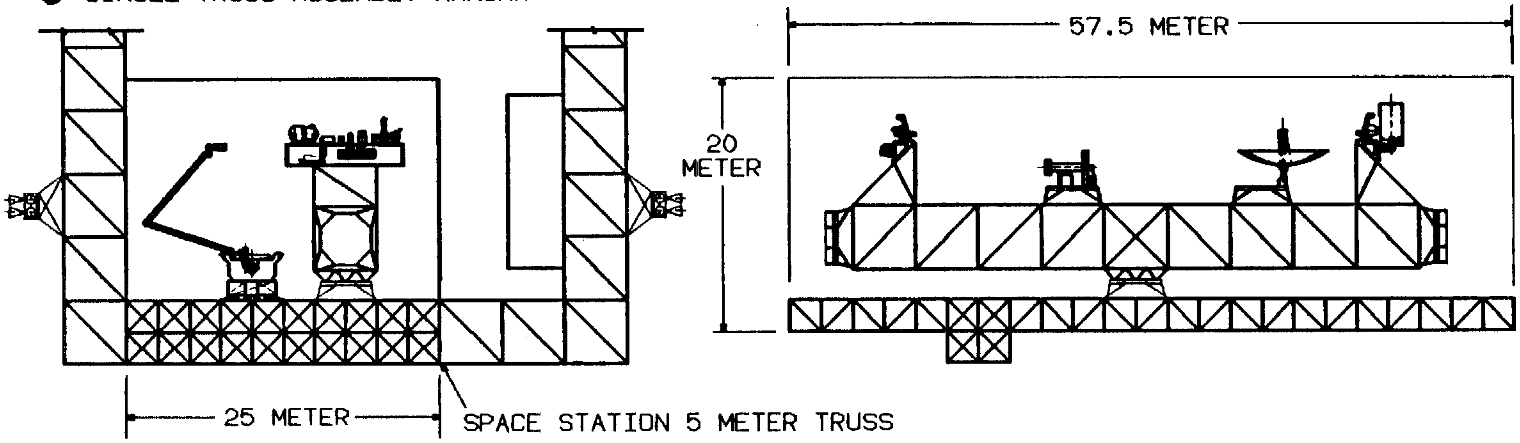
An external volume of 57.5m x 20m x 35m would be required for assembly of the ESGP vehicle.

The double truss assembly hangar external volume requirement shown on the bottom of the figure is 35m x 35m x 17.5m; however, the two truss elements would have to be mated outside of the hangar assembly facility and again require additional bottom truss support.

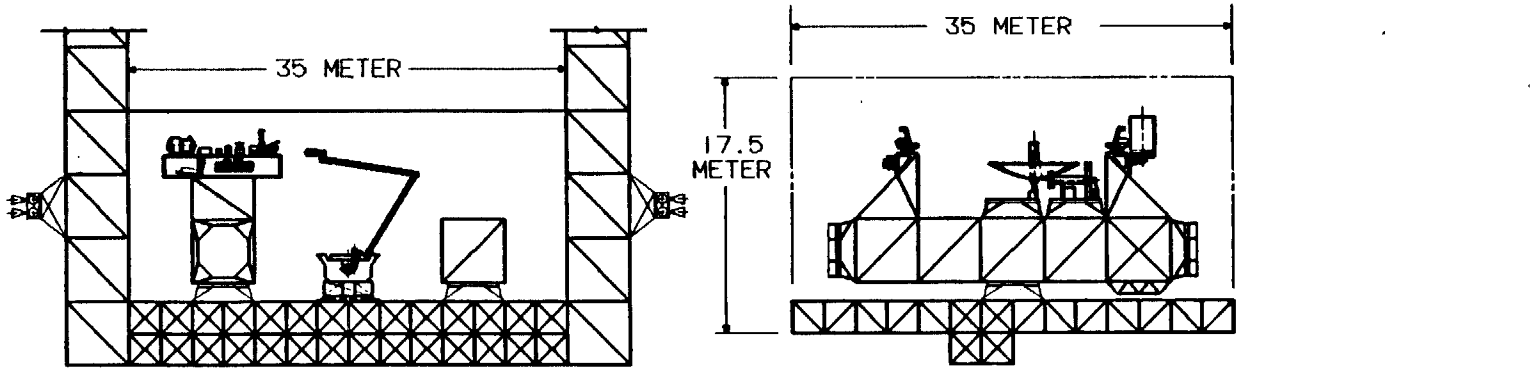
ADVANCED ESGP IN HANGAR ASSEMBLY VOLUMETRIC REQUIREMENT

IN HANGAR ASSEMBLY - VOLUMETRIC REQUIREMENT

- SINGLE TRUSS ASSEMBLY HANGAR



- DOUBLE TRUSS ASSEMBLY HANGAR

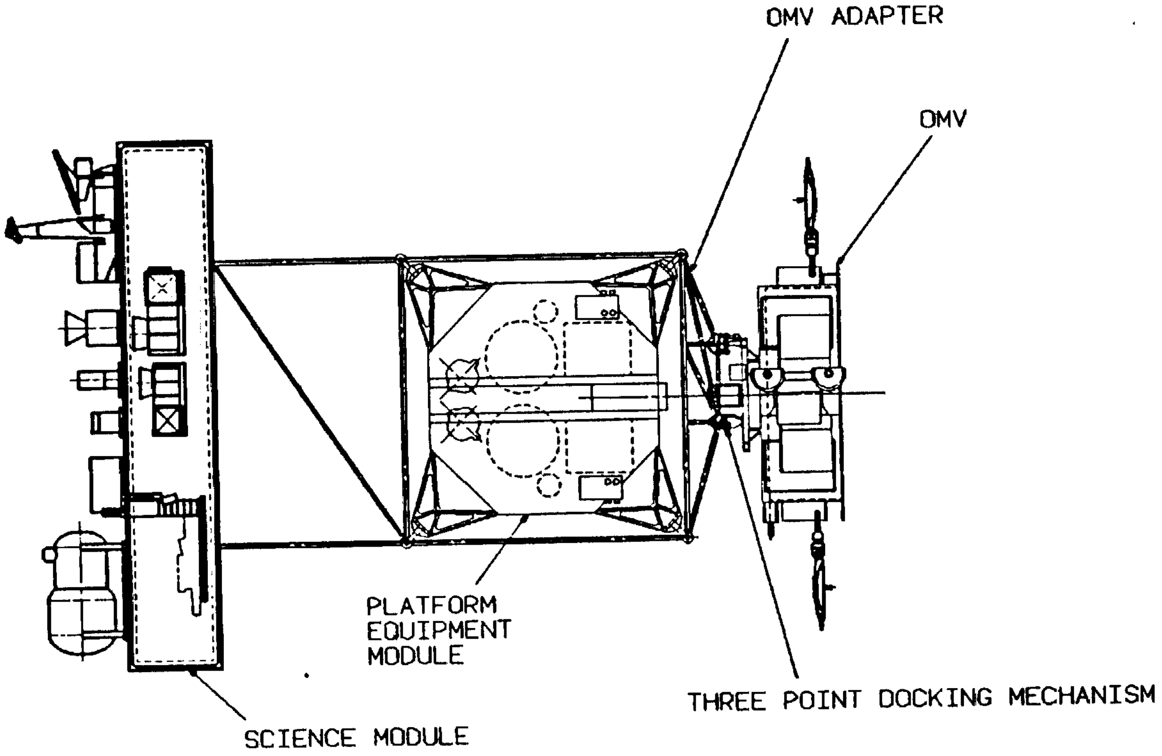


PTF TRANSFER CONFIGURATION AT SSF

The completed ESGP vehicle is transferred to the PTF from SSF using an OMV-like vehicle. The ESGP/OMV interface is shown in the figure. A three point docking mechanism is used in the interface design.

PTF TRANSFER CONFIGURATION AT SSF

PLATFORM TRANSFER FROM SPACE STATION TO LTV



GEO PLATFORM END VIEW

FTS STRUCTURAL ASSEMBLY TASK ANALYSIS

The Vehicle Operations Database was used to develop the operational scenario for the FTS structural analysis.

The process begins with a detailed understanding of each procedural step, and emphasizes involvement of crew systems engineers with significant space-related operations experience throughout the scenario development process. The product of the approach (shown in the figure) is a step-by-step analysis of each task in the overall scenario, with step performance times, FTS appendage utilization, FTS vision system utilization, FTS work station control functions, and significant support equipment reuirements identified for each step.

FTS STRUCTURAL ASSEMBLY
- TASK ANALYSIS -

	STEP	RMS	FTS APPENDAGES			FTS VISION ELEMENT				WORKSTATION
	TIME (MIN)		ARM 1	ARM 2	LEG	L W/F	L N/F	R W F	R N/F	
3.0 STRUT 1 INSTALLATION (DETAIL LEVEL)										
3.1 TRANSFER FTS TO DISPENSER ACCESS POSITION	.5	M				X		X		
3.2 CONFIGURE VISION SYSTEM FOR LEG ENGAGE OPERATION	.4	H				X		X		
3.3 POSITION FTS LEG TO GRIP DISPENSER ATTACH POINT	.3	H			X	X		X		
3.4 GRID DISPENSER ATTACH POINT	.1	H			X	X		X		
3.5 CONFIGURE VISION SYSTEM TO OBSERVE ARM OPERATION	.4	R				X		X		
3.6 POSITION ARM TO GRIP STRUT 1	.3	R	X			X	X	X		
3.7 GRIP STRUT 1	.1	R	X			X	X			
3.8 CONFIGURE VISION SYSTEM TO TRACK STRUT TRANSFER	.9	R						X		
3.9 RELEASE STRUT 1 FROM DISPENSER	.2	R	X			X	X	X		
3.10 RELEASE LEG GRIP ON DISPENSER	.1	H			X					
3.11 WITHDRAW LEG TO TRANSPORT POSITION	.1	H			X					
3.12 TRANSFER FTS STRUT 1 TO INSTALLATION POSITION	1.5	M	X			X		X		

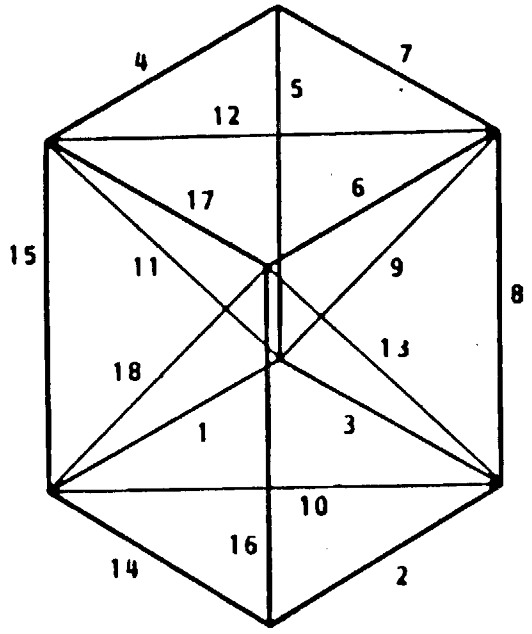
LMSC TIMELINE ANALYSIS OF FTS TRUSS BAY ASSEMBLY

The figure shows the results of a FTS Truss Bay Assembly simulation performed at Lockheed (LMSC) using the SILMA robotic simulation software CIMSTATION run on a Silicon Graphics 3130 work station.

Functional timeline analyses of these and other simulations were used for comparison with FTS task functional analysis. Comparative FTS timeline analysis shown in the figure indicates a much longer time required (up to 157 minutes in one estimation) for telerobotic assembly of truss bays. The joint Lockheed-Silma Inc. assembly simulation, included in the report in reference (7), indicates substantially long truss bay assembly durations using the FTS.

The simulation proved to be a useful design tool because the ease of simulation allows many alternatives to be explored. After the original geometries and kinematics are defined, different scenarios can be created quickly. Some scenarios investigated the design issues of: (1) optimal assembly sequence, (2) identification of high-risk areas for collisions, (3) camera appendage interference, (4) assembly time, (5) design tradeoffs for base location and attachment points to workpiece, (6) controlling the robot in interactive mode, (7) realtime simulation speed tradeoffs, (8) lighting conditions and (9) DoF of appendages, link lengths, and total reach.

LMSC TIMELINE ANALYSIS OF FTS TRUSS BAY ASSEMBLY



STRUT NO.	TIME (MINUTES)	
1	6.9	
2	6.9	
3	10.7	
4	6.9	
5	10.7	
6	6.9	
7	10.7	
8	6.9	
9	10.7	
10	10.1	
11	10.1	
12	10.1	
13	10.1	
14	9.8	117.7
15	9.8	
16	9.8	
17	9.8	
18	9.8	
		156.7

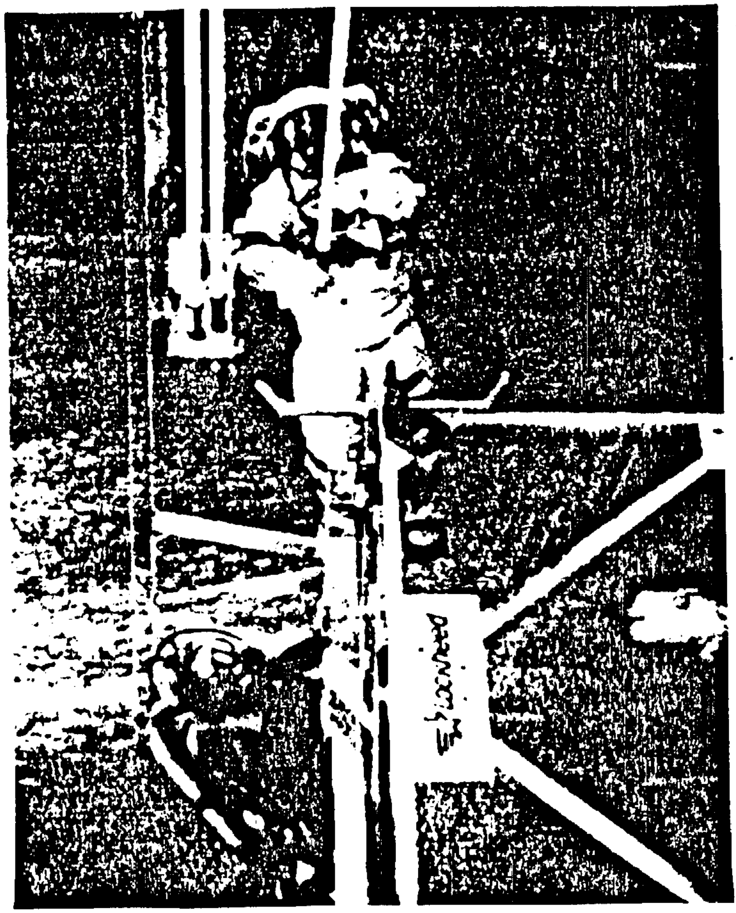
NEUTRAL BUOYANCY SIMULATION OF SSF TRUSS BAY ASSEMBLY

Lockheed has completed an internally-funded project on Space Station Assembly Technology (SSAT) which was used to evaluate EVA assembly of the SSF truss assembly.

The figure shows SSAT Program underwater test simulation of EVA Space Station truss installation (FEL Task no. 1). Functional timeline analyses of these and other simulations are used for comparison with FTS task functional analysis. As detailed in the Space Station Assembly Techniques and Structures report contained in reference (7), duration of assembly for one truss bay by EVA underwater simulation was 204 seconds.

NEUTRAL BUOYANCY SIMULATION OF SSF TRUSS BAY ASSEMBLY

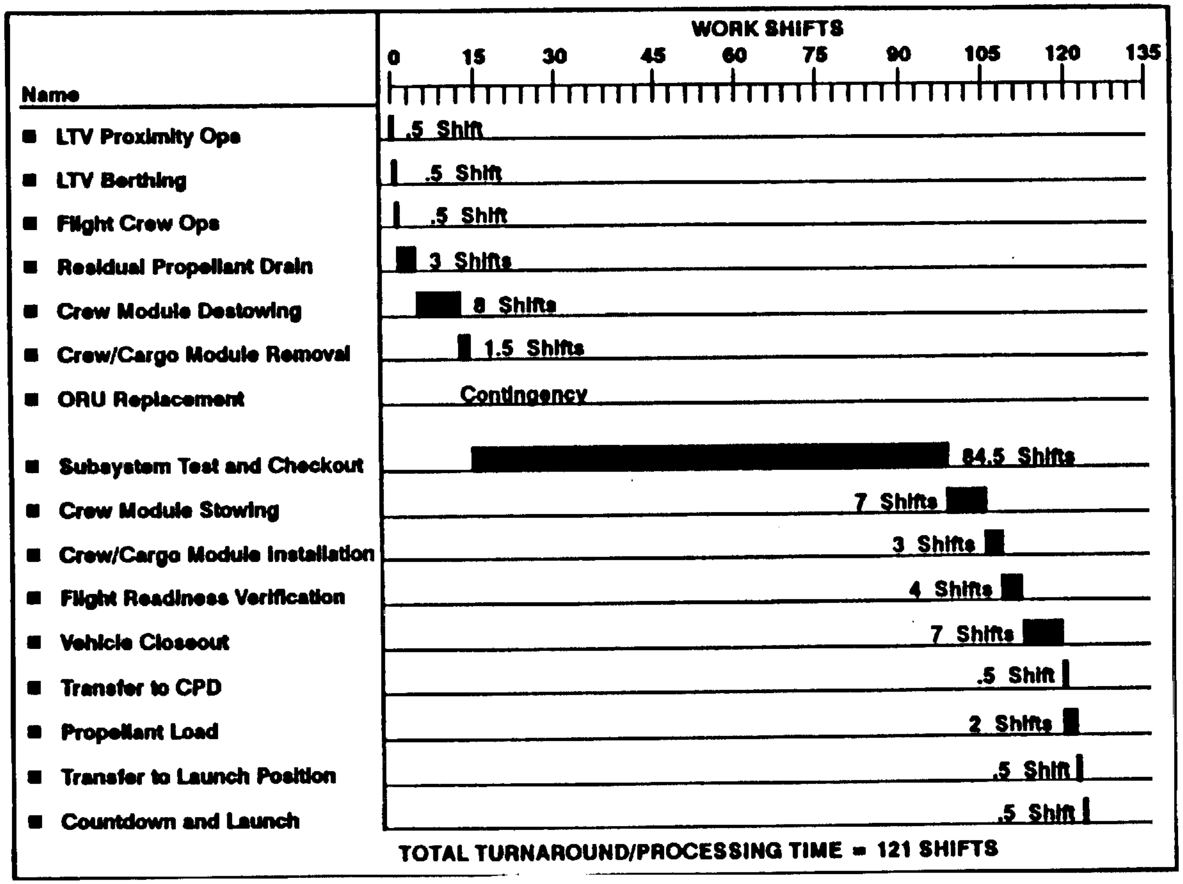
- LMSC / SSAT -



OVERALL ON-ORBIT LTV TURNAROUND FLOW

An overall generic timeline for Lunar vehicle turnaround (Lunar vehicle proximity operations at SSF through propellant load and launch) is shown in the figure. This timeline of 121 shifts is a summation of the subtask timelines for refurbishment of each major engineering system, with parallel operations incorporated where feasible. Contingency ORU replacements are not included in the overall turnaround timeline. The timeline data was obtained from reference (18).

OVERALL ON-ORBIT LTV TURNAROUND FLOW



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ESGP
CHECKOUT
&
LAUNCH PREPARATION
REQUIREMENTS

BASELINE ESGP LEO CHECK-OUT SSF INTERFACES

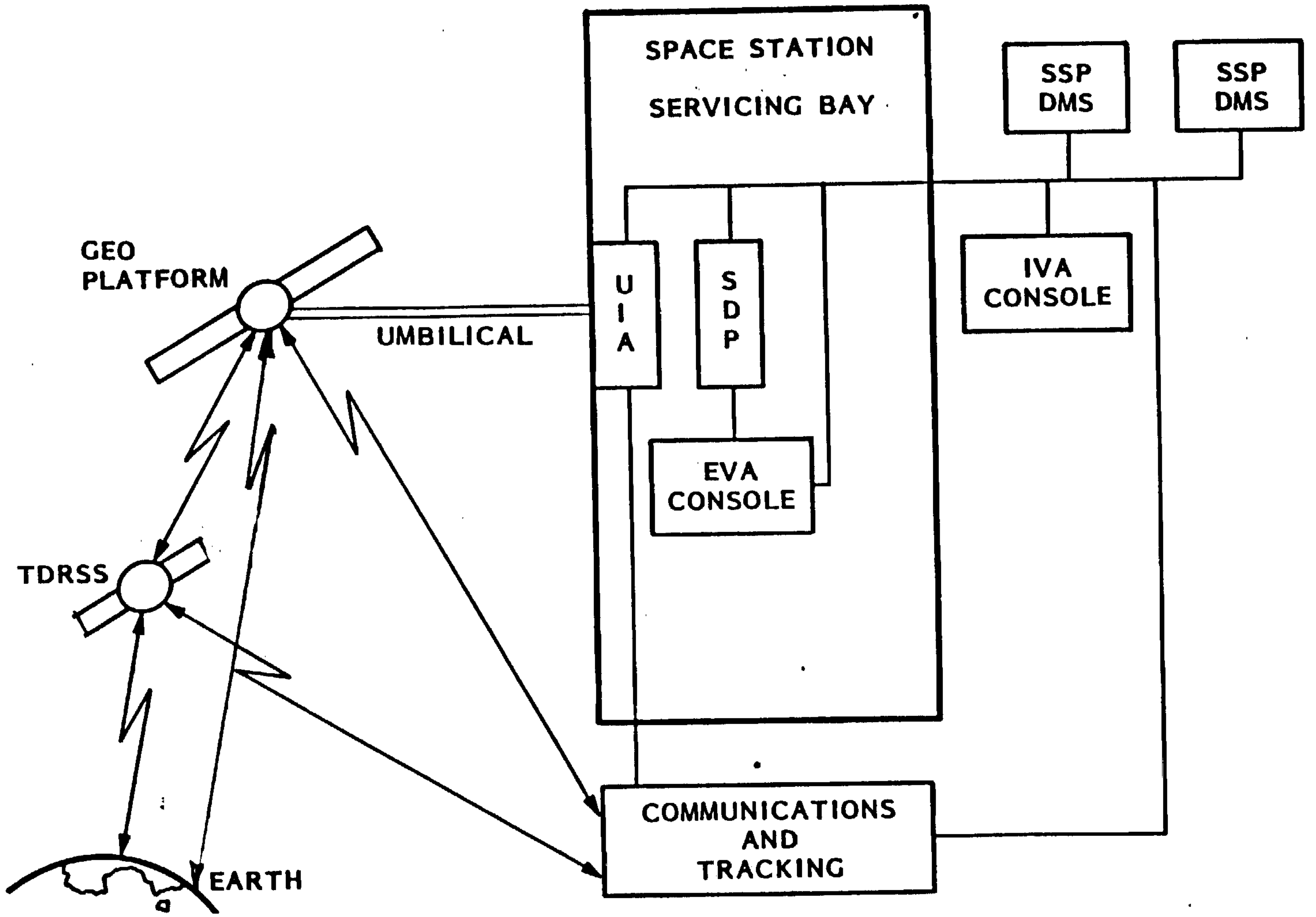
The ESGP/SSF interfaces required for LEO check-out are identified in the figure. Several Communication and Tracking links are possible from the SSF depending on the location of the ESGP depending on the location of the ESGP vehicle during launch readiness testing. Both the TDRSS and direct broadcast link (limited coverage) will be used during checkout activities.

A complete launch readiness test will be performed after mating with the LTV/STV and the ESGP is in close proximity (co-orbiting platform) with SSF.

NASA SPACE FLIGHT

BASELINE ESGP LEO CHECK-OUT SSF INTERFACES

Lockheed



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EVOLUTIONARY SSF RESOURCE REQUIREMENTS

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EVOLUTIONARY SSF RESOURCE REQUIREMENTS

The SSF resource requirements are contained in the figure. The top-level assembly operations functional flow was used to identify requirements in the following areas:

- SSF Facility Interface
- SSF Facility Cupolas and OPS/COMM Module
- RF Interfaces
- Data Management
- Electrical Power
- Fluids

EVOLUTIONARY SSF
RESOURCE REQUIREMENTS

o <u>SSF FACILITY INTERFACE</u>

ASSEMBLY WORK PLATFORM AND I / F ADAPTER
ESGP ELEMENT POWER & DATA I / F - PDGF
ESGP ELEMENT THERMAL CONTROL
PORTABLE WORK STANDS
GROUNDING MECHANISM

o <u>SSF FACILITY CUPOLAS & OPS / COMM MODULE</u>

IVA WORK STATION & REMOTE CONTROL TV
RMS / FTS REMOTE CONTROL
MULTI - PURPOSE APPL CONSOLE - MPAC & MONITOR
TLM TEST / CALIB SET
DMS, PWR, COMM MONITORS

o <u>RF INTERFACES</u>

KU - BAND LINK
S - BAND LINK
BUS I / F ADAPTERS

o <u>DATA MANAGEMENT</u>

NOMINAL DATA RATE < 1 Mbps (VERIFICATION & CHECKOUT)

o <u>ELECTRICAL POWER</u>

MSC AVG POWER APPROX 2.6 KW / HR (ASSEMBLY & DEPLOYMENT)
ESGP THERMAL CONTROL APPROX 3 KW / HR (VERIFICATION & CHECKOUT)

o <u>FLUIDS</u>

ARGON CRYOGEN APPROX 10 GAL & TOP - OFF I / F

EVOLUTIONARY SSF RESOURCE REQUIREMENTS

A summary of the ESGP/SSF resource requirements are included in the figure. Requirements are identified in the following areas:

- Total Mass
- Total Power
- External Volume
- Internal Volume
- Robotics
- EVA/IVA Crew Time

EVOLUTIONARY SSF RESOURCE REQUIREMENTS

- o GEOPLATFORM TOTAL MASS (DRY) - 25616 lb
- o GEOPLATFORM TOTAL POWER - 8 kW
  (only during end - to - end system test)
- o EXTERNAL VOLUME - 58m x 20m x 35m
  (completed assembled platform)
- o INTERNAL VOLUME - ASSEMBLY / STORAGE

NORTH / SOUTH SCIENCE MODULES	- 9.3m x 4.5m x 4.5m
EQUIPMENT SUBSYSTEM MODULES	- 1.7m x 4.5m x 4.5m
RADIOMETER ANTENNA ASSEMBLIES	- 3.3m x 4.5m x 4.5m
TRUSS ASSEMBLY FIXTURE	- 5.0m x 4.5m x 4.5m

- o ROBOTICS - 2 MSC and 1 FTS
- o EVA CREW TIME - 6 WORK SHIFTS - ASSEMBLY OPERATIONS
- o IVA CREW TIME - 38 WORK SHIFTS - ASSEMBLY OPERATIONS

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SECTION 3

ESGP SERVICING REQUIREMENTS

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SSF
SERVICING
SYSTEM

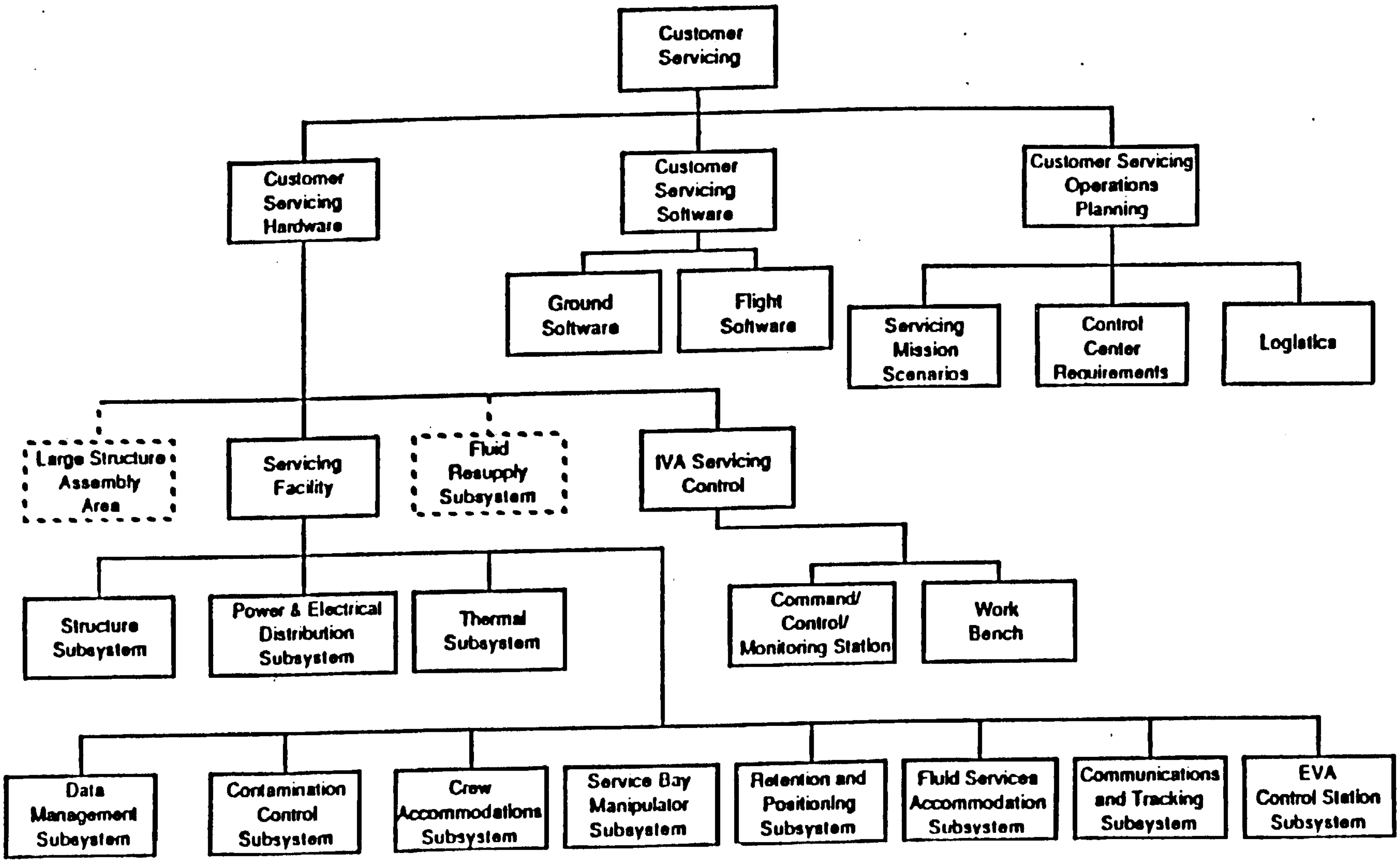
Lockheed

SERVICING SYSTEM BLOCK DIAGRAM

The SSF Servicing System architecture is shown in the figure. The Advanced ESGP will require the following major interfaces to be established for servicing at SSF.

- Large Structure Assembly Area - Platform
- Servicing Facility - ESGP module elements
- Fluid Resupply Subsystem - Argon cryogen
- IVA Servicing Control - Command and control

SERVICING SYSTEM BLOCK DIAGRAM



- Customer Servicing
  - Customer Servicing Hardware
    - Large Structure Assembly Area
    - Servicing Facility
      - Structure Subsystem
      - Power & Electrical Distribution Subsystem
      - Thermal Subsystem
      - Data Management Subsystem
      - Contamination Control Subsystem
      - Crew Accommodations Subsystem
      - Service Bay Manipulator Subsystem
      - Retention and Positioning Subsystem
      - Fluid Services Accommodation Subsystem
      - Communications and Tracking Subsystem
      - EVA Control Station Subsystem
    - Fluid Resupply Subsystem
    - IVA Servicing Control
      - Command/ Control/ Monitoring Station
      - Work Bench
  - Customer Servicing Software
    - Ground Software
    - Flight Software
  - Customer Servicing Operations Planning
    - Servicing Mission Scenarios
    - Control Center Requirements
    - Logistics

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SERVICING SCENARIOS

INTEGRATED OPERATIONS PLANNING FOR SSF ESGP SERVICING

The overall integrated operations planning concept developed by LMSC for SSF customer servicing on Work Package 3 consists of servicing operations models, verified operations plans, and servicing operations planning output.

The servicing operations model consists of three computerized units. One is the scenario generator previously described that models the maintenance and servicing operations. The second is the servicing operations simulator to verify fit and function of hardware and scenario task relationships. The third is a spares/parts manager that lists ORUs, components, etc., and was not utilized in the study effort.

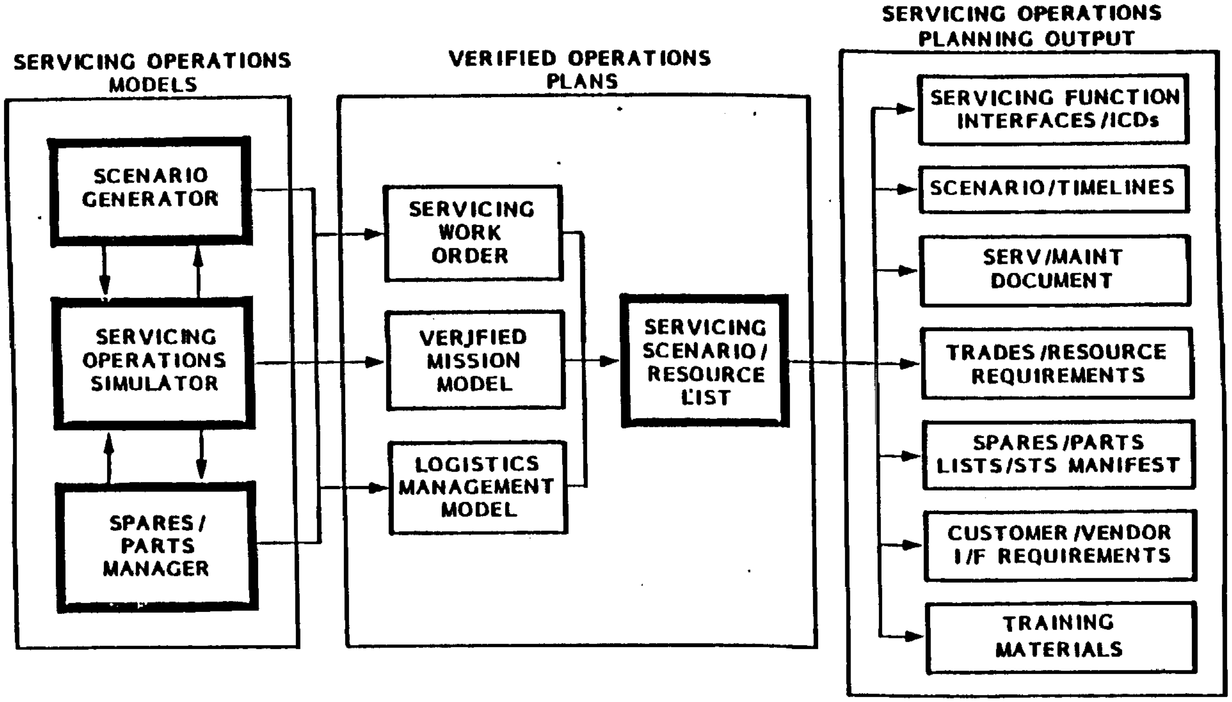
When used interactively, the models can provide inputs to the verified operations plans which generate the servicing work orders, the verified mission model, and the logistics management model. These three are then combined into the servicing scenario and resource list.

The verified operations plan is then used to generate the individual outputs needed for the actual customer servicing function including:

Scenarios and timelines
Servicing function ICDs
Servicing facility assembly and servicing documentation
Trades and resource requirements
Spares/parts lists and their STS manifest
Customer and vendor interface requirements training materials

The integrated servicing operations planning and mission scenario generation provides a total package in on-orbit servicing planning, resource management and support services planning. It provides resource/logistics requirements, orbiter manifesting needs, timelines, and customer support interfaces by providing input data to logistics management, STS manifests, NASA centers, and customer/vendor pipelines.

INTEGRATED OPERATIONS PLANNING FOR SSF ESGP SERVICING



MASTER SERVICING FUNCTION LIST - ACTIVITY FILE -

An activity file shown the interfaces of each task with other tasks contained in the "master activity file" (generic) for servicing and maintenance at the SSF. The file shown in the figure is produced by LMSC from trades and analyses, historical data, simulations, etc., for permanent entry into the database. The top-level functional flow for any servicing mission consists of: receipt of the servicing work order (10,000 series), preparation for the mission (20,000 series), conduct of mission (30,000 series), and post-mission activities (40,000 series).

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MASTER SERVICING FUNCTION LIST - ACTIVITY FILE -

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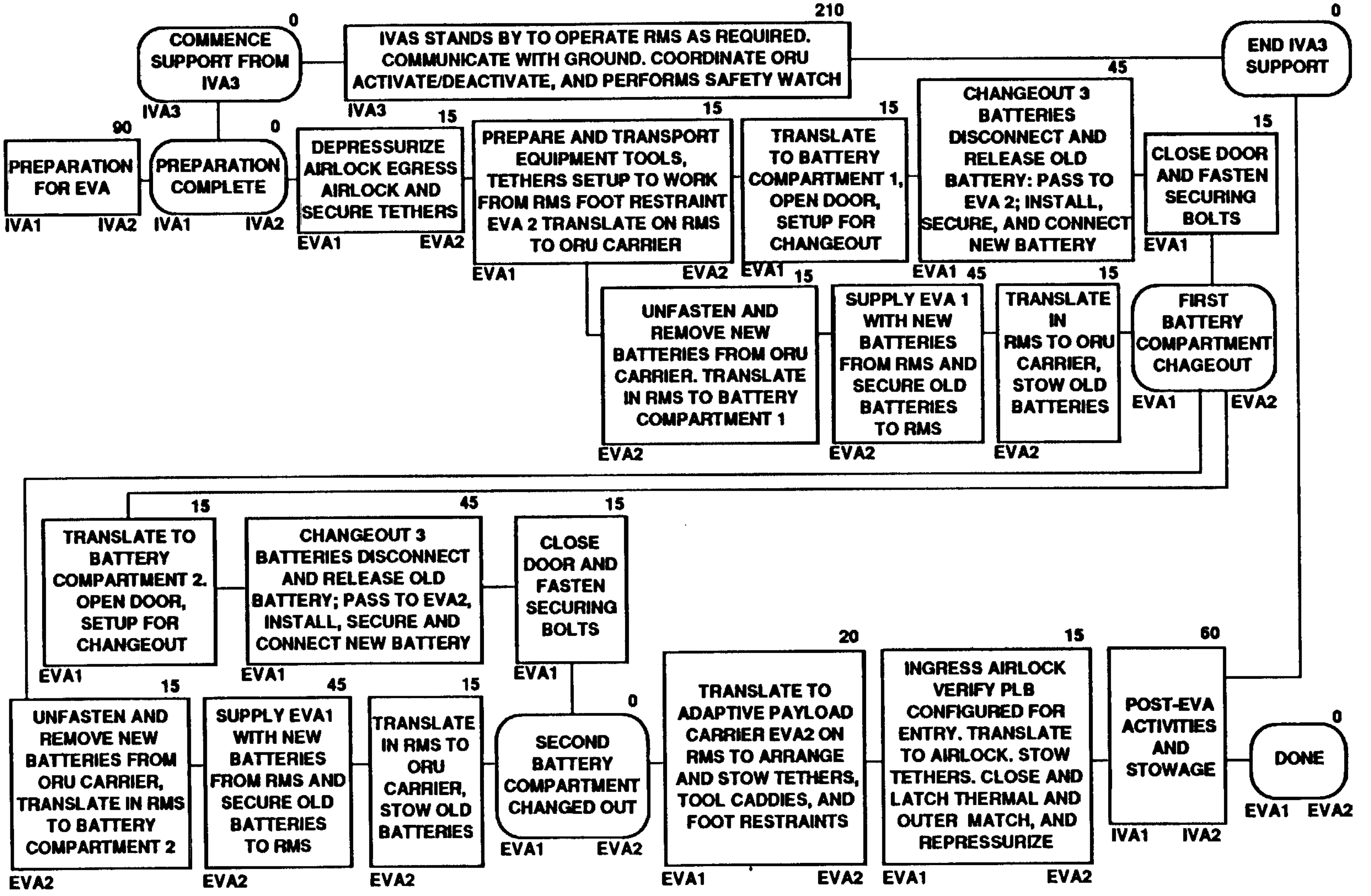
FILE NO.	FUNCTION TITLE	FUNCTION DEFINITION
10000	RECEIVE WORK ORDER	RECEIVE AN AUTHORIZATION TO PERFORM A SVC'G OP ON CUSTOMER
20000	PREPARE FOR MISSION	ACTIVITIES NEEDED TO BE ACCOMPLISHED PRIOR TO STARTING SERVICING MISSION
21000	PREP & CONDUCT OV LOGISTICS MISSION	BRING EQUIPMENT NEEDED FOR MISSION TO STATION VIA STS
22000	CONDUCT TRAINING	PRE-MISSION TRAINING FOR SS AND GROUND CREWS FOR THIS MISSION
23000	PREPARE OMV	PREPARATION OF OMV AS REQUIRED FOR THIS MISSION
24000	PREPARE SS SERV SITE	PREPARE SERVICNG BAY, OR SITE FOR THIS MISSION
25000	PREP SERV'G TOOLS & EQUIP	PREPARE TOOLS & EQUIPMENT IN LOG MODULE. HAB MODULES OR STOR/SVC'G BAY
26000	PREP FF/PL SYSTEMS	COMMAND FF/PL SYSTEMS TO RENDEZVOUS/DOCKING READINESS
30000	CONDUCT MISSION	ON-ORBIT PERFORMANCE OF SERVICING MISSION OF ONE CUSTOMER
31000	PRE-SVC'G SUPPORT OPS	OPS NECESSARY TO PREPARE CUSTOMER, EQUIPMENT AND PERSONNEL
31100	PRE-SVC'G OMV OPS (PROMV)	PRE-SVC'G RETRIEVAL FREE FLYER TO STATION
31300	PRE-SVC'G OV OPS (PROV)	PRE-SVC'G OPERATIONS OF ORBITER VEHICLE IF IT IS USED DIRECTLY IN SVC
31400	PRE-S'G SOMV OPS (PRSOMV)	SAME AS 31100, WITH "SMART FRONT END" OMV
31500	PRE-EVA OPS (PREVA)	EVA ACTIVITIES PRIOR TO STARTING SERVICING
31700	PRE-IVA OPS (PRIVA)	IVA ACTIVITIES PERIOR TO STARTING SERVICING
32000	SERVICING	SERVICING OPERATIONS: ACCOMPLISHING CHANGES TO THE CUSTOMER
32100	INSPECT	INSPECT CUSTOMER AT ANY TIME BEFORE, DURING OR AFTER OTHER ACTIVITIES
32200	ASSEMBLE/DISASSEMBLE	MAJOR ASSY/DISASSY OF CUSTOMER OR FACILITY
32300	MAINTENANCE	CLEANING OR REFURBISHING
32400	REPAIR	REPAIRING ANY PART OF CUSTOMER
32500	REMOVE & REPLACE	R & R of ORUS OR OTHER EQUIPMENT
32600	MODIFY	ALTER CONFIGURATION, OR UPGRADE CUSTOMER
32700	REPLENISH	REFUEL, OR ADD SOLIDS TO CONSUMABLES CONTAINERS
32800	MONITOR/TEST	PERFORM MONITORING OR TEST ON CUSTOMER

BATTERY CHANGEOUT FUNCTIONAL FLOW NETWORK

A functional flow network example is included for an analysis of a battery ORU changeout task. The task flow networks and related approaches are used to define (1) the major activities or functions that need to be done, (2) the times at which they are done and (3) the interaction among the various tasks.

Each element in the network indicates the functions performed, the completion time required (based on ground simulations) and the EVA and IVA crew members participating in that function.

BATTERY CHANGEOUT FUNCTIONAL FLOW NETWORK



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SERVICING RESOURCE REQUIREMENTS

SERVICING RESOURCE REQUIREMENTS

The Servicing Resource Requirements for the Evolutionary SSF are included in the figure. In addition to the previously identified customer servicing facility requirements for servicing of ESGP module elements, the following requirement areas are identified:

- Total Mass
- Total Power
- External Volume
- Internal Volume
- Robotics
- Customer Servicing Facility

EVOLUTIONARY SSF
RESOURCE REQUIREMENTS

- o GEOPLATFORM TOTAL MASS (DRY) - 25616 lb
- o GEOPLATFORM TOTAL POWER - 8 kW
  (only during end - to - end system test)
- o EXTERNAL VOLUME - 58m x 20m x 35m
  (completed assembled platform)
- o INTERNAL VOLUME - ASSEMBLY / STORAGE

  NORTH / SOUTH SCIENCE MODULES - 9.3m x 4.5m x 4.5m
  EQUIPMENT SUBSYSTEM MODULES - 1.7m x 4.5m x 4.5m
  RADIOMETER ANTENNA ASSEMBLIES - 3.3m x 4.5m x 4.5m
  TRUSS ASSEMBLY FIXTURE - 5.0m x 4.5m x 4.5m

- o ROBOTICS - 2 MSC and 1 FTS

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CONCLUSIONS

AND

RECOMMENDATIONS

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CONCLUSIONS

The SSF transportation node concept could serve to accommodate on-orbit assembly of an Advanced Earth Science Geostationary Platform. Assembly of the truss structure of the Advanced ESGP can be done either via a telerobotic mode or a mode that involves cooperative EVA and telerobotic operations. In addition, the Mobile Servicing Centre provides assembly and maintenance support functions for platform assembly and element installation. Advanced ESGP assembly operations require much less utilization of SSF resources than similar processing operations for LTVs.

Staging of the Advanced ESGP at the SSF relieves SI size constraints by allowing incremental launches and on-orbit assembly. In addition, this approach allows cryogen top-off of SIs that require it, reducing SI launch weights. Finally, the availability of a limited SI checkout capability prior to insertion into the operational geostationary orbit significantly reduces operations risks associated with a large complex platform.

CONCLUSIONS

- ON - ORBIT ASSEMBLY OF ADVANCED ESGP COULD BE ACCOMMODATED AT THE SSF TRANSPORTATION NODE CONCEPT
- ESGP TRUSS STRUCTURE ASSEMBLY COULD BE DONE IN BOTH A TELEROBOTIC MODE & COOPERATIVE EVA / TELEROBOTIC OPERATIONS MODE
- THE MSC PROVIDES KEY ASSEMBLY & MAINTENANCE SUPPORT FUNCTIONS FOR PLATFORM ASSEMBLY & ELEMENT INSTALLATION ACTIVITIES
- SSF STAGING RELIEVES SI SIZE CONSTRAINTS & ALLOWS CRYOGEN TOP - OFF OF SELECTED SIs
- LIMITED SI CHECKOUT IS POSSIBLE PRIOR TO GEO ORBIT INSERTION WHICH SIGNIFICANTLY REDUCES OPERATIONS RISKS ASSOCIATED WITH A LARGE COMPLEX PLATFORM
- LTV PROCESSING OPERATIONS REQUIRE SIGNIFICANTLY MORE SSF RESOURCES THAN ASSEMBLY OPERATIONS FOR THE ADVANCED ESGP

RECOMMENDATIONS

Computer based automation analysis tools such as the Space Operations Data Analysis System (SODAS) and the robotic simulation, CIMSTATION, are required to provide a standardized analysis of on-orbit assembly operations studies and reduce study completion times. The various databases allow standard methods of finite resource allcoation to be established using periodic tracking and margin assessment. These control tools help manage resources critical to the evolution SSF such as power, space, volume, EVA time, and IVA time.

On-orbit assembly techniques must be evaluated with respoect to EVA and robotic activities to optimize evolution SSF productivity. Since EVA will have higher risks and is a more costly and scarce resource than IVA teleoperations, the first goal is to eliminate or minimize EVA through all means possible, including review of assembly and packaging strategy and emphasizing IVA telerobotics and robotics capabilities.

Dynamic analysis studies need to be performed to complement the CIMSTATION kinematic simulations. These studies can be initiated with a number of different dynamic analysis software packages. With the CIEM system, the modal and dynamic analysis modules ARCD and ATTPRED can be used. Lockheed also has multibody dynamics modeling capability with the DYNACON and AUTOLEV simulation programs. Finally, the CIMSTATION dynamics package can be used to study the robotic simulation of all rigid-body effects associated with the various manipulators.

Utilization of a separate propellant tank farm or co-orbiting platform will minimize contamination issues for both the evolution SSF and the Advanced ESGP payload and instrumentation.

The on-orbit assembly techniques evaluated for the Advanced ESGP facility resulted in the requirement for a second Mobile Servicing Centre (MSC) to be positioned at the platform assembly site. The evolution SSF Transportation Node currently provides a two MSC capability.

RECOMMENDATIONS

- o CONTINUE DEVELOPMENT OF INTEGRATED SPACE OPERATIONS MODELING AND ANALYSIS SYSTEMS
  - VEHICLE PROCESSING OPERATIONS DATABASE (VPOD)
  - SCIENCE MISSION OPERATIONS DATABASE (SMOD)
  - SSF OPERATIONS DATABASE (FOD)
  - CIMSTATION
- o SIMPLIFY ON-ORBIT ASSEMBLY OPERATIONS THROUGH EVALUATION OF OPTIONAL TELEROBOTIC SIMULATIONS
- o MAXIMIZE USE OF ROBOTIC & AUTOMATED ASSEMBLY TECHNIQUES
- o INITIATE ASSOCIATED CONTROLS - STRUCTURES INTERACTIVE SYSTEM STUDIES (DYNAMIC ANALYSIS) TO COMPLEMENT KINEMATIC SIMULATIONS
- o UTILIZATION OF A SEPARATE PROPELLANT STORAGE FACILITY
- o UTILIZATION OF TWO MOBILE SERVICING CENTRE'S (MSC) FOR ASSEMBLY OF LARGE PLATFORM STRUCTURES

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ADVANCED ESGP
SCIENCE INSTRUMENTS

- APPENDIX A -

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MICROWAVE
RADIOMETER

ADVANCED ESGP MICROWAVE RADIOMETERS

The driving requirements for the microwave radiometers are presented on the accompanying chart. Although 4 microwave radiometers are featured in the Advanced ESGP strawman payload, it is reasonable to expect that only 2, the Low Frequency Microwave Radiometer (LFMR) and the Microwave Sounder/Imager (MSI), will be used for detailed studies. The other two will likely be used for general surveys and their resulting smaller diameter will not be a design driver.

The 20m diameter for the LFMR can be realized using a deployable mesh-type antenna. In spite of the fact that it is deployable, the size of the package is likely to require attachment of the antenna package to the ESGP at the Space Station prior to transfer to the geostationary orbit.

The 7m diameter MSI will use a solid design antenna and will be required to have a high surface contour accuracy. As this type of antenna is currently feasible, no unique Space Station support requirements are anticipated.

ADVANCED ESGP
MICROWAVE RADIOMETERS

- o 4 MICROWAVE RADIOMETERS FEATURED IN STRAWMAN
- o LOW FREQUENCY MICROWAVE RADIOMETER (LFMR) AND MICROWAVE SOUNDER / IMAGER (MSI) USED FOR DETAILED STUDIES (HIGH RESOLUTION, LARGE DIAMETER)

LFMR / MSI REQUIREMENTS

	LFMR	MSI
FREQUENCY (GHz)	18 - 55	55 - 230
TYPE	MESH	SOLID
DIAMETER (m)	~20	~7
RESOLUTION (km)	~20	~20

CONSIDERATIONS

The basic requirement for microwave radiometers for the Advanced ESGP is for a nearly constant resolution over the entire bandwidth of interest. This ensures that various atmospheric structures and phenomena of interest that are examined to the same degree of detail, in spite of the microwave channel being used.

This resolution requirement raises a dilemma in the case of microwave radiometers. For observations at frequencies less than 50 GHz, mesh antenna designs are permissible, allowing light-weight stowable and relatively inexpensive designs to be developed. As shall be shown, high spatial resolution at the low frequencies requires a large diameter antenna.

However, to avoid transmission loss at higher frequencies, a solid antenna is preferred for observations conducted at frequencies that exceed 50 GHz. The solid antenna requirements are further complicated by the necessity of a high surface contour accuracy required for observations at frequencies greater than 200 GHz. Such a design is impractical for the large diameter antenna required for low frequency radiometer, necessitating a second, smaller radiometer dedicated for high spatial resolution at higher frequencies.

CONSIDERATIONS

- PREFER NEAR - CONSTANT RESOLUTION OVER BANDWIDTH OF INTEREST
- MESH ANTENNA POSSIBLE FOR FREQUENCIES LESS THAN 50 GHz
- SOLID ANTENNA REQUIRED FOR FREQUENCIES GREATER THAN 50 GHz TO AVOID TRANSMISSION LOSS
- HIGH SURFACE CONTOUR ACCURACY NECESSARY FOR FREQUENCIES GREATER THAN 200 GHz

MICROWAVE SENSOR MEASUREMENTS/FREQUENCIES

Some of the more important parameters which are expected to be measured by the Advanced ESGP microwave radiometers, together with the frequencies at which these measurements are made are shown on the accompanying table. The frequencies shown are "generic" in the sense that, except for temperature and pressure soundings where the frequencies are determined by specific molecular resonances, the measurements can generally be made over a broad range of frequencies and engineering considerations will likely determine the specific choice.

The large number of parameters requiring measurement at multiple frequencies allows the competing geophysical phenomena which normally contribute to the detected radiance to be identified. An example is the measurement of sea ice. Ice has a much different emissivity than water and, therefore, can be readily distinguished. Because of this, the areal extent of ice can be distinguished at any of a wide range of frequencies. On the other hand, microwave radiation penetrates ice and scatters from inclusions such as pockets of brine. These change whith the age of the ice and affect its emissivity. By comparing emissivity at several frequencies, one can distinguish first-year ice from multiyear ice and in some circumstances distinguish other properties of the ice.

MICROWAVE SENSOR MEASUREMENTS / FREQUENCIES

	FREQUENCY (GHz)									
PARAMETER	6.6	10	18	21	37	50-60	90	160	183	230
SOIL MOISTURE	C									
SNOW	C	C	A		A		B			
OCEAN PRECIP		B	A	C	B					
LAND PRECIP			B		A		A		B	B
SEA SURFACE TEMP	A	B	B	B	B	C				
SEA ICE EXTENT			A		A		C			
SEA ICE TYPE	C	B	A		A		B			
WIND SPEED (OCEAN)		A	B	C	C					
WATER VAPOR PROFILE				B	C	B	C	B	A	A
TOTAL WATER VAPOR (OCEAN)			A	A	B					
CLOUD WATER (OCEAN)				B	A		B			
TEMPERATURE PROFILE				C	C	A	C			

KEY
A = necessary
B = important
C = helpful

SOURCE
HMMR EOS VOLUME IIe

MICROWAVE RADIOMETER PARAMETRIC SIZING

Spatial resolution as a function of frequency for various microwave radiometer antenna diameters is illustrated on the following page. The figure was prepared using the equation found in Wilson and Swanson (1988)*. The plot assumes that the microwave radiometer is pointed at the nadir, allowing maximum resolution (resolution decreases as a function of the radiometer slant range).

The plot shows that for an antenna of a given diameter, spatial resolution increases as the operating frequency increases.

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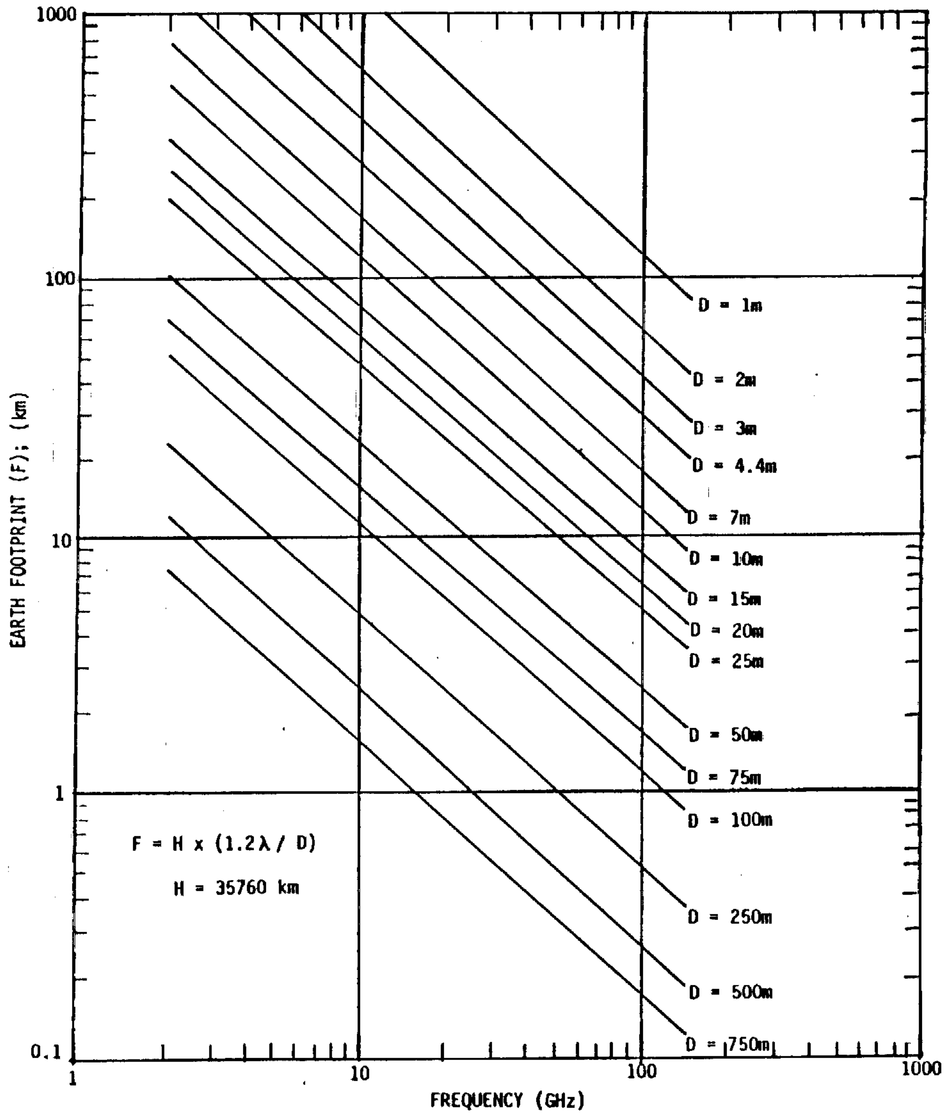
* Wilson, W.J., and Swanson, P.N., 1988, "Millimeter Radiometer System Technology." Presentation to NASA Technology Workshop on Earth Science Geostationary Platforms, September 1988.

MICROWAVE RADIOMETER PARAMETRIC SIZING



MICROWAVE RADIOMETER REQUIREMENTS

The temperature sounding, precipitation monitoring and water vapor and cloud measurement requirements of the microwave radiometer is given on the accompanying chart. The chart was derived from data contained in a document issued by the Geostationary Platform Earth Science Steering Committee on Jan. 20, 1988.

Atmospheric temperature profiles are measured by using sets of frequencies and combining the data from several channels for which the altitudes of peak response are each separated by several kilometers, yielding vertical resolution of several kilometers. The volume scattering by precipitation at frequencies above 40 GHz causes brightness temperature depressions whose magnitudes are related to the aboundance of precipitation, primarily above the freezing level. Water vapor profiles over the ocean can be monitored well because at 100 GHz the atmosphere is sufficiently transparent that the reflective ocean surface provides a cold background against which the integrated water vapor emits approximately linearly. In addition, clouds exhibit a radiometrically warm signal against the radiometrically cold ocean surface and benefit from the lower frequencies (such as 31 GHz) which allow better cloud water dynamic range and a colder oceanic background with which to contrast.

It was assumed that for an Advanced ESGP, at least the adequate and preferably the ideal requirements would be met for the microwave radiometer. In the case of precipitation measurements of 10 km resolution at 6 GHz requiring a 214m diameter dish, a reasonable compromise was arrived at through consultation with NASA/MSFC of a 20 meter diameter LFMR giving 36km resolution at 18 GHz. The higher frequency requirements of the Microwave Sounder/Imager can be met by an approximately 7m diameter dish giving a resolution of up to 20 km over the bandwidth of interest.

MICROWAVE RADIOMETER REQUIREMENTS

TEMPERATURE SOUNDING

	FREQUENCY (GHz)	RESOLUTION (km)	DIAMETER (m)
ADEQUATE	110 - 120	50 @ 120 GHz	2.14
IDEAL	50 - 120	20 @ 120 GHz	5.36

CLOUD AND WATER VAPOR

	FREQUENCY (GHz)	RESOLUTION (km)	DIAMETER (m)
ADEQUATE	110 - 183	30 @ 183 GHz	2.34
IDEAL	31 - 183	10 @ 183 GHz	7.03

PRECIPITATION

	FREQUENCY (GHz)	RESOLUTION (km)	DIAMETER (m)
ADEQUATE	110 - 230	20 @ 230 GHz	2.79
IDEAL	6 - 230	10 @ 6 GHz	214
COMPROMISE	6 - 230	36 @ 18 GHz*	20

* 108 km @ 6 GHz

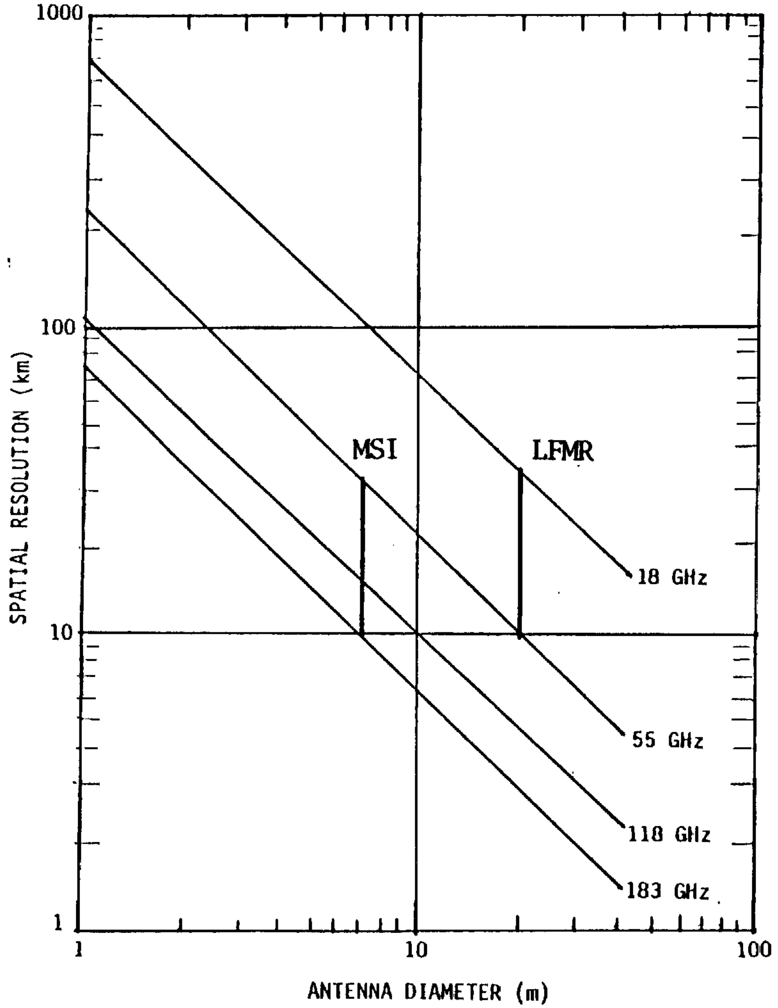
MICROWAVE RADIOMETER ANTENNA DIAMETER

The final chart of this section illustrates the spatial resolution as a function of frequency that will be realized with the LFMR and the MIS.

The vertical line labeled "MSI" shows the spatial resolution for the 7m MSI antenna. It can be seen that for the lower frequencies (55 GHz), that the spatial resolution is on the order of 40km, with resolution increasing to about 15km at 118 GHz and better than 10 km at 183 GHz.

The vertical line labeled "LFMR" shows the spatial resolution for the 20m LFMR antenna. At the lower operating frequency of 18 GHz, spatial resolution is approximately 40km with performance increasing to nearly 10km resolution at 55 GHz.

MICROWAVE RADIOMETER ANTENNA DIAMETER



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IMAGER MIRROR SIZE

IMAGER OBJECTIVES OVERVIEW

At the current time, objectives exist for the ESGP Geostationary Earth Processes Spectrometer (GEPS) and the High Resolution Earth Processes Imaging (HEPI). It is likely that similar objectives will exist for the Advanced ESGP imagers, with the only major modification being higher spatial resolution especially at long-wavelength infrared spectral regions.

Another major difference in the nature of the ESGP and Advanced ESGP imagers is that the GEPS and HEPI are sized to meet 80 to 90 percent of their objectives at a nominal spatial resolution. The next generation imagers are likely to be sized to meet at least 90 percent of their objectives at a maximum spatial resolution, resulting in a larger diameter mirror, with the concomitant packaging and weight impacts associated with increasing the mirror diameter of an imaging instrument.

IMAGER OBJECTIVES
- OVERVIEW -

- o OBJECTIVES EXIST FOR ESGP GEPS AND HEPI
- o SIMILAR OBJECTIVES EXPECTED FOR ADVANCED ESGP
- o ADVANCED ESGP IMAGERS LIKELY TO FEATURE HIGHER RESOLUTION ESPECIALLY AT LWIR
- o GEPS AND HEPI SIZED TO MEET 80 TO 90% OF OBJECTIVES AT NOMINAL RESOLUTION
- o ADVANCED IMAGERS EXPECTED TO BE SIZED TO MEET AT LEAST 90% OF OBJECTIVES AT MAXIMUM RESOLUTION

MIRROR SIZE CONSIDERATIONS

The major items of consideration with regard to imager mirror size are listed on the accompanying chart. The primary driver of mirror size is not only the required spatial resolution but the wavelength that the high resolution is required. As shall be shown, high resolution observations in the long-wavelength infrared regime require much higher mirror diameters than similar resolutions in visible wavelengths.

The large mirror diameter not only influences the packaging of the associated instrument, but also the weight of the instrument as the weight of a mirror increases proportionally to the square of the diameter of the mirror (provided that the mirror thickness remains constant).

In addition, the high spatial resolution can only be accomplished if the mirror is held steady to alleviate blurring. Accordingly, the higher the spatial resolution, the more stringent the pointing requirements imposed on the platform.

When the pointing stability issue is considered with regard to the entire platform, it becomes clear that it is likely to be expensive and complex to provide an ultra-stable pointing capability that can only be utilized by a limited number of imaging instruments. Rather, the logical solution is to have an instrument-internal precise pointing capability for any imagers with large and/or heavy mirrors.

MIRROR SIZE CONSIDERATIONS

- LWIR OBSERVATIONS AT HIGH RESOLUTION REQUIRE LARGE APERTURES (> 1 METER)
- MIRROR WEIGHT PROPORTIONAL TO SQUARE OF MIRROR DIAMETER
- HIGH SPATIAL RESOLUTION REQUIRES STRINGENT POINTING REQUIREMENTS
- PRECISE POINTING OF LARGE / HEAVY MIRRORS LIKELY TO REQUIRE SI - SPECIFIC POINTING SYSTEM

RESOLUTION AND APERTURE AS A FUNCTION OF WAVELENGTH

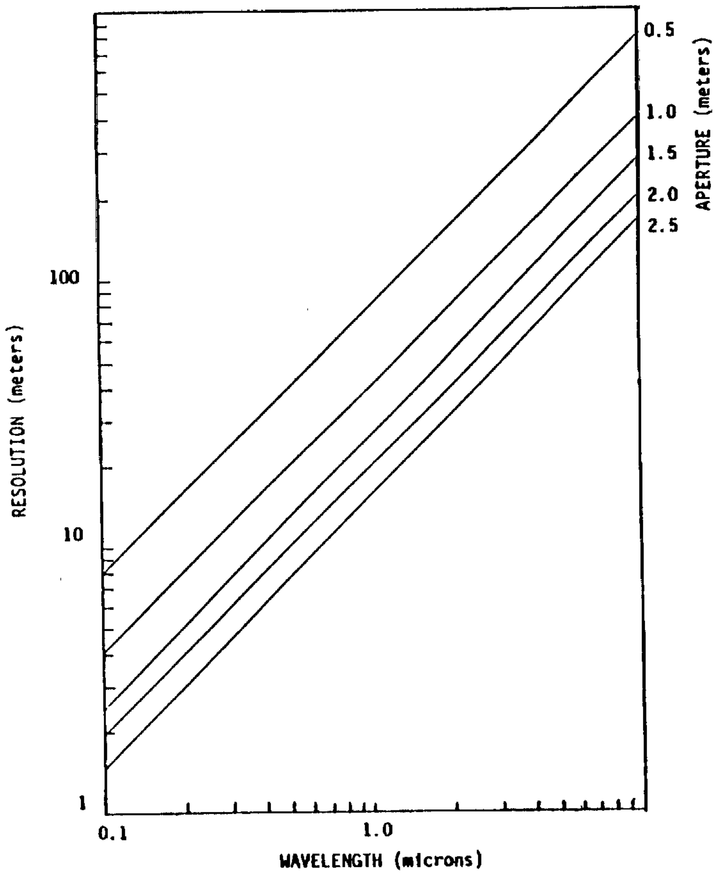
To illustrate the relationships between spatial resolution, wavelength and required mirror apertures, the following equation was used to determine that for a mirror of a given diameter, the resoluiton decreases as a function of wavelength. Similarly, high resolution at longer wavelengths requires a larger mirror than if the same resolution was required at shorter wavelengths.

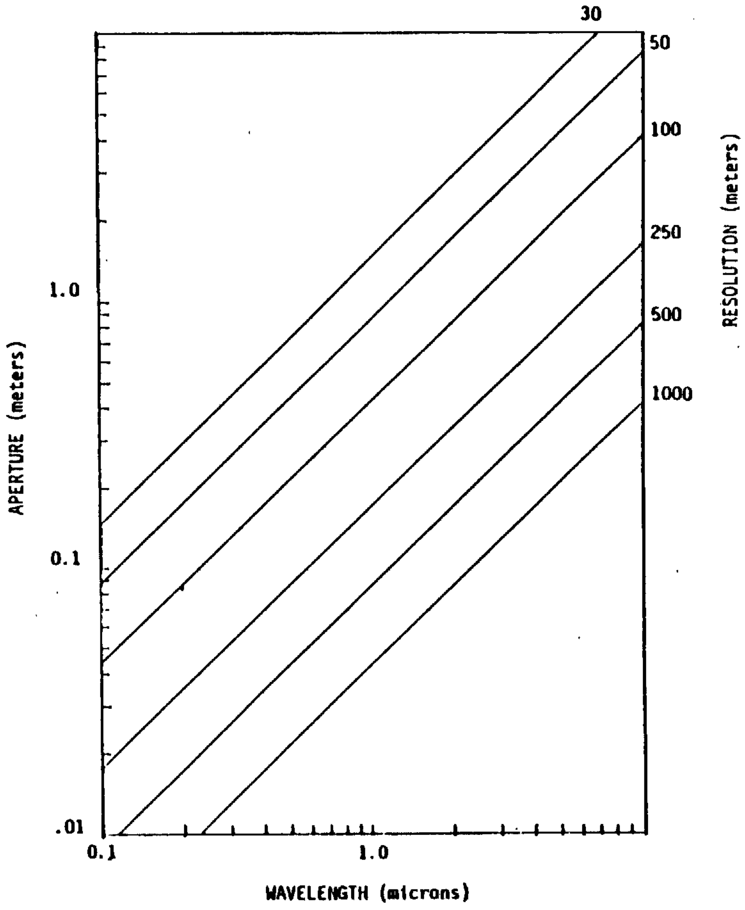
$$R = 1.2\ H\lambda / D$$

R = spatial resolution
λ = wavelength
D = mirror aperture
H = Platform altitude (35760 km)

These effects are clearly illustrated in the accompanying figures, which are a plot of mirror aperture as a function of wavelength for spatial resolutions ranging from 30 to 1000 meters, and a similar plot with resolution plotted as a function of wavelength for mirror apertures ranging from 0.5 to 2.5 meters.

RESOLUTION / APERTURE VS WAVELENGTH





IMAGER OBJECTIVES

It has already been shown that two imagers for the ESGP (GEPS and HEPI) exist and are likely to be modified to form next-generation imagers for the Advanced ESGP.

To determine the likely mirror sizes for the advanced imagers, it was necessary to evaluate the objectives of the GEPS and HEPI and use these to extrapolate the characteristics for future imagers. The draft report of the Earth Science Steering Committee lists observing objectives for the HEPI and GEPS instruments. These objectives are shown on the accompanying chart which lists the observed phenomenon, desired wavelengths, desired resolution and identifies the appropriate imager.

IMAGER OBJECTIVES

OBSERVED PHENOMENON	WAVELENGTHS	RESOLUTION	SENSOR
Cloud Motion	.35 - 1.1 um	500 m	GEPS
Convective Storms	.50 - 4.0	500	GEPS
Hurricanes	6.7 - 14.2	1000	GEPS
Fog	.50 - 12.7	500	GEPS
Dust Storms	1.1 - 3.7	100 - 10000	GEPS
Sea Surface Temperature	1.5 - 12.5	200 - 1000	GEPS
Coastal Flooding	.35 - 12.5	100	HEPI
Shoreline Changes	.35 - 1.1	50 - 100	HEPI
River Sediment Plumes	.40 - .90	50 - 200	HEPI
River Flooding	.35 - 12.5	300 - 500	GEPS
River Flooding	.35 - 12.5	100	HEPI
Wetland Extent	.35 - 1.1	100 - 300	HEPI
Wetland Extent	.35 - 1.1	100 - 300	GEPS
Wetland Extent	10.5 - 12.5	1000	GEPS
Irrigation Schedule	10.5 - 12.5	1000	GEPS
Soil Type	.40 - .90	100	HEPI
Soil Type	.90 - 2.4	200	HEPI
Soil Type	.35 - 1.1	300 - 500	GEPS
Land Use Composites	.35 - 1.1	100	HEPI
Air Pollution Episodes	.31 - .33	100 - 10000	GEPS
Aerosol / Haze Plumes	.35 - .90	100 - 1000	HEPI
Eruption Detection	.28 - .32	50	HEPI
Eruption Detection	.30 - 1.2	50 - 200	HEPI
Eruption Detection	8 - 12	500	GEPS
SO2 Emissions	.30 - .32	100	HEPI
SO2 Emissions	8 - 12	500 - 1000	GEPS
Ocean Productivity	.40 - .90	200 - 1000	GEPS
Vegetation Mapping	.40 - .70	30 - 50	HEPI
Forest Senescence	.70 - 2.4	50 - 100	HEPI
Ecosystem Stress	.40 - .70	30 - 50	HEPI
Ecosystem Stress	.70 - 2.4	50 - 100	HEPI
Biomass Burning	.70 - 1.2	500	GEPS
Cloud Variability	.55 - 3.7	1000	GEPS
Emitted Longwave Flux	.55 - 3.7	1000 - 2000	GEPS

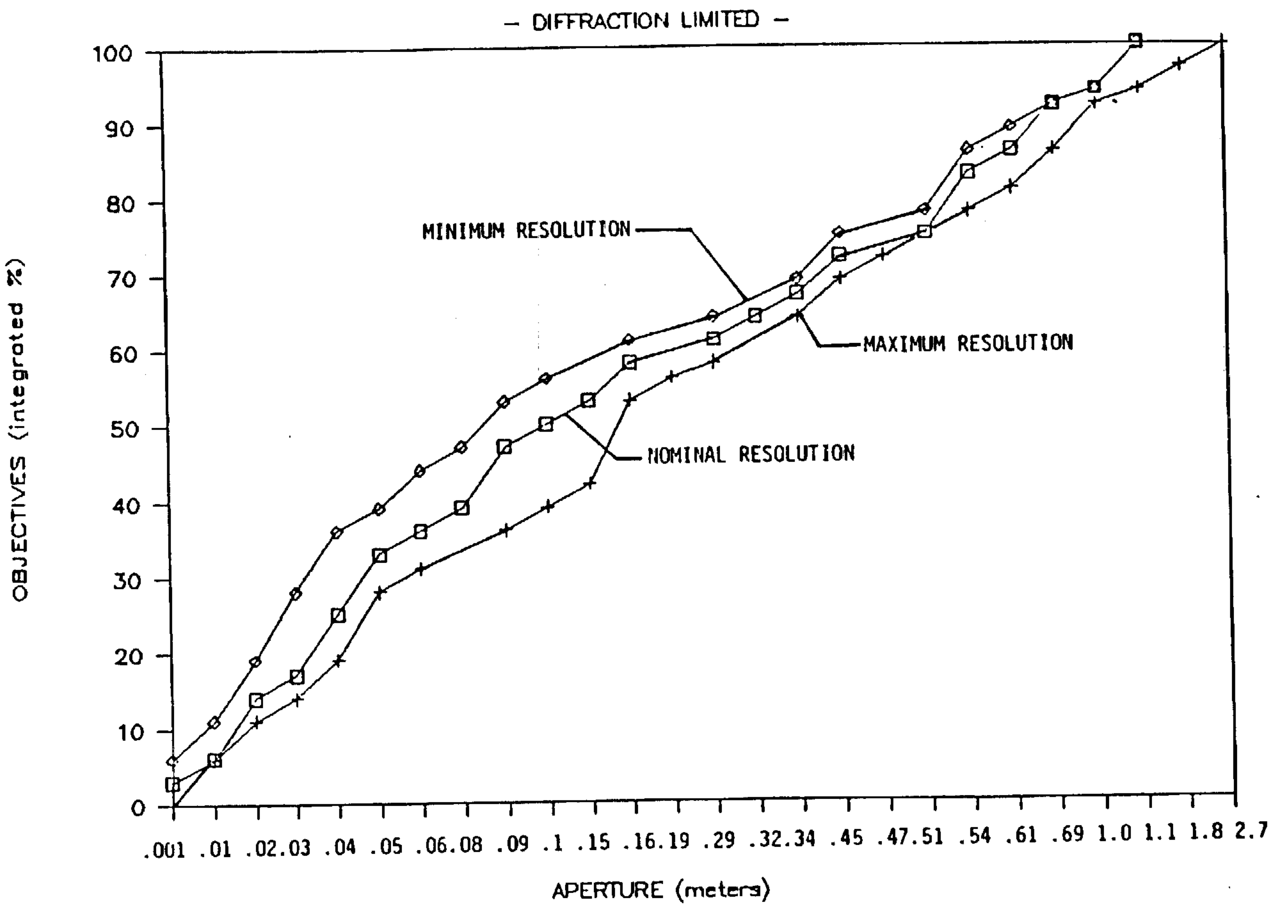
HEPI APERTURE REQUIREMENTS

To determine the actual aperture requirements for an imager, the observing objectives were combined with the equation shown previously. In this process, the observing wavelengths were combined with the associated spatial resolutons for each sensor and objective. In addition, three aperture requirements were generated for each objective, based on a nominal, maximum and minimum resolution.

To illustrate how this was done, consider the river sediment plume objective requiring usage of HEPI at wavelengths of 0.4 to 0.9 microns with spatial resolutions of 50 to 200 meters. Nominal resolution was assumed to represent the degraded resolution expected for a fixed mirror diameter as a function of longer wavelength. In other words, the 50 meter resolution was necessary at 0.4 microns, while 200 meter resolution was needed at 0.9 microns to achieve the particular objective. In the case of maximum resolution, the 50 meter resolution was assumed to be required at both 0.4 and 0.9 microns, while for minimum resolution, the 200 meter resolution was assumed to be required at both 0.4 and 0.9 microns.

The aperture requirements shown on the accompanying chart feature the requirements plotted as a function of the integrated percentage of specific imager objectives for the three resolution categories. As described earlier, it is reasonable to expect that a HEPI-type imager for an Advanced ESGP would be sized to accomplish at least 90 percent of the objectives at maximum resolution. The line on the chart indicates that this requires a mirror aperture approaching 2.1 meters in diameter.

HEPI APERTURE REQUIREMENTS

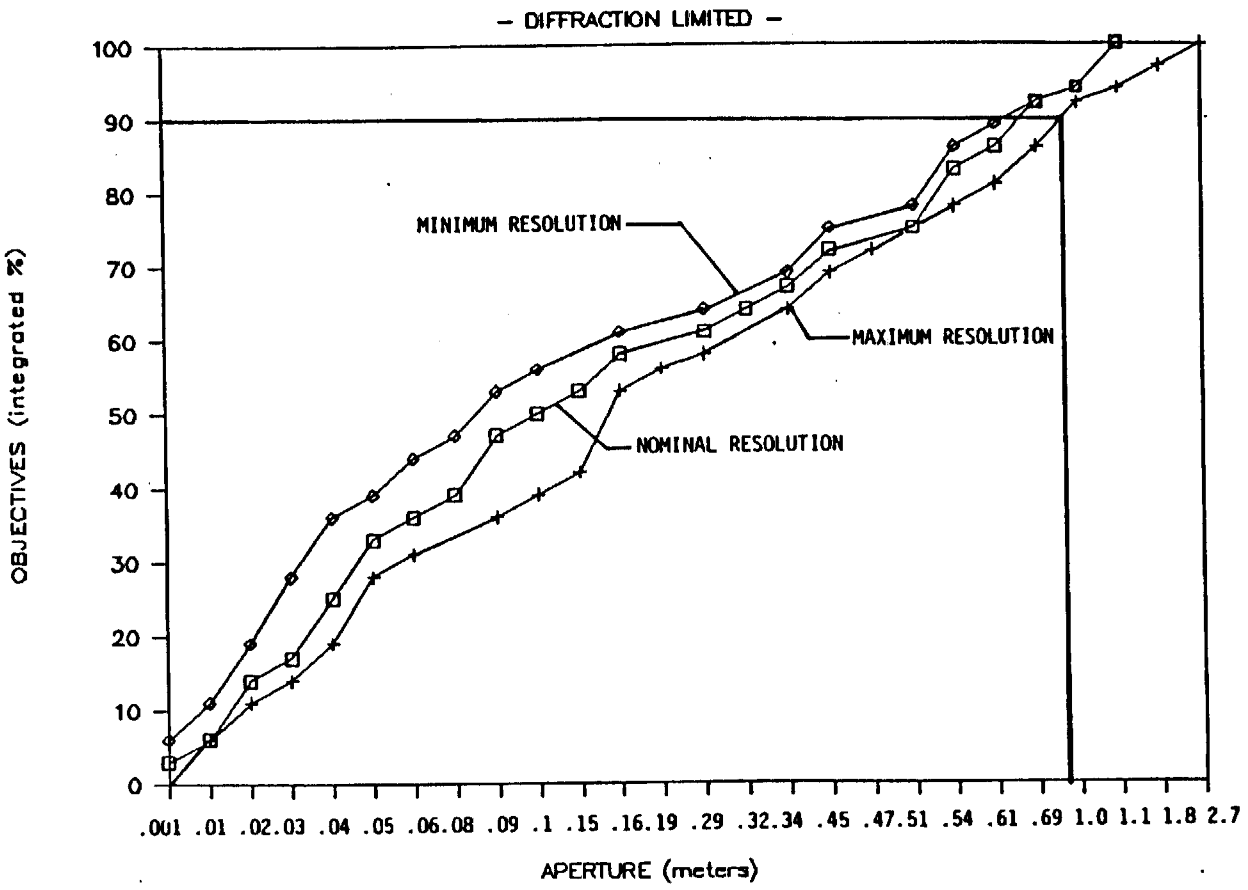


GEPS APERTURE REQUIREMENTS

The accompanying figure presents the GEPS aperture requirements as a function of the integrated percentage of the imager objectives. The data indicates that if maximum resolution is required for the entire wavelength span of interest, a mirror aperture of 2.7 meters is required. However 90 percent of the desired objectives (typical performance expected for an Advanced GEPS) can be met at maximum resolution with an aperture of approximately 1 meter in diameter.

The particular GEPS objectives which drive the mirror diameter include imaging of fog to 500 meter resolution at 12.7 microns, which requires a 1.1 meter mirror aperture for the three resolution categories. In addition, the desire to monitor sea surface temperature changes with resolutions of 200 meters at 12.5 microns would require a 2.7 meter aperture, however, the nominal and minimum 1000 meter resolution can be achieved with a mirror as small as 0.54 meters.

GEPS APERTURE REQUIREMENTS

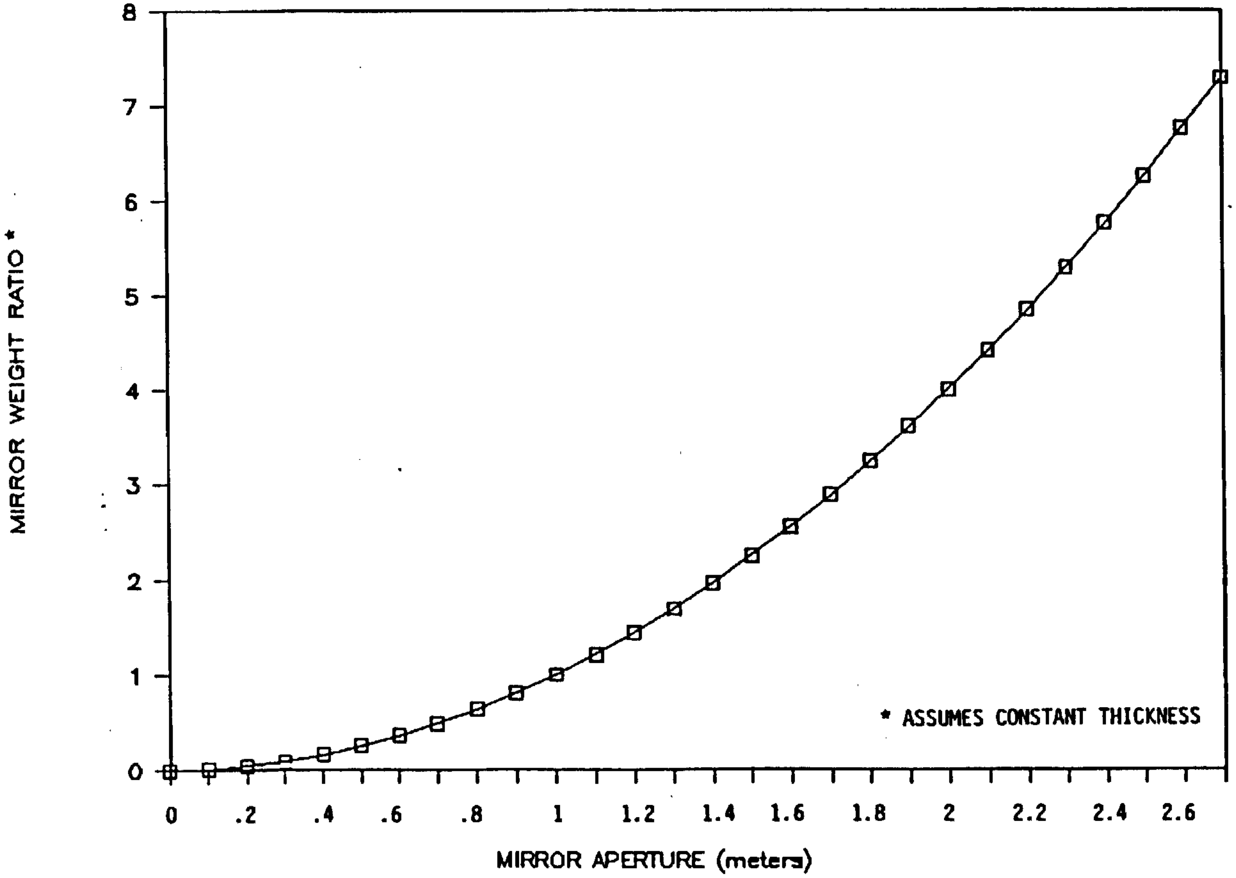


MIRROR APERTURE AS A FUNCTION OF WEIGHT

One of the major drawbacks of larger mirrors is not only the additional size but the additional weight of the mirror. The accompanying figure illustrates that mirror weight increases as the square of the mirror aperture. In other words, a mirror two meters in diameter weighs four times as much as a one meter mirror.

The plot was drawn with mirror weights normalized to a one meter aperture but even more importantly, they assume constant mirror thickness. For terrestrial applications, the severe weight penalties of larger mirrors have usually been circumvented by using a thinner mirror or using a honeycomb template to remove excess mirror material from the back of the mirror. The only drawback in this approach is that the thinner but larger mirrors tend to be more flexible and susceptible to figure distortion due to gravitational effects.

MIRROR APERTURE VS WEIGHT



— NORMALIZED TO 1 m APERTURE —

* ASSUMES CONSTANT THICKNESS

IMAGER REQUIREMENTS SUMMARY

The derived imager requirements for the Advanced ESGP are summarized on the accompanying chart. High resolution (between 30 to 100 meters) currently achievable in the visible and short-wavelength infrared, is expected to be expanded out to 12.5 microns. In an effort to accomplish at least 90 percent of the expected imager objectives, a high resolution HEPI-type imager will require an approximately 2.1 meter diameter aperture. For a GEPS-type imager, similar requirements result in a 1.0 meter aperture.

As mirror weight increases proportionately to the square of the mirror diameter, a 2.1 meter mirror could weigh up to four times as much as a one meter mirror. The weight and size of such a mirror and the expected resulting weight and size of the actual imaging instrument, coupled with the stringent pointing requirements that high resolution produce, will likely result in an instrument-specific pointing system.

IMAGER REQUIREMENTS
- SUMMARY -

- o ANTICIPATE HIGH RESOLUTION (~30 to 100m) OUT TO 12.5 MICRONS
- o ADVANCED HEPI REQUIRES ~2.1m APERTURE
- o ADVANCED GEPS REQUIRES ~1.0m APERTURE
- o 2.1m MIRROR COULD WEIGH UP TO 4 TIMES AS MUCH AS A ONE METER MIRROR
- o STRINGENT POINTING REQUIREMENTS WITH LARGE AND HEAVY MIRROR WILL LIKELY REQUIRE INSTRUMENT - SPECIFIC POINTING SYSTEM

POINTING STABILITY REQUIREMENTS

The inherent complexity of ensuring high spatial resolution for imaging instruments is illustrated on the accompanying chart. The required pointing stability is given as a function of the desired spatial resolution. The stability was derived assuming that the pointing is held to within 10 percent of the instrument field of view (IFOV).

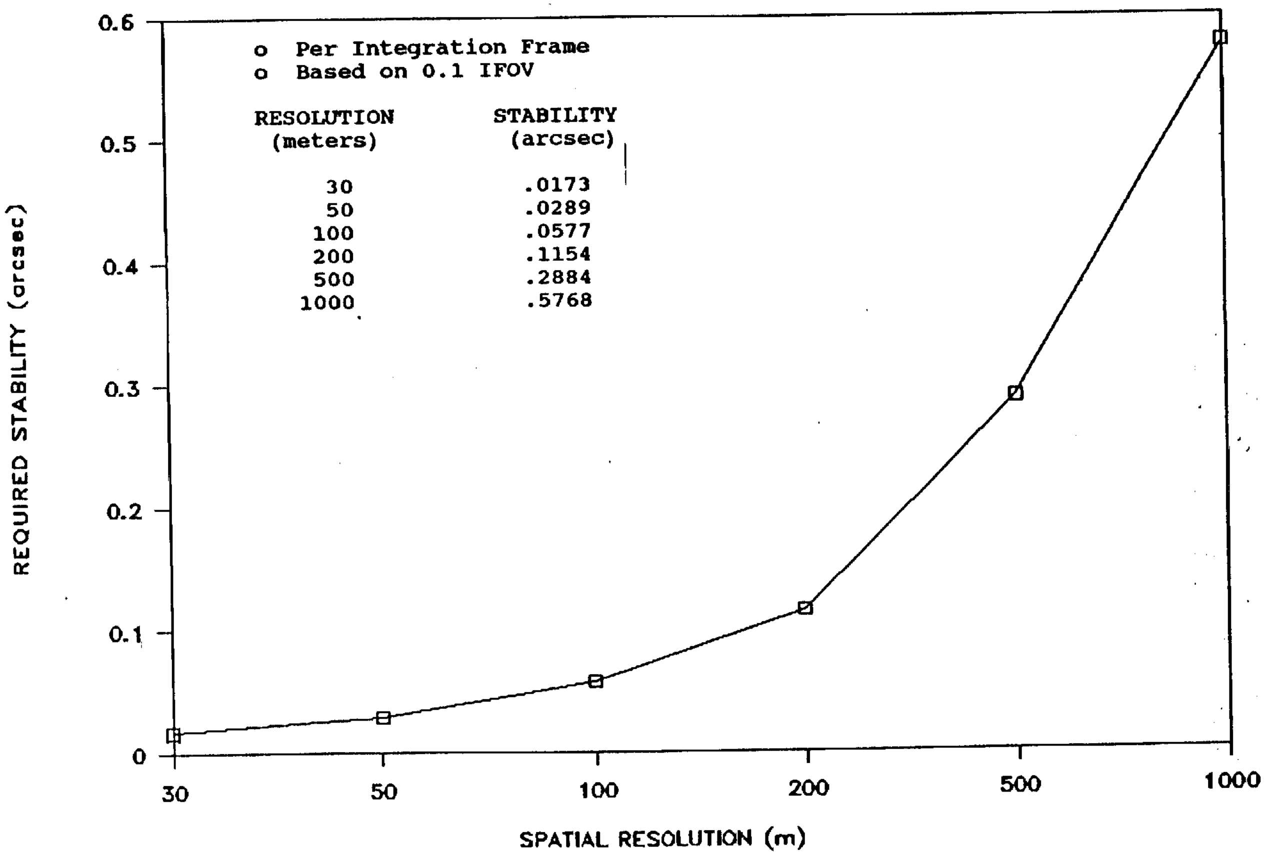
The table inset into the figure dramatically illustrates the tight pointing requirements. For a resolution of only 1000 meters, the required stability is 0.5768 arc-seconds, while for a resolution of 30 meters, the required stability is more than an order of magnitude greater at 0.0173 arc-seconds.

The major problem with the stringent pointing stability required for high resolution imagers is that the cost and complexity of the Platform pointing control subsystem is extremely high. The problem is exacerbated when the imager is heavy and large. A likely alternative is that instruments that require high stability be similarly required to provide their own pointing control subsystem, essentially decoupling them from the platform pointing subsystem.

POINTING STABILITY REQUIREMENTS

Lockheed

– ASSUMES .1 IFOV –



- Per Integration Frame
- Based on 0.1 IFOV

RESOLUTION (meters)	STABILITY (arcsec)
30	.0173
50	.0289
100	.0577
200	.1154
500	.2884
1000	.5768

CRYOGEN CONSUMABLES

The expected emphasis for Advanced ESGP instruments on the long-wavelength infrared spectral regime is expected to drive the cooling implementation that such detectors require. For observations at long wavelengths, detectors need to be cooled to extreme temperatures to obtain the required sensitivity. It is expected that these desired temperatures will be below 60K, which is too cool to be obtained through strictly passive means.

Two types of cooling methods are commonly used for operating temperatures that can not be achieved strictly passively. The first is through the use of mechanical refrigerators or Stirling Coolers. The major problem with these is the question of limited lifetime and the pointing instabilities transmitted to the Platform by the mechanical motions of these devices.

The second choice is the use of cryogens whereby different types are used dependent on the desired operating temperature. However, regardless of which type is used, the fact that cryogen boils off under normal usage results in the cryogen supply effectively governing instrument lifetime.

With the added emphasis on long-wavelength observations and the cooler operating temperatures required, it is likely that cryogens will be used at least one instrument for the Advanced ESGP. In an effort to maximize instrument lifetime, top-off of the cryogen supply at the Space Station prior to transfer to the geostationary orbit is recommended.

CRYOGEN CONSUMABLES

- LWIR OBSERVATIONS REQUIRE COOL DETECTORS
- UARS CLAES DETECTORS OPERATE AT 15K FOR 12.7 MICRON DATA
- CRYOGENS COMMONLY USED FOR $T < 60K$
- TYPICAL CRYOGENS INCLUDE CH4 ($T = 60K$), Ar ($T = 48K$), AND Ne/CO2 ($T = 15.5K$)
- CRYOGEN SUPPLY EFFECTIVELY GOVERNS INSTRUMENT LIFETIME
- CRYOGEN TOP-OFF AT SSF PRIOR TO GEO TRANSFER WILL MAXIMIZE LIFETIME FOR SIs THAT USE CRYOGEN

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NASA

ROBOTIC SYSTEM CHARACTERISTICS

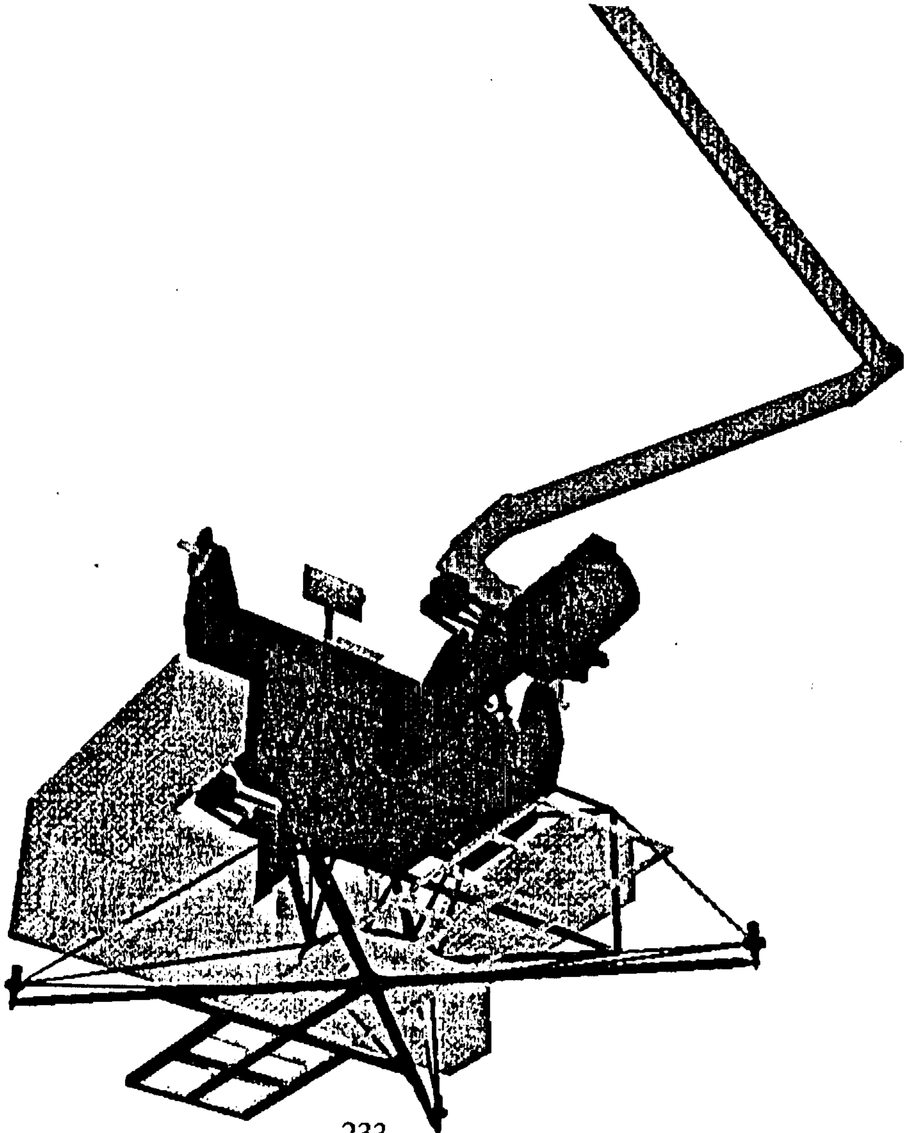
- APPENDIX B -

Lockheed

MOBILE SERVICING CENTRE - 3D MODEL

A full three dimensional view of the MSC is shown with the SSRMS in the deployed position. The figure was obtained from the Lockheed CAEDS object modeling system, which was used as an input to the CIMSTATION program.

MOBILE SERVICING CENTRE
- 3D MODEL -



MOBILE SERVICING CENTRE
OPERATIONAL MODES/TASKS

The MSC is primarily teleoperated by an IVA and/or EVA crewmember from an MSS control station. Some autonomous functions will be available for initial MSC operations, and additional autonomy will be incorporated as a growth capability. A list of the various control modes available for the MSC components is included below.

a. Force and moment accommodation
b. Collision avoidance
c. Human in the loop trajectory processing
d. Bi-directional control (from either end effector)
e. SSRMS/SPDM coordinated control
f. Coordinate re-referencing
g. Line Tracking
h. Rate Hold
i. Rate input scale selection
j. Rate limit selection
k. Position/orientation hold selection

MOBILE SERVICING CENTER OPERATIONAL MODES / TASKS

	CONTROL MODE				
	HUMAN IN THE LOOP			AUTOMATIC TRAJECTORY	
CONTROL FEATURE	NORMAL	SINGLE JOINT	OPERATOR COMMANDED	PRE-STORED AUTO SEQUENCE	PRE-STORED JOINT POSITION AUTO-SEQ
FORCE-MOMENT ACCOMMODATION/LIMITING	X	X	X	X	X
COLLISION AVOIDANCE	X	X	X	X	X
HUMAN-IN-THE-LOOP PROCESSING	X	X			
BI-DIRECTIONAL CONTROL	X	X	X	X	X
SSRMS / SPDF COORDINATED CONTROL	X		X	X	
COORDINATE RE-REFERENCING	X		X	X	
LINE TRACKING			X	X	
RATE HOLD	X	X			
RATE INPUT SCALE SELECTION	X	X			
RATE LIMIT SELECTION	X	X	X	X	X
POSITION/ORIENTATION HOLD SELECTION	X				

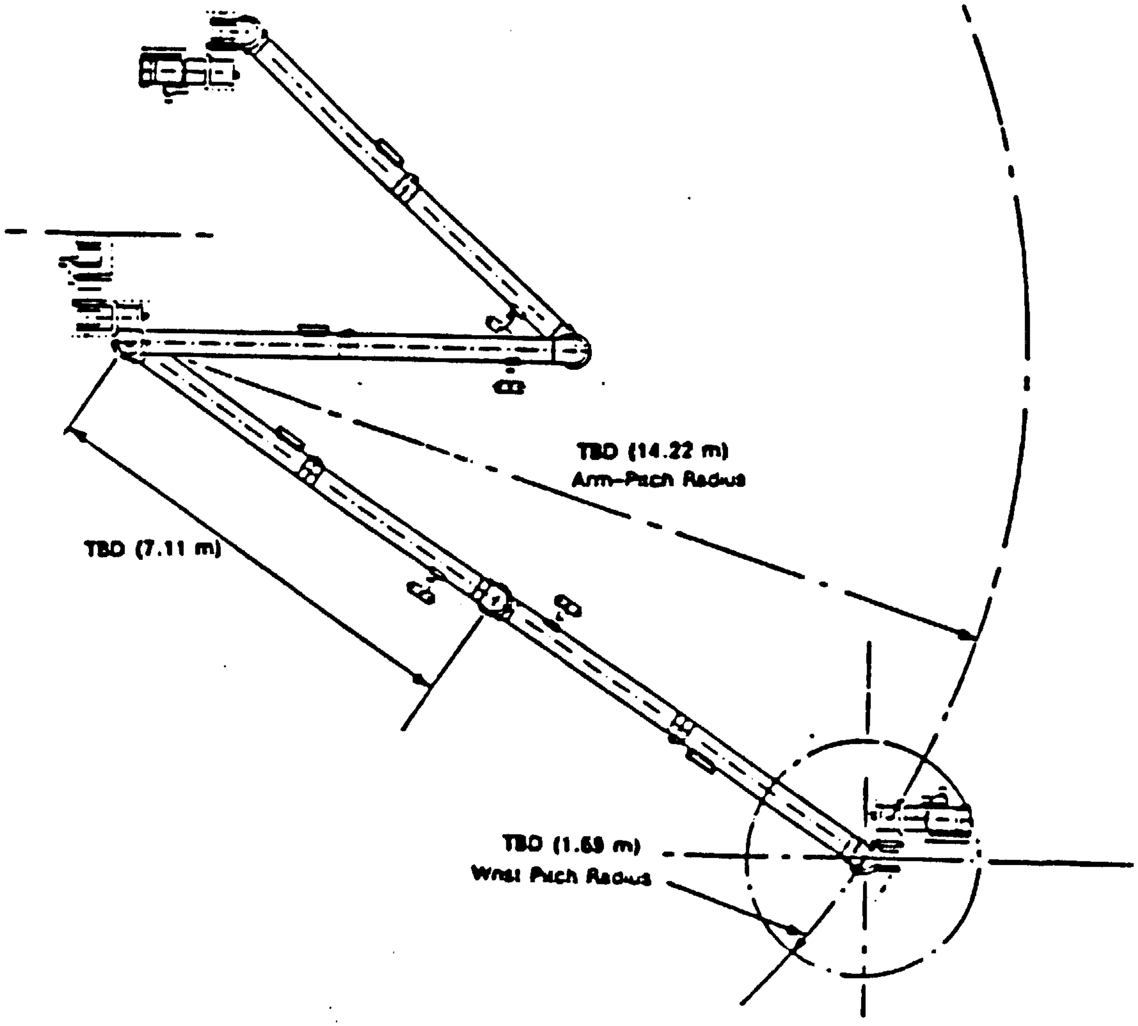
MOBILE SERVICING CENTRE
REACH/WORK ENVELOPE

The MSC reach/work envelope consists of the MT and SSRMS characteristics described below.

The MT can reach at least 5 m (one truss bay) in a single plane. The reach envelope associated with a plane change is slightly more complex, involving reaching to the perpendicular truss bay plane.

The reach length of a fully extended SSRMS is 17.6 m (57.7 ft). The joint limits and independence should allow a reach envelope of almost a full sphere of this radius, subject to obstructions by the truss, MBS, etc. The work envelope may be estimated by using the work envelope radius of 15.9 m (52.2 ft) as shown in the figure to allow all degrees of freedom in the wrist to be accessed.

MOBILE SERVICING CENTRE REACH / WORK ENVELOPE



MOBILE SERVICING CENTRE - CONSTRAINTS -

Mobility/Stabilization Constraints

a. The MRS depends on the MT for stabilization and transportation to the worksite. The MRS can be transported to any location that the MT can access, and operates from MSC utility ports located as shown in the figure.

b. The MT is self-mobile. It translates along the truss structure and stabilizes itself using node latch pins located at the corners of the truss bay faces. The MT may translate along any suitable open truss bay face equipped with node latch pins.

c. The SSRMS may obtain mobility from the MT when attached to the MRS, or it may relocate itself (using symmetry and bidirectional control capabilities) on PDGFs suitably spaced along the Space Station exterior. The SSRMS is stabilized at is base attachment to a PDGF.

Operational Constraints

a. The MSC will only have one control station active at a time. Shutdown of any MSC element will be possible at any time from any active or monitoring MSS control station.

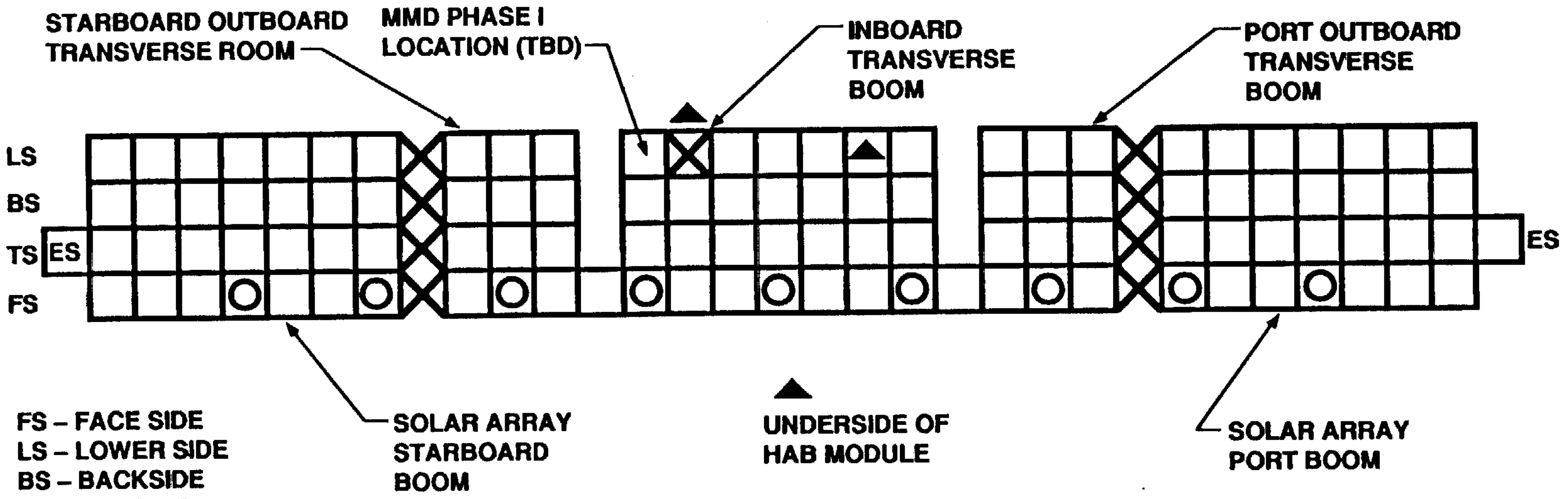
b. Manipulative (SSRMS, SPDM, FTS) operations will not be performed while the MSC is in motion.

c. A maximum of 10 kW will be supplied to the MSC, including payload and FTS power.

d. The MT will have the capabiltiy of translating up to TBD truss bays on battery power.

MOBILE SERVICING CENTRE

CONSTRAINTS



FS – FACE SIDE
LS – LOWER SIDE
BS – BACKSIDE
TS – TOP SIDE
ES – EXTERIOR SIDE

☐ MSC RIGHT OF WAY CORRIDOR

○ MSC UTILITY PORT TBD

▲ SSRMS POWER DATA
GRAPPLE FIXTURE TBD

☐ SSRMS GRAPPLE FIXTURES TBD

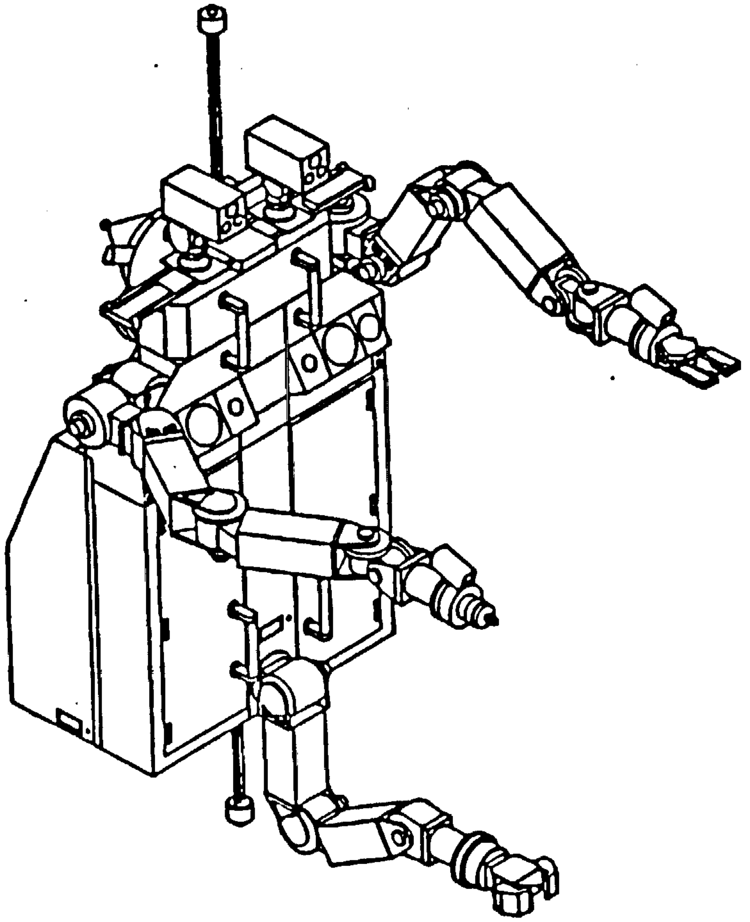
☒ MMD LOCATION

NOTE: THE MSC MAY MOVE TO EITHER PLANE TO FULFILL OPERATIONAL REQUIREMENTS

FLIGHT TELEROBOTIC SERVICER CHARACTERISTICS

The FTS is a multi-purpose, dexterous robotic system as shown in the accompanying figure. It has two manipulators and is capable of dual arm coordinated control. It is designed to assist and reduce EVA by performing assembly, maintenance, servicing, and inspection tasks. The baseline FTS will be primarily teleoperated, with limited autonomous modes. As the system evolves, more autonomous capability will be developed and implemented. The FTS is intended to evolve and enhance on-orbit human/machine capabilities. It plays a critical role in the assembly of an Advanced Geostationary Platform at SSF.

FLIGHT TELEROBOTIC SERVICER CHARACTERISTICS



FLIGHT TELEROBOTIC SERVICER
OPERATIONAL MODES/TASKS

The FTS operates in four modes, as shown in the figure:

a. Transporter Attached

    1. SRMS Transporter Attached

    2. SSRMS Transporter Attached - Structural attachment, power, data, and video are provided via a Power Data Grapple Fixture (PDGF). It is the primary mode used for assembly of the geostationary platform bus.

    3. OMV Transporter Attached - Utilities provided by the OMV.

b. Fixed Base Dependent - Structural attachment, power, data, and video are provided via the Worksite Attachment Mechanism (WAM).

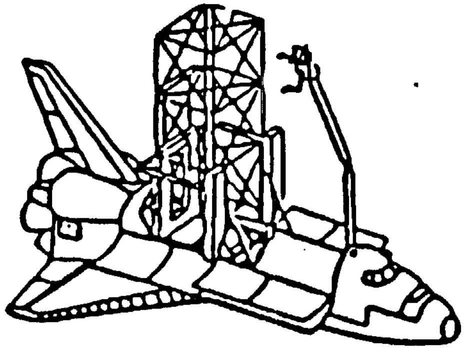
c. Fixed Base Independent - Structural attachment is provided through the WAM, power is provided by internal FTS batteries, and data / video are provided via the FTS communications system.

d. Fixed Base Umbilical - Structural attachment is provided through the WAM; power, data, and video are provided via the FTS/SRMS umbilical, or via an umbilical between the Orbiter Payload Bay and the FTS.

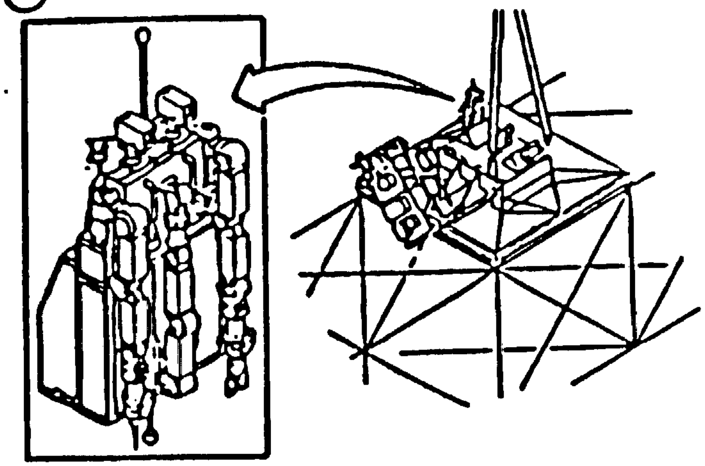
The FTS can install and remove truss members, install Station Interface Adapters on the truss, change out ORU's, and/or perform inspections while mounted on the SSRMS.

FLIGHT TELEROBOTIC SERVICER OPERATIONAL MODES / TASKS

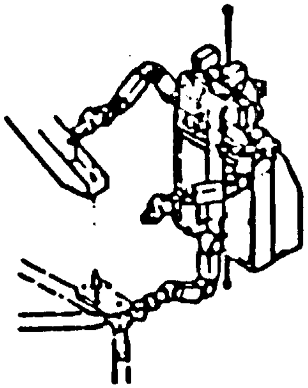
Ⓐ SSFTS OPERATIONS FROM THE ORBITER PAYLOAD BAY



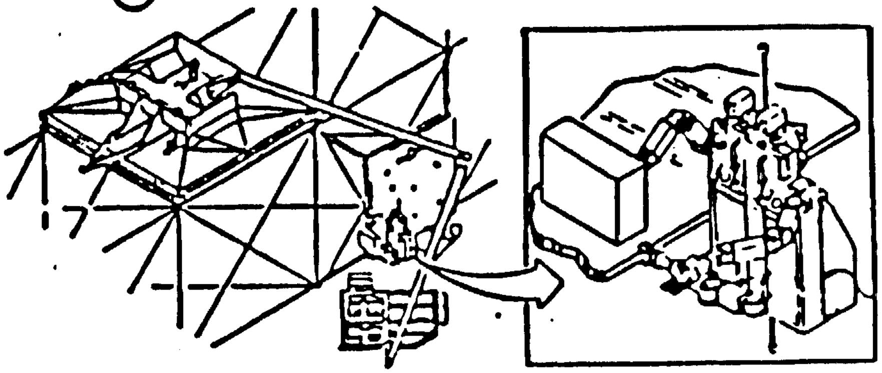
Ⓑ TRANSPORTER ATTACHED OPERATIONS ON FREEDOM



Ⓒ FIXED BASE INDEPENDENT OPERATIONS ON FREEDOM



Ⓓ FIXED BASE DEPENDENT OPERATIONS ON FREEDOM



FLIGHT TELEROBOTIC SERVICER
REACH/WORK ENVELOPE

The FTS reach/work dimensions are shown in the figure:

a. The FTS can reach any worksite location within 72 inches of the stabilization point (berthing point or mobility/stability aid).

b. The FTS can work through an access opening of 44 inch height by 61 inch width to a depth of 26 inches.

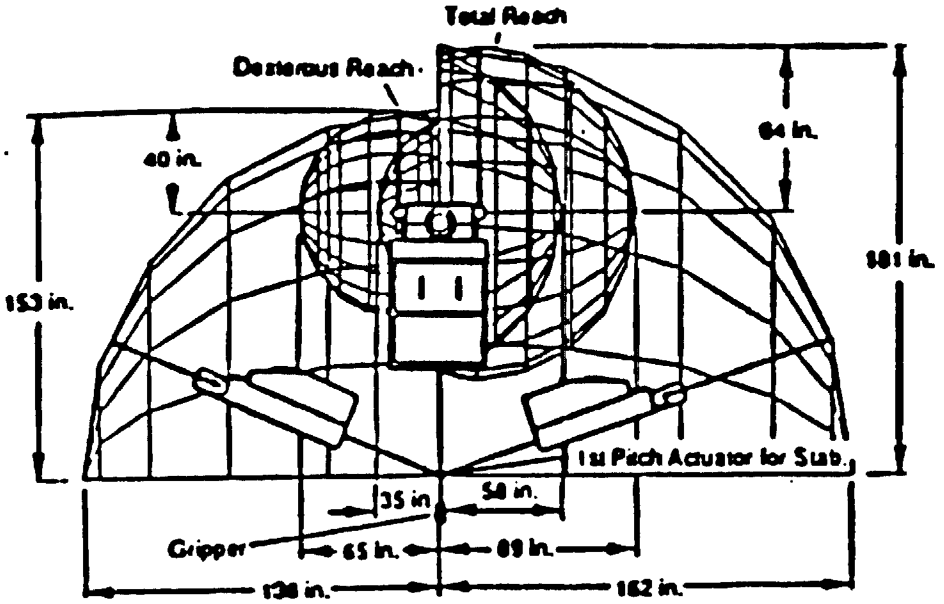
c. The FTS can manipulate workpieces around obstructions with a minimum clearance of 4.0 inches at any point.

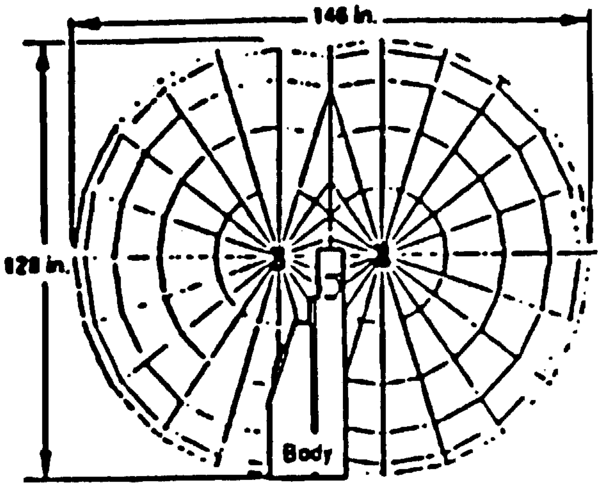
The truss assembly/removal task requirements are capabilities shown were used in the simulation program.

NASA SPACE FLIGHT

FLIGHT TELEROBOTIC SERVICER
REACH / WORK ENVELOPE

Lockheed





OFF-SET SHOULDER AND REACH PROVIDE CAPABILITY TO ACCESS BODY FOR TOOL STORAGE, UMBILICAL CONNECTION, INSPECTION

REACH EASILY ACCOMMODATES TASKS

Task	Requirement	Capability
Radiator Panel Assembly	Attachment Point to Wrist > 9-ft	Dexterous Reach = 11-ft 6-in.
ORU Changeout	Attachment Point to User I/F > 11-ft 8 in	Total Reach = 13-ft 6 in.
ORU Changeout Truss Install/Remove	Body to User I/F > 3-ft	Arm Length = 5 ft (to User I/F)

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AUTOMATED ANALYSIS TOOLS

- APPENDIX C -

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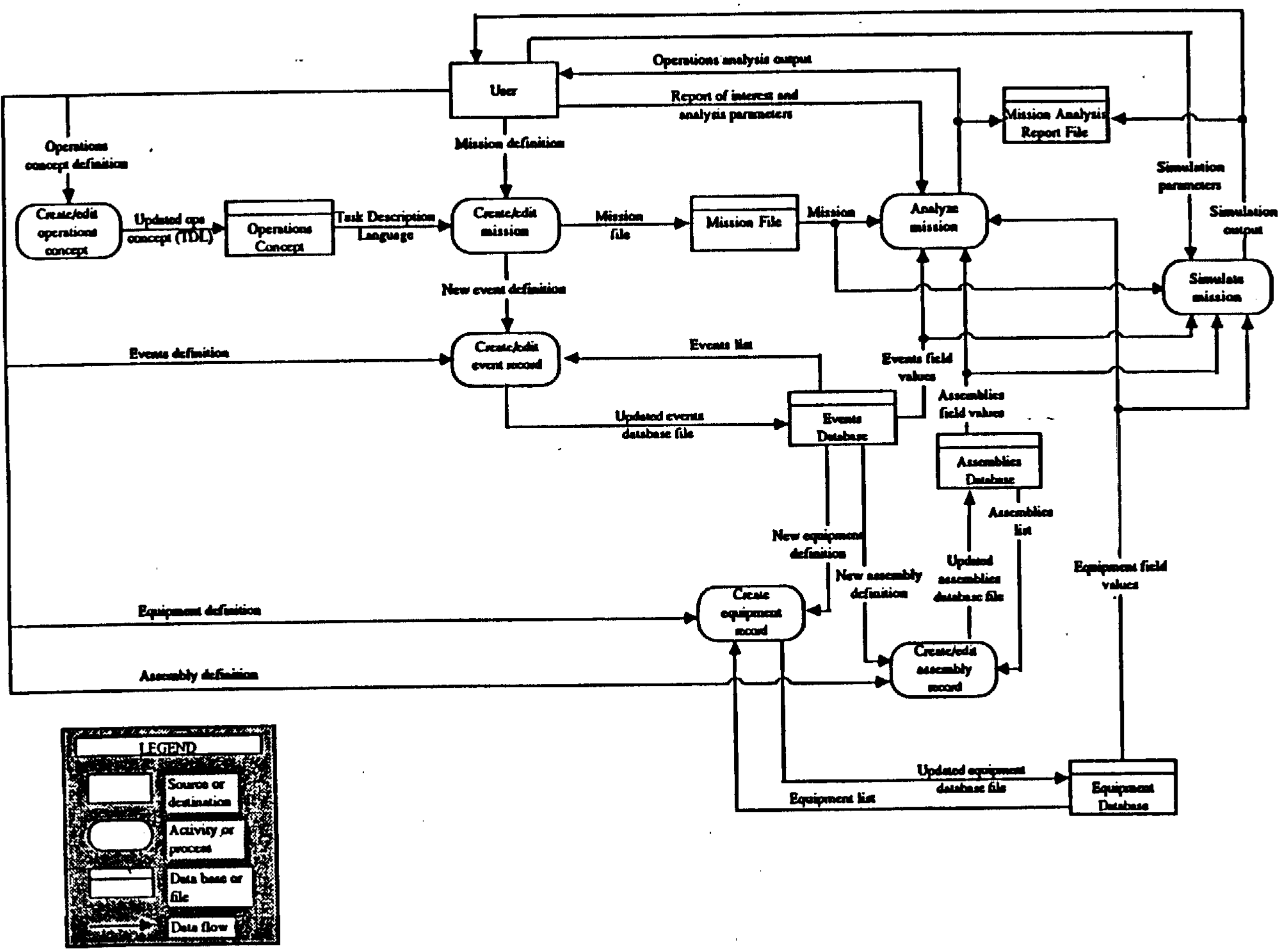
SODAS FUNCTIONAL REQUIREMENTS FLOW DIAGRAM

The SODAS functional requirements flow diagram is shown in the figure and concepts of a number of integrated databases are identified below:

- operations concept - a set of on-orbit operations flows in TDL files. Depending on user reqirements, separate operations concepts may exist for VPOD, SMOD, and FOD.
- missions - a sequential flow of required activities. A mission is a deterministic path through the operations concept (e.g. on-orbit assembly of an Advanced Geostationary Platform at SSF).
- events - required activities. Events can be mapped to tasks identified in the operations concept. Depending on user needs, separate events databases may exist for VPOD, SMOD, and FOD. The events databases hold data on event duration, and on required crew, skills, equipment, and hardware.
- equipment - SSF and transportation node elements and tools used in on-orbit operations. The equipment database is shared among VPOD, SMOD, and FOD. The database holds the hierarchical relationships among equipment, and eqipment specific data such as resource (e.g., power, communication, thermal, fluids) needs, mass and dimensions.
- hardware - components or modules of a vehicle or science mission not provided by SSF, i.e., mission-unique equipment or vehicle assembly. Depending on user requirements, separate hardware databases may exist for VPOD, SMOD, and FOD. The database holds the hierarchical relationship among hardware and subhardware, and hardware specific data such as resource requirements, mass and dimensions.

SODAS is implements in ORACLE and ANSI-C for maximum portability among different computer architectures and operating systems. However, the current platform is an IBM-compatible 386 workstation running PC-DOS.

SODAS
FUNCTIONAL REQUIREMENTS FLOW DIAGRAM



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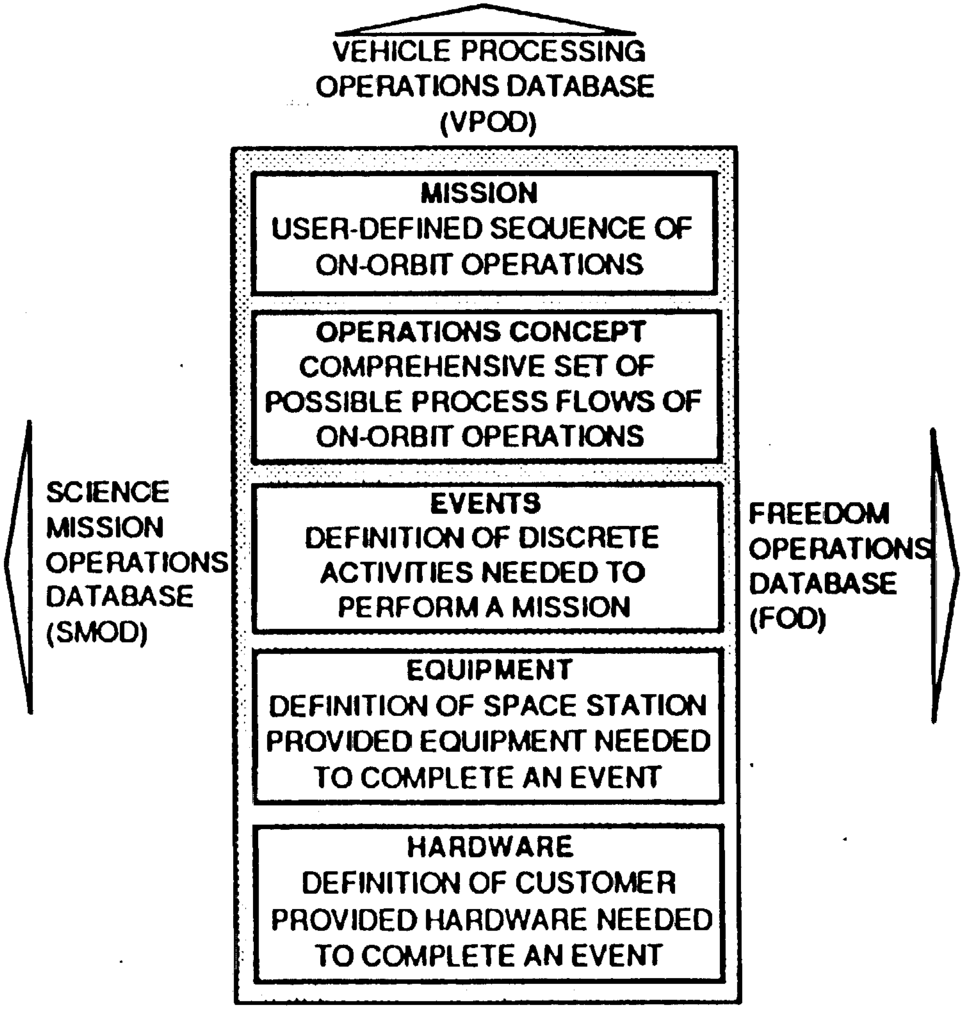
SPACE OPERATIONS DATABASE & ANALYSIS SYSTEM (SODAS)

As shown in the figure, the Space Operations Database and Analysis System (SODAS) is used to store and maintain the operations analysis information. SODAS is an automated on-orbit operations modeling tool that provides for rapid development, modification, and analysis of mission scenarios, and interfaces with the VPOD, FOD, and SMOD databases. SODAS uses a structured methodology for defining on-orbit operations. It allows analysts to define on-orbit events, to specify SSF-provided equipment and mission-specific hardware (e.g., vehicle assemblies) needed to perform the events, and to define a mission scenario. For mission scenarios, SODAS produces cost models, timelines, and reports on SSF resource usage requirements such as power, thermal control, and communications. SODAS also provides reports on required crew members and necessary crew skill. This data can be used to define payload and user accommodations.

SPACE OPERATIONS DATABASE & ANALYSIS SYSTEM (SODAS)



VEHICLE PROCESSING
OPERATIONS DATABASE
(VPOD)

SCIENCE
MISSION
OPERATIONS
DATABASE
(SMOD)

MISSION
USER-DEFINED SEQUENCE OF
ON-ORBIT OPERATIONS

OPERATIONS CONCEPT
COMPREHENSIVE SET OF
POSSIBLE PROCESS FLOWS OF
ON-ORBIT OPERATIONS

EVENTS
DEFINITION OF DISCRETE
ACTIVITIES NEEDED TO
PERFORM A MISSION

EQUIPMENT
DEFINITION OF SPACE STATION
PROVIDED EQUIPMENT NEEDED
TO COMPLETE AN EVENT

HARDWARE
DEFINITION OF CUSTOMER
PROVIDED HARDWARE NEEDED
TO COMPLETE AN EVENT

FREEDOM
OPERATIONS
DATABASE
(FOD)

COMPUTER INTEGRATED ENGINEERING AND MANUFACTURING SYSTEM (CIEM)

LMSC established the CIEM Project in 1985 to implement CAD/CAE/CAM technology for the company. The following services are provided:

- Development and implementation of a CIEM System
- Computer program evaluations, procurement, installation, training
- User support
- Computing environment architecture and procurement assistance
- Central point of contact for software/computing equipment vendors
- Source for CAD/CAE/CAM technology information

Areas of expertise include: solid modeling; assembly/mechanism design; structural/thermal analysis; configuration/data management; expert systems; and manufacturing planning. These technology areas have a potential contribution to all SSF Advanced Concepts Tasks.

As part of CIEM System development, evaluations were performed to identify the most effective commercially available software for structrual design and analysis and data management, resulting in selection of IDEAS for engineering and ORACLE for data management. IDEAS, being the integration basis and a significant part of the analysis capability of IDEAS**2, provides a high degree of analytical commonality with the customer and an effective means of data exchange through IDEAS universal files. LMSC is experienced in production use of non-IDEAS technical software integrated into IDEAS**2, viz., NASTRAN, ADAMS, TRASYS and SINDA. Other modules of IDEAS**2 could easily be integrated into the CIEM System through the IDEAL language, or the entire IDEAS**2 program could be implemented. CIEM's adoption of the ORACLE RDBMS also enables convenient access to CTA's "VPOD."

LMSCs CAD/CAE/CAM implementation though the CIEM Project has resulted in a high degree of commonality with NASA in technical expertise, data management, and analytical tools. This commonality provides an excellent matrix for engineering cooperation and data interchange.

COMPUTER INTEGRATED ENGINEERING AND MANUFACTURING SYSTEM (CIEM)

INTERACTIVE 3-D SOLIDS MODELING	INTERACTIVE 3-D FINITE ELEMENT MODELING AND ANALYSIS	SPACECRAFT SYSTEMS DESIGN AND EVALUATION
COMPONENT DESIGN AND PLACEMENT	STRUCTURAL/THERMAL ANALYSIS (NASTRAN)	CONTROL SYSTEMS DESIGN
INTERFERENCE CHECK (GEOMOD)	MODAL AND DYNAMIC ANALYSIS (ARCD AND ATTPRED)	THERMAL CONTROL SYSTEMS DESIGN
MASS AND INERTIA PROPERTY	ORBITAL ANALYSIS (OL)	PROPULSION SYSTEMS DESIGN AND EVALUATION
IDEAS^2		

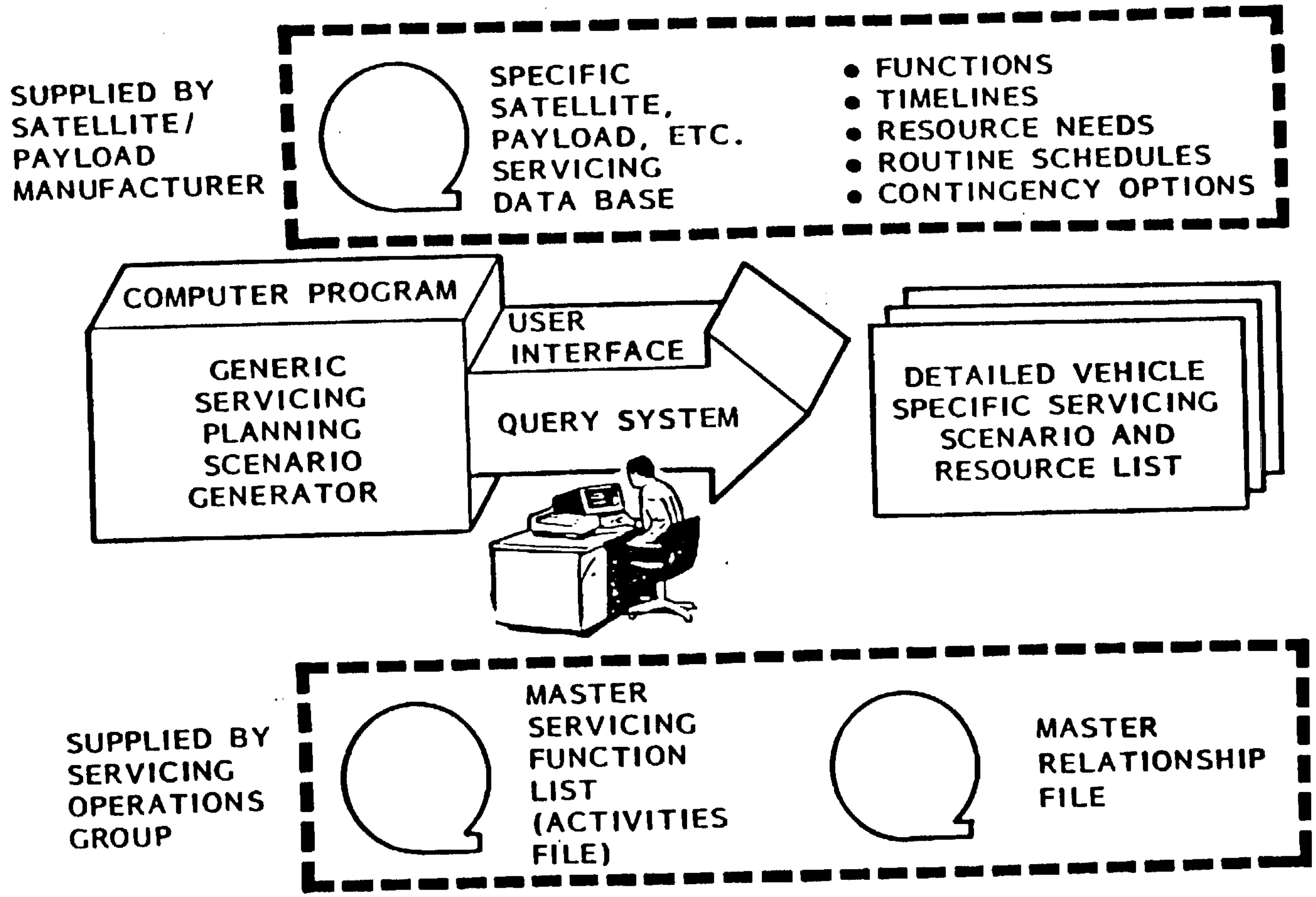
AUTOMATED SCENARIO GENERATOR

The automated scenario generator computer program concept was initially developed by LMSC for NASA/GSFC in support of servicing scenario database efforts on Work Package 3. Database systems developed for SSF include Vehicle Operation Database (VPOD) and Space Operations Database and Analysis System (SODAS). The automated scenario generator program characteristics and capabilities:

- Support design of servicing facilities;
- Incorporate comprehensive vehicle-specific database;
- Provide detailed function/task list scenarios with timelines and resource allocation and consumption date;
- Produce scenarios with task flow diagram of function relationships;
- Generate scenarios by interactive query system;
- Handle routine, as well as special/contingency servicing missions;
- Permit easy updating of the database in real time.

AUTOMATED SCENARIO GENERATOR

COMPUTER PROGRAM CONCEPT



SUPPLIED BY
SATELLITE/
PAYLOAD
MANUFACTURER

SPECIFIC
SATELLITE,
PAYLOAD, ETC.
SERVICING
DATA BASE

- FUNCTIONS
- TIMELINES
- RESOURCE NEEDS
- ROUTINE SCHEDULES
- CONTINGENCY OPTIONS

COMPUTER PROGRAM

GENERIC
SERVICING
PLANNING
SCENARIO
GENERATOR

USER
INTERFACE

QUERY SYSTEM

DETAILED VEHICLE
SPECIFIC SERVICING
SCENARIO AND
RESOURCE LIST

SUPPLIED BY
SERVICING
OPERATIONS
GROUP

MASTER
SERVICING
FUNCTION
LIST
(ACTIVITIES
FILE)

MASTER
RELATIONSHIP
FILE

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