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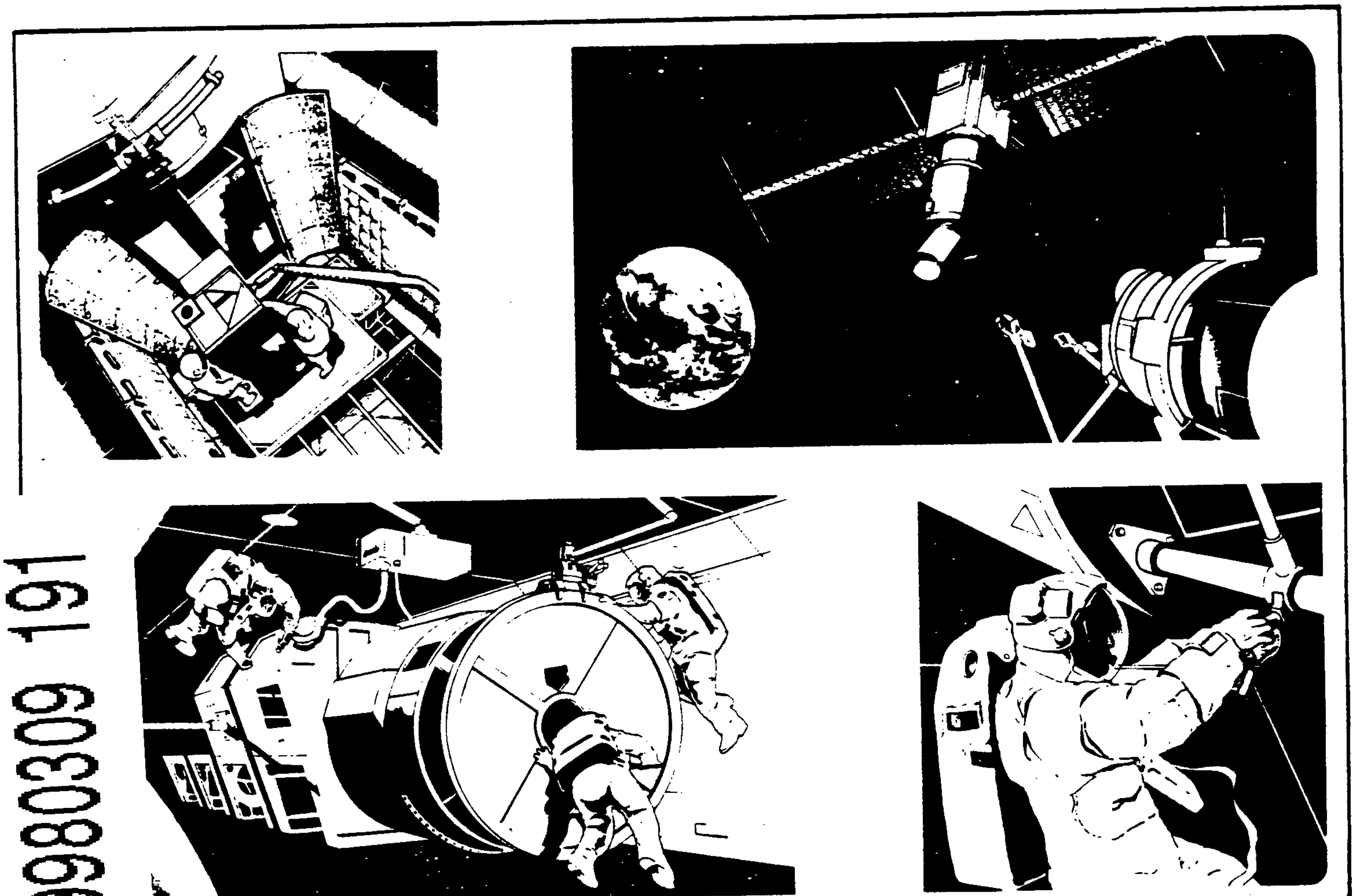
FINAL REPORT

Space Assembly, Maintenance and Servicing Study



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VOLUME IV: Concept Development Plan

Lockheed / BOEING / Honeywell / CSI / ITRI / Carnegie-Mellon University

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Vol. IV

SPACE

ASSEMBLY - MAINTENANCE - SERVICING

(SAMS) STUDY

FINAL REPORT

VOLUME IV

CONCEPT DEVELOPMENT PROGRAM

INDEX TO VOLUMES

LMSC-F104866
Vol. IV

FOREWORD

This Space Assembly, Maintenance, and Servicing (SAMS) Study final report is submitted by Lockeed Missiles and Space Company in response to SAMS Study CDRL-027A2, per contract number F04701-86-C-0030.

This document is divided into the following five volumes:

Volume	I	Executive Summary
Volume	II	System Analysis
Volume	III	Design Concepts
Volume	IV	Concept Development Plan
Volume	V	Neutral Buoyancy and Simulation Report

The Concept Development Plan section, Volume IV, contains the following sections:

Section	1.0	Introduction
Section	2.0	Program Summary
Section	3.0	Application Selection Methodology
Section	4.0	Candidate Selection and Prioritization
Section	5.0	Candidate Development Plan
Section	6.0	Integrated Concept Development Program

Questions and/or comments concerning this document should be directed to Thomas E. Styczynski at 408-756-6671.

APPROVED ______________________
Carl D. Patterson,
SAMS Study Program Manager

ACRONYMS

AI	Artificial Intelligence
AKM	Apogee Kick Motor
ASE	Airborne Support Equipment
AXAF	Advanced X-Ray Astronomical Facility
BSTS	Boost Surveillance Tracking System
CDP	Concept Development Program
CDR	Critical Design Review
CG	Center of Gravity
COMSAT	Communications Satellite
CY	Calender Year
DoD	Department of Defense
DRM	Design Reference Mission
ESS	Equipment Support Section
EVA	Extra Vehicular Activity
FLT	Flight
FOC	Full Operating Capability
FSS	Flight Support System
FTS	Flight Telerobotic Servicer
G	Gravity
GRO	Grosynchronous
GSFC	Goddard Space Flight Center
HEO	High Earth Orbit
I/F	Interface
IOC	Initial Operating Capability
IUS	Inertial Upper Stage
JPL	Jet Propulsion Labs
JSC	Johnson Space Center
LDEF	Long Duration Exposure Facility
LEO	Low Earth Orbit
LeRc	Lewis Research Center
LMSC	Lockheed Missiles & Space Company, Inc.
M	Million
MMS	Multimission Satellite

ACRONYMS (Cot'd)

NASA	National Aeronautics and Space Administration
NB	Neutral Buoyancy
NBS	Neutral Buoyancy Simulation
OMV	Orbital Maneuvering Unit
OPS	Operations
ORU	Orbital Replaceable Unit
OSCRS	Orbital Spacecraft Consumables Resupply Study
OTV	Orbital Transfer Vehicle
POC	Proof of Concept
RMS	Remote Manipulator System
RCS	Reaction Control System
SAMS	Space Assembly, Maintenance, and Servicing
SDI	Strategic Defense Initiative
SDIO	Strategic Defense Initiative Office
SIRTF	Space Infared Telescope Facility
STS	Space Transportation System
TBD	To Be Determined
WETF	Water Emersion Test Facility

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INTRODUCTION

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Section 1.0
CONCEPT DEVELOPMENT PROGRAM

1.0 INTRODUCTION

The next step in the maturity of the Space Assembly, Maintenance Servicing (SAMS) is to move from the study of Methodology and Potential Application into an Initial Operating Capability (IOC). This step is predicated on the initiative of the Air Force to apply the SAMS concepts to existing and proposed programs. The SAMS Concept Development Program (CDP) plan defines the analyses, studies, technology development and ground/flight testing which will lead to a SAMS IOC.

This concept development program (CDP), Volume IV of the SAMS final report, contains a summary of the selection of CDP candidates and a plan for completing the required analysis, tests and demonstrations. This volume will highlight the sources of the CDP candidates and discuss the influence of on-going SAMS related programs within other government agencies (I.E. National Aeronautics and Space Administration (NASA), Department of Defense (DoD). The CDP candidates were analyzed to establish key technology developments and were prioritized for highest potential pay-off to SAMS. Finally a five year plan was generated including ROM cost and schedule.

SAMS

PROGRAM SUMMARY

SECTION 2.0

Section 2.0
PROGRAM SUMMARY

2.1 SAMS STUDY

2.1.1 Scope/Purpose

The SAMS Study analyzed and established cost effective spacecraft system, mission and design approaches which will improve mission success and spacecraft performance through the application of space assembly, maintenance and servicing. The study provided the Air Force with an understanding of the steps and hardware necessary to implement a SAMS program as well as a supporting cost data.

2.1.2 Approach

A simplified approach to the SAMS Study is shown in Fig. 2-1. The approach highlights the flow of the study from consolidated requirements thru design concepts and scenarios into the system/cost/benefit analyses all documented in the final report.

The input to the consolidated requirements was a combination of the Space Transportation Architecture Study (STAS) database augmented by the NASA civil needs database and a Lockheed Missiles and Space Company (LMSC) mission database. Figure 2-2 illustrates the relationship of the SAMS Design Reference Missions (DRM) to the four STAS scenarios (constrained to full Space Defense Initiative (SDI); the early and late SAMS epochs and the location grouping).

After establishing the five DRM locations, further analysis was completed to establish the selection criteria for proceeding with concept design and cost/benefit analysis. This selection criteria concentrated on missions which had sufficient design/system detail (i.e. subsystem design, reliability data, mission performance data and consumable requirements) to provide the basis for further analysis.

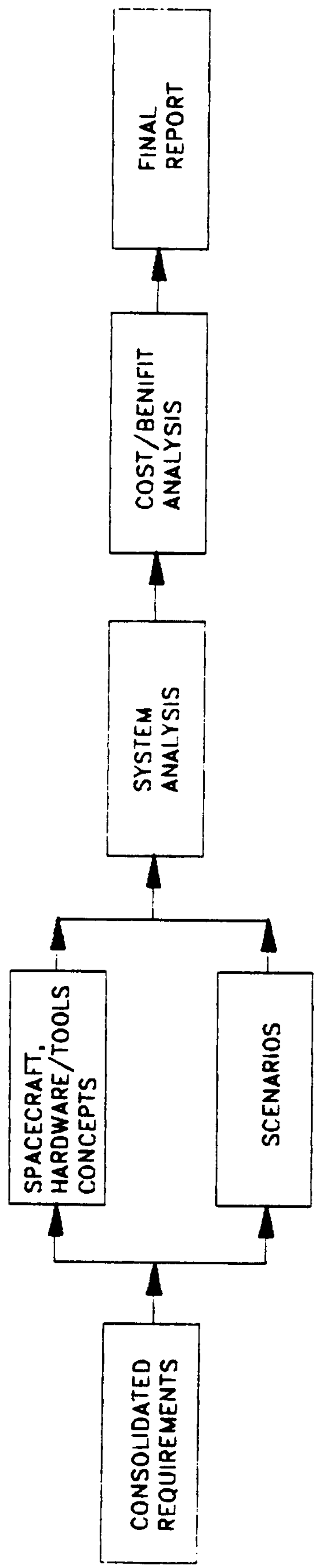
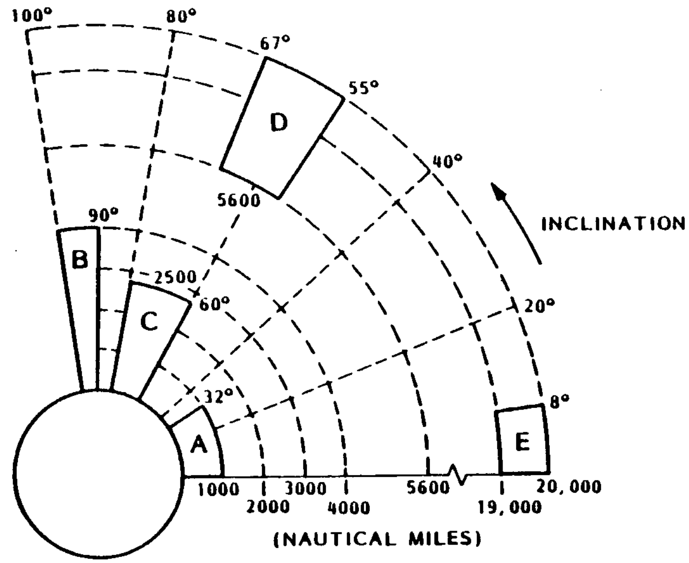


Figure 2-1 SAMS Study Approach



SCENARIO	DRM A	DRM B	DRM C	DRM D	DRM E	OTHERS	TOTALS		
							NO. PROGRAMS	EARLY	LATE
1	209	46	2	5	108	12	382	151	231
2	210	48	4	7	108	17	394	153	241
3	227	48	7	7	108	17	414	153	261
4	247	49	10	7	110	24	447	154	293

Fig. 2-2 Data Base Missions

The output of the consolidated requirements were both design and mission requirements focusing on SAMS application. Table 2-1 summarizes the design and mission analysis approaches for each design reference mission.

Table 2-1 DESIGN REFERENCE MISSION OVERVIEW

DRM-1 LOW EARTH ORBIT/LOW INCLINATION
LARGE OBSERVATORY
- o ANALYZE OPTIMIZATION OF RELIABILITY VERSUS WEIGHT
- o CONCEPT SPACECRAFT DESIGNS FOR MANNED AND REMOTE MAINTENANCE AND SERVICING

DRM-2 LOW EARTH ORBIT/POLAR
EARTH OBSERVATION
- o BASELINE AND MAINTAINABLE PROGRAM COST ANALYSIS
- o DETAILED RELIABILITY ANALYSIS INCLUDING OPTIMIZATION OF RELIABILITY VERSUS WEIGHT
- o COMPARATIVE LIFE CYCLE COST ANALYSIS
- o CONCEPT DESIGN OF SPACECRAFT MODIFICATINS FOR BUS AND PAYLOAD MAINTENANCE AND FUEL/BATTERY SERVICING

DRM-3 LOW EARTH ORBIT/MID-INCLINATION
SDI SATELLITES
- o LARGE CONSTELLATION ORBIT MECHANICS ANALYSIS
- o COMPARATIVE LIFE CYCLE COST REPLACEMENT VERSUS SAMS FOR LARGE CONSTELLATIONS
- o MANNED AND REMOTE ASSEMBLY DESIGN CONCEPTS

DRM-4 HIGH EARTH ORBIT/MID-INCLINATION
MILITARY COMSAT
- o COMPARATIVE COST ANALYSIS OF REPLACEMENT, REFUELING AND BOTH REFUELING AND MAINTENANCE
- o CONCEPT DESIGNS OF MODULAR SPACECRAFT ORU EXCHANGE AND REFUELING

DRM-5 GEOSYNCHRONOUS
GEO PLATFORM/COMSAT
- o COMPARATIVE COST ANALYSIS OF REPLACEMENT, REFUELING AND BOTH REFUELING AND MAINTENANCE
- o CONCEPT DESIGNS OF MODULAR SPACECRAFT FOR ORU EXCHANGE AND REFUELING

Next concept designs and scenarios were developed to meet the consolidated requirements. The design concepts addressed spacecraft, hardware and tools as applied to the three SAMS elements, assembly-maintenance-servicing. This task studied the impacts of manned-EVA versus remote/robotic servicing requirements; opportunities for modularity and standardization; and applications and developments in hardware tools. As a parallel effort scenarios were developed to exercise mission options and establish tool/hardware requirements.

Finally, systems analyses consisting of trades in mission scenarios and design approaches were documented in the cost/benefit analysis for each DRM. The entire study was documented in a five volume final report. Table 2-2 lists the title and content of each of the five volumes.

Table 2-2 SAMS FINAL REPORT

VOLUME	TITLE	CONTENTS
I	EXECUTIVE SUMMARY	Concise summary of SAMS Study approach and results
II	SYSTEM ANALYSIS	Summary of the system analysis,consolidated requirements trades cost/benefit analysis
III	DESIGN CONCEPTS	Spacecraft, hardware tool concept designs for the five DRMs interface definitions
IV	CONCEPT DEVELOPMENT PLAN	A plan for analysis, test and demonstrations to move SAMS into initial operating capability
V	NEUTRAL BUOYANCY AND SIMULATION REPORT	Report on the results of the SAMS simulation testing in neutral buoyancy and 1-G robotics demonstration

2.2 CONCEPT DEVELOPMENT PROGRAM

2.2.1 Scope/Purpose

The concept development program (CDP) is the intermediate step between the SAMS Study and Initial Operating Capability (IOC). Based on the results of the study, this program will focus on developing the enabling technologies necessary to take this step. With an IOC goal of 1990 this CDP will concentrate on near term analyses studies, ground demonstration tests and flight demonstration tests of SAMS related activity.

The definition of "SAMS related" is definitely open for discussion. For the purpose of this study this definition relates the three system functions (assembly, maintenance and servicing), to the technology developments, system design and system support requirements. Using this definition, the CDP candidate can be matrixed from system function, to system elements, to subsystem elements, and to the component level. Utilizing this approach, the satisfaction of the technology and program planning could occur at any level to fit budget and time constraints.

2.2.2 Approach

The following five step method was utilized in the development of the concept development program (COP) plan:

1) Develop the CDP candidate work sheets
2) Categorize by application
3) Prioritize by subsystem technology criticality
4) Develop candidate development plans
5) Produce an integrated program plan

The flow of these five steps is illustrated in Fig. 2-3.

The development of the CDP plan started with the Design Reference Missions (DRM) and the prior work reviews which focused the candidate technologies to the SAMS functional group requirements and provided an understanding of the work completed to date. Additional input resulted from the SAMS concept designs where specific design requirements and interface definition required additional development and test to verify the design approach. Finally, the SAMS program solicited inputs from other programs which are required to incorporate SAMS type requirements in the design (i.e. space station, advanced X-ray astronomical facility (AXAF), space infared telescope facility (SIRTF), or are considering SAMS application (i.e. boost surveillance tracking system (BSTS)). The result was a list of CDP candidates documented to a standardized worksheet (Ref. Fig 2-4). The candidate worksheets are contained in appendix A of this volume.

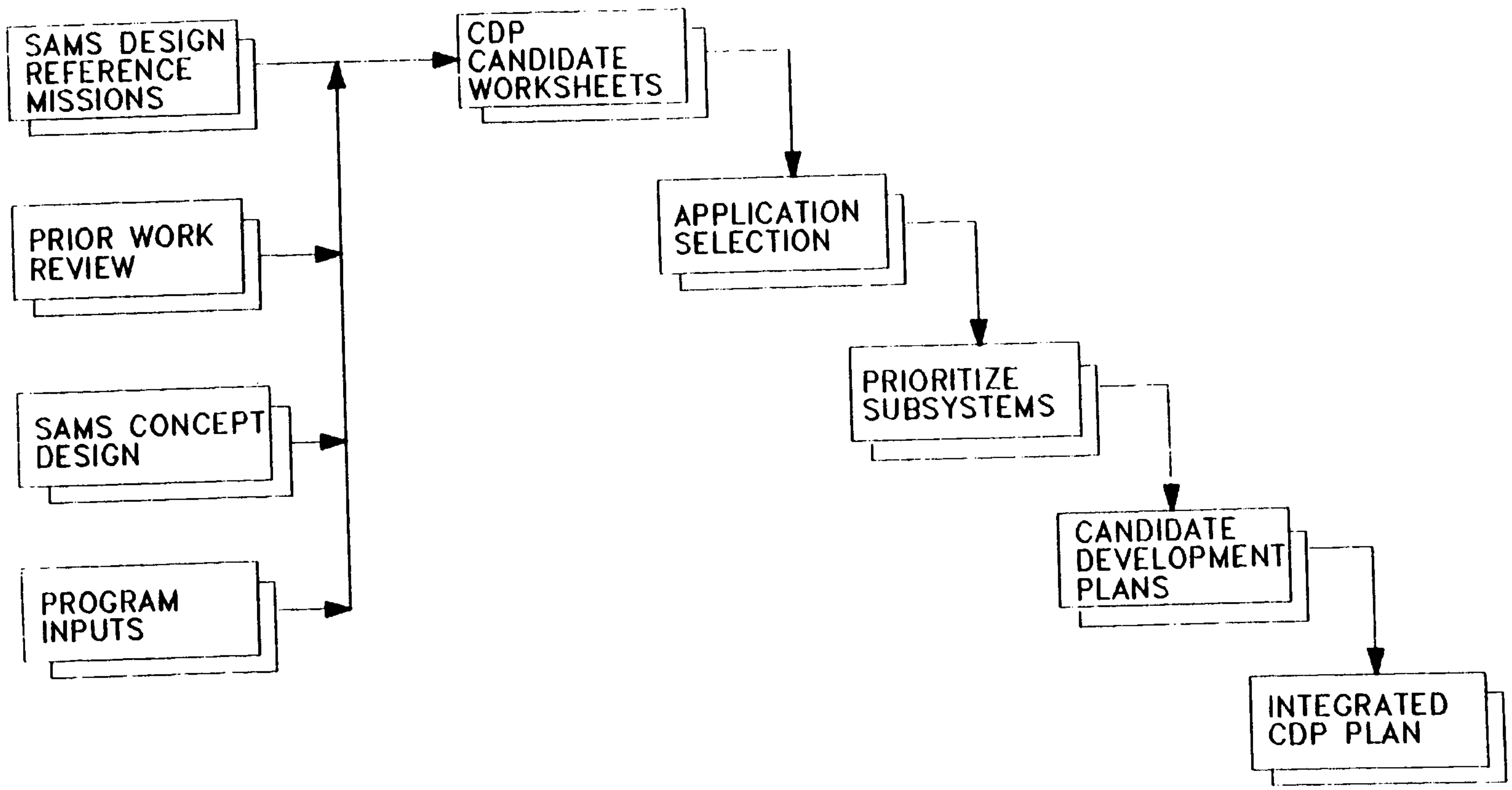


Figure 2-3 Concept Development Program Plan
Development Flow

Following the listing of the possible candidates a first level prioritization was completed in the application selection. This prioritization was based on SAMS requirements determined by DRM analysis and resulted a determination of the system and subsystem requirements for each of the following five SAMS application categories:

1) Remote ORU changeout
2) Large structure assembly
3) Bipropellant tanker systems
4) Cryogenic tanker systems
5) Complimentary technologies

The system and subsystems were further divided to the component technology requirements.

The next step was to prioritize the subsystem by their technical criticality to SAMS implementation. This step utilized risk weighting factors to evaluate the maturity, complexity, technical impact, cost and schedule for the subsystem candidates. Risk worksheets were developed for each SAMS application category requiring system development.

The data was next utilized to define candidate development plans for each of the five categories. These plans included a road map for subsystem development, determination of ground/flight test requirements, estimated schedules for development spans and a determination of the requirements for particular effort to improve the schedule.

The final step is the integrated plan which proposes the satisfaction of the technology requirements for a proposed timeframe. This plan includes rough order of magnitude (ROM) cost estimates.

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME:

BRIEF DESCRIPTION:

CURRENT STATE OF DEVELOPMENT:

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

TECHNOLOGY NEEDS FOR THIS CONCEPT:

OUTLINE OF DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS:

ESTIMATED COST AND BASIS OF ESTIMATE:

ESTIMATED SCHEDULE AND BASIS:

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE:

ESTIMATED CONSEQUENCE OF FAILURE:

CONTACT NAME:

TELEPHONE:

Fig. 2-4 SAMS CDP Development Plan

SAMS

APPLICATION SELECTION METHODOLOGY

SECTION 3.0

Section 3.0
APPLICATION SELECTION METHODOLOGY

3.1 FUNCTIONAL ORGANIZATION OF SAMS ELEMENTS

A wide range of different technologies must be developed and proven in order to provide SAMS capabilities on orbit. In order to provide more focus to the concept development program, four systems were chosen to represent the individual SAMS functions. For purposes of the concept development program, the satisfaction of technology and program planning could occur at this system level or at the subsystem/component level, depending on the budget and time constraints. The four systems chosen to represent SAMS functions are as follows:

Maintenance - Remote Orbital Replacement Unit (ORU) Change-out
Assembly - Large System Assembly, manned
Servicing - Bipropellant Tanker
Servicing - Cryogenic Tanker

These systems each have uses across multiple design reference missions (DRMs) as shown in Fig. 3-1. ORU change-out, the basis for all maintenance activity on-orbit, has applicability in all the DRMs defined for the SAMS study. Large system assembly has special applicability in DRMs 3 and 4, which involve large SDI constellations and large communication satellites, respectively. In order to properly service the large observation satellites of DRM 1, the earth observation systems of DRM 2, and the large communication satellites and platforms of DRM 5, a bipropellant tanker for propellant resupply would be necessary. The cryogenic tanker, on the other hand, would meet the fluid resupply requirements of DRM 3 and 4 satellites. All of these systems would require effective on-orbit docking and manipulation technologies to accomplish servicing. Also referenced in Fig. 3-1 are the complimentary technologies which would support the various DRMs but do not fall directly under the four major systems defined earlier. An example of a complimentary technology would be a logistics support study to develop sparing and availability models.

SERVICER FUNCTION / MISSION	ORU CHANGEOUT	LARGE SYSTEM ASSEMBLY	BIPROPELLANT TANKER	CRYOGENIC TANKER	COMPLIMENTARY TECHNOLOGIES
DRM 1 NASA LARGE OBSERV.	✓		✓		✓
DRM 2 EARTH OBSERV. SYSEM	✓		✓		✓
DRM 3 LARGE SDI CONSTEL.	✓	✓		✓	✓
DRM 4 LARGE COM SAT MILITARY SUPPORT	✓	✓		✓	✓
DRM 5 GEO PLTF LG COMSAT	✓		✓		✓

Figure 3-1 SAMS Function verses DRM

Because of the high servicing rate required by a large SDI constellation, DRM 3 is especially dependent on a logistically effective and efficient means of delivering materials on-orbit.

This section discusses the systems representing the 5 major technology areas of the concept development program with respect to their major elements and requirements. Each system is evaluated in respect to the dependencies it has on related subsystem technologies, both those existing and requiring further development. These subsystems are then further discussed to identify the requirements imposed on them and the developments necessary to successfully demonstrate SAMS capability.

3.2 REMOTE ORU CHANGE-OUT SYSTEM

3.2.1 Description Of A Remote ORU Change-Out System

The objective of this concept development program is to show that spacecraft modules can be exchanged by a remote servicing system controlled from a remote location. The objective is part of a larger goal to show spacecraft designers that on-orbit servicing can be effectively implemented into their programs. A significant demonstration of ORU change-out capability must be performed before spacecraft are to be designed for repair on orbit. Figure 3-2 shows a concept for a servicer developed by the LMSC team for servicing DRM 2, a Earth observation satellite. Because of its several large appendages, this satellite makes docking and berthing more difficult. Satellites in this orbit are candidates for servicing by either remote or EVA means, but the philosophy followed by this study is that by designing for servicing with simple mechanized devices, one finds the satellite is much easier to service using EVA techniques (as a backup) as well. The ORU change-out system, therefore, concentrates mainly on the remote aspects of satellite maintenance. Though EVA operations are certainly applicable, manned operations are discussed more thoroughly in the following section on large system assembly.

The servicer concept of Fig. 3-2 contains an ORU storage rack and module exchange mechanism mounted on an OMV. The servicer would approach the docking

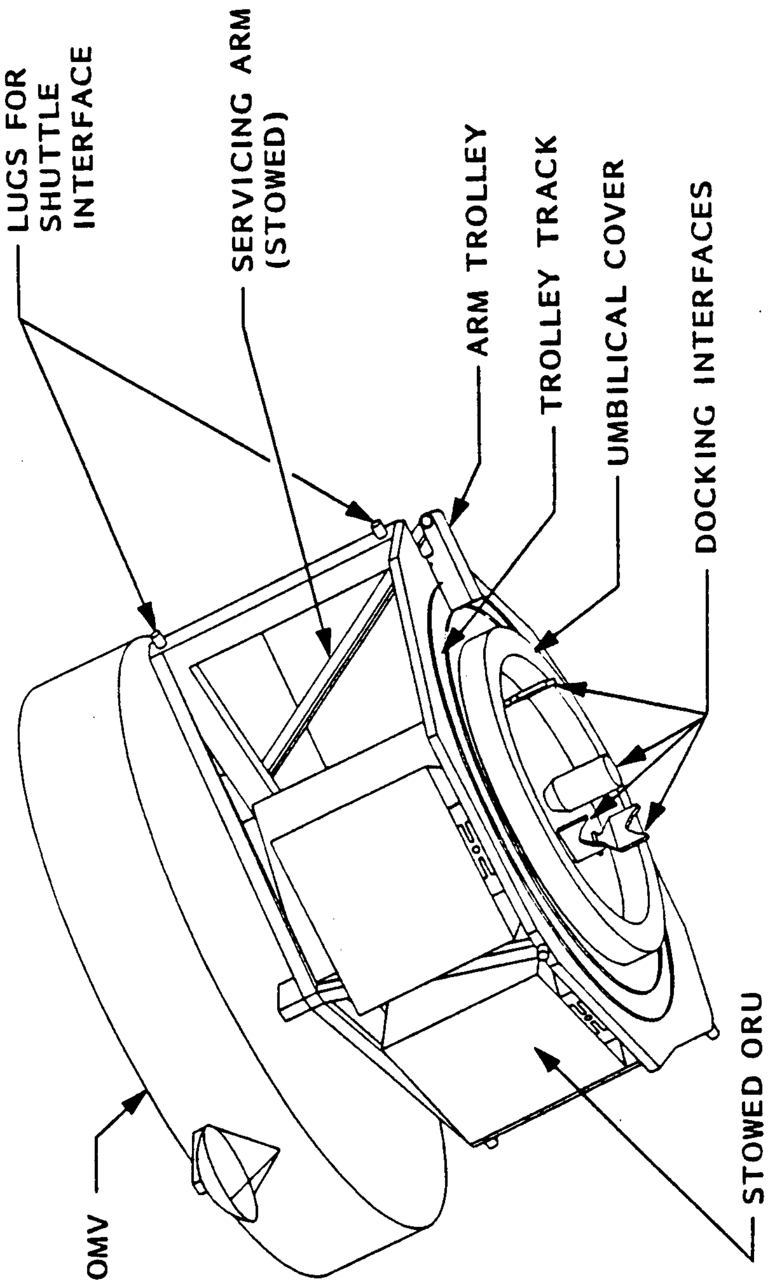


Fig. 3-2 DRM 2 Servicer Concept

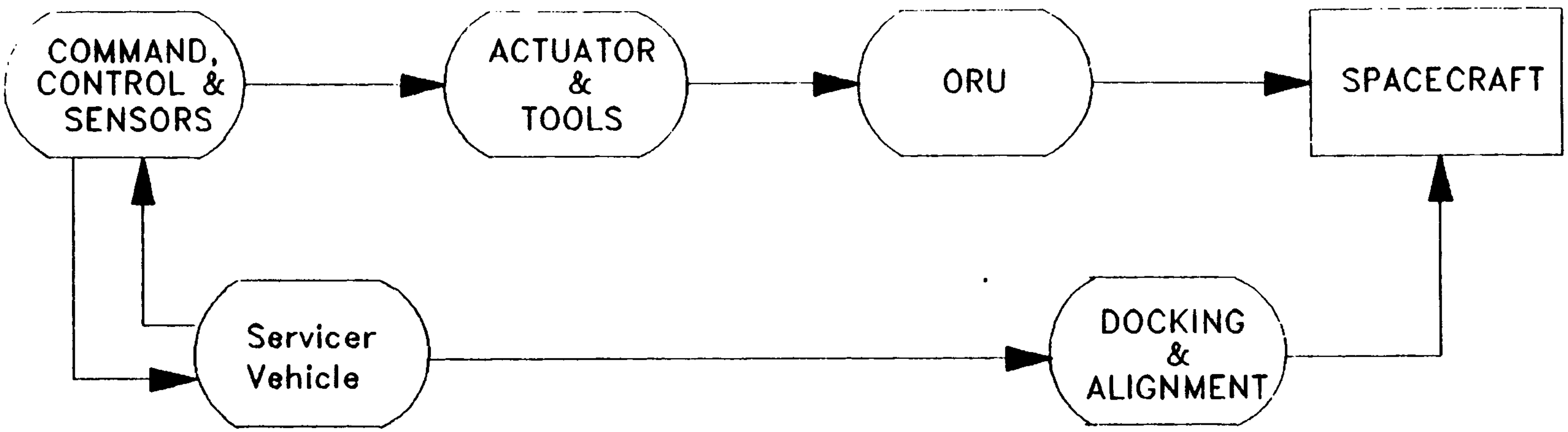
face of the servicable satellite. An RMS type end effector is deployed on the end of an extendable boom. It accomplishes the first contact and soft docking through use of the boom's end effector grapple fixture. The boom is then retracted until the hard docking latches are actuated. At that point the two spacecraft become one rigid body and the transfer of ORUs is an easily solved three dimensional geometry problem.

3.2.2 Major System Elements

The major elements of the remote ORU change-out technology area are shown in Fig. 3-3. The associated concept development programs will lead to the demonstration of exchange of orbital replacement units (ORUs) between a spacecraft and the servicer system spare module stowage rack. In order to perform the change-out in a remote fashion, command, control, and sensor technologies (including associated software) must be further developed. These are needed to enhance the operation of both the actuators and tools, as well as the servicer vehicle itself. Interfacing both with the actuators and the spacecraft are the ORUs themselves. Another important technology area that must be addressed is that of docking and alignment between the servicer vehicle and the spacecraft to be serviced. Each of these major subsystems are further discussed in the next section.

3.2.3 Identification of SAMS Application Development Needs

After defining the major system elements of the ORU change-out technology, the required subsystems related to each were identified. Included under the element of command, control and sensors is the intelligent control architecture which enables operations planning and sequencing of complex tasks by a supervisory human operator. The integration of large amounts of high speed data coming from the proximity, optical, and collision systems is required. The development of a servicer vehicle requires advancement in continuous control of real time processes including electrical power, propulsion system, and thermal system health and maintenance monitoring. Guidance and navigation systems and contamination control systems are also required. In the case of actuators, the capability to operate coordinated



REQUIREMENTS

Sensors: Optical Proximity Collision Sensing Software Architecture Data Fusion Operations Control Operator Station	Power Thermal Guidance & Navigation Attitude Control Propulsion Proximity Orbit Transfer Contaminant Control	Arms: Number Capability Vacuum Operation Tools: End Effectors Task Specific Devices	Mounting Com- patible Alignment Connector Design Interfaces: Structural Electrical Fluid Data Thermal Com- patible ORU Specific Requirements Fault Detection	Aquisition & Alignment Mechanical Connection Mutual Grounding	Access Envelope Reference & Docking Fixtures Electrical Connect Interface Compatibility Structural Thermal Control/Comm Operational Mode: Control Standby Safeing Mutual Grounding Fault Detection

Fig. 3-3 Major System Elements Remote ORU Change-out System

multiple armed servicers is needed. Tools such as advanced end effectors and trades between multi-use and task specific devices are required. In addition to the actual design of the ORUs themselves, requirements include mounting compatibility with the spacecraft and actuator mechanisms to locate and install the ORU in its proper location. Alignment and connector design interfaces include structural, electrical,fluid and data link ups. Compatability with the spacecraft thermal systems and the ability to detect and isolate faults within the target spacecraft would also be capabilities required to perform change-out operations. Of critical importance is the development of reliable and effective docking and alignment systems. The acquisition and alignment of spacecraft, the associated mechanical connections, and mutual grounding techniques are required. With respect to the spacecraft itself, requirements include definition of the access envelope, reference and docking fixtures, safeing and grounding paths. The interface compatibility requirements with respect to structural, thermal, electrical, and control systems must be developed.

3.3 LARGE SYSTEM ASSEMBLY - MANNED

3.3.1 Description of Large System Assembly

In order to meet the requirements of future space projects, the assembly of large systems on orbit has been chosen as a critical technology area. This includes exploring the capabilities of new EVA hardware, comparing assembly approaches, structural integration of designs, and establishing optimal task design and procedural planning. Figure 3-4 shows an example candidate for large system assembly technologies, a space based radar structure, which could be assembled either by using EVA (Fig. 3-5) or mechanized assembly techniques. Because the remote applications of technology were mostly categorized under the ORU change-out section of this report, the large system assembly area will attempt to cover the EVA aspects of SAMS not discussed earlier.

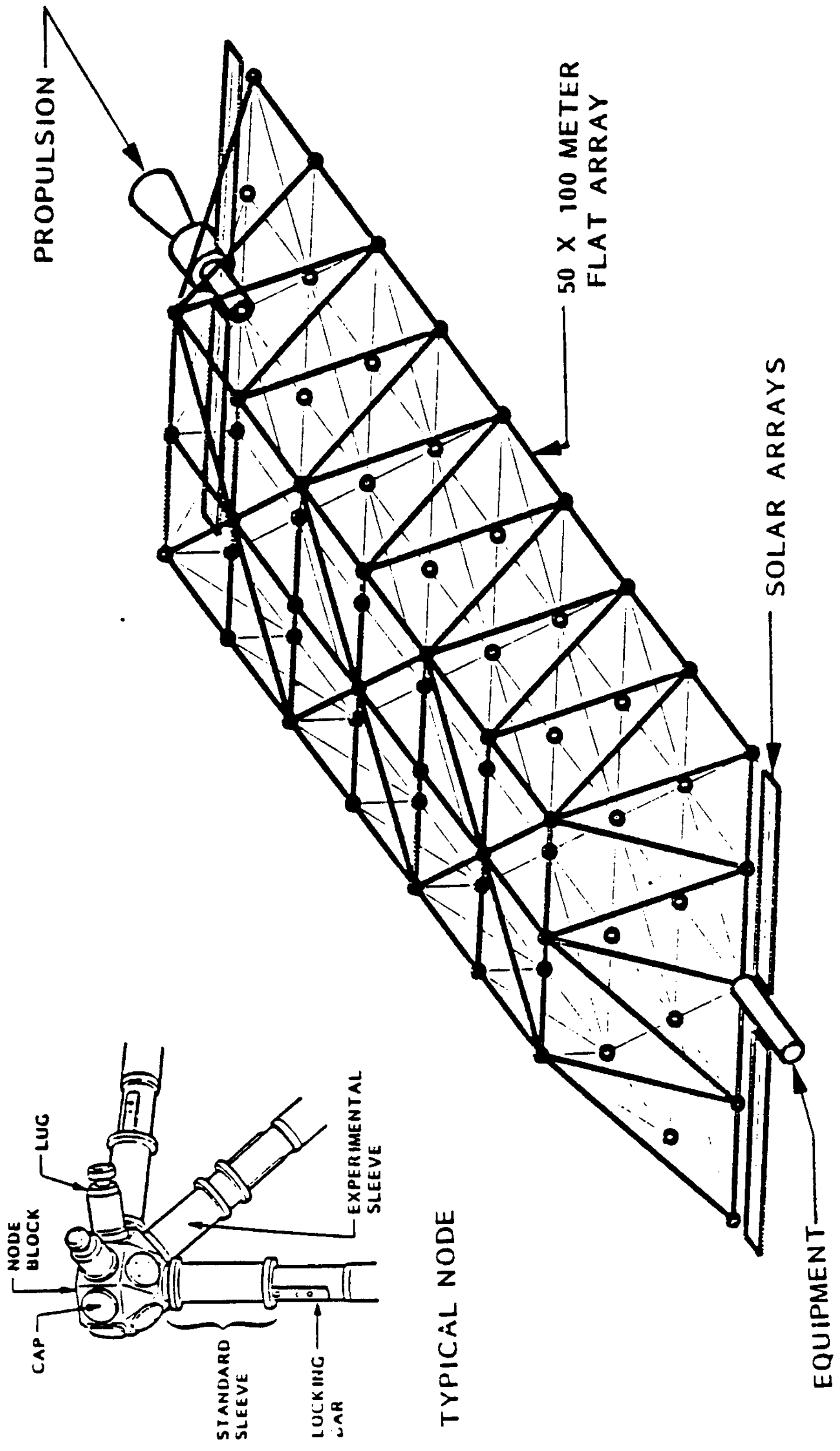


Fig. 3-4 Space Based Radar Assembly

Fig. 3-5 EVA Assembly Technology

3.3.2 Major System Elements

Those system elements identified with large system assembly are shown in Fig. 3-6. In order to assemble spacecraft or platforms on orbit, the hardware elements of the structure itself, as well as EVA tools and aids will be required. Associated with the hardware elements are the logistics required to insure part supply and availability. In support to the EVA activities are technologies related to the work platform needed by crewmembers to accomplish the assembly tasks. Each of these major system elements have requirements which are described in more detail in the following section.

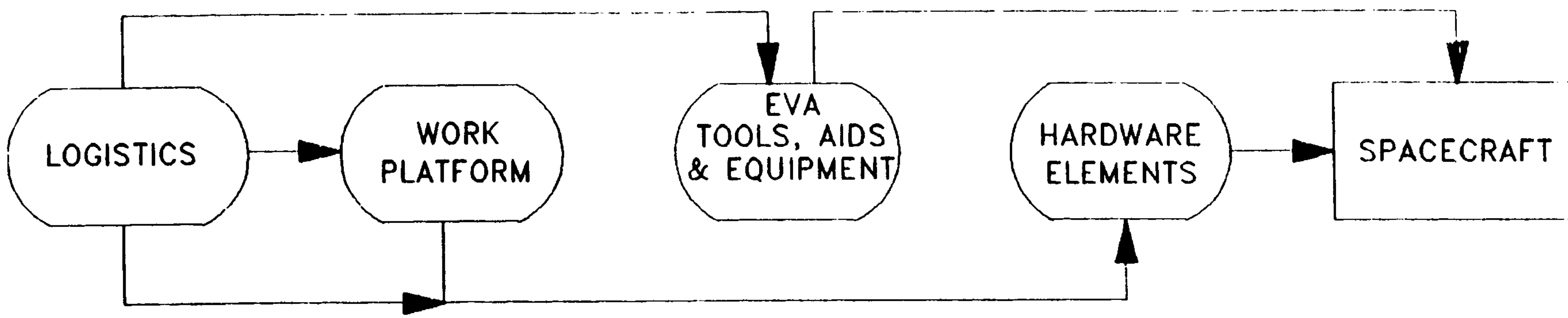
3.3.3 Identification of SAMS Application Development Needs

In order to support the assembly of large systems on-orbit, certain technology are required to support the above mentioned major system elements. Spacecraft modularity in design, which also allows for simplified integration of utilities such as electrical power and thermal fluid distribution, will also assist in component data link-up capability. Standardization of nodes and latches, thermal blanket designs, and fluid release designs are required. EVA activity will require further development in suit technology that leads to higher pressure zero-pre-breath and radiation hardened capabilities. Associated with human factors is task design and optimization, which would involve the integration of material flow on site and the overall logistics support system. Work platform development, including the docking, power, part storage and habitat systems, is also needed to perform large system assembly.

3.4 BIPROPELLANT TANKER SYSTEM

3.4.1 Description of the Bipropellant Tanker

The near term resupply of all categories of fluids, including propellants, are critical to the success of space based servicing operations. Because it is so expensive to build, launch, and operate spacecraft on-orbit, refueling represents a servicing ability with real economic advantage. The on-orbit resupply of fluids depends on special techniques for acquisitioning and



REQUIREMENTS

Transportation Rendezvous Docking Materials Handling Color Coding Training Facilities Simulators	Docking Power Habitat ORU Storage & Conditioning Parts, Storage & Supply	Suits: High Pressure Tools EVA Equipment Support Equipment Task Design & Optimization	Structural Electrical Distribution Generation Fluid Thermal Active Passive Utility Integration Fluid Loop Fabrication Quick Disconnect Latches	Modular Design Docking & Assembly Fixtures Compatibility Interface Compatibility Structural Thermal Control/Command Operational Modes Check-out Alignment Start-up

Fig. 3-6 Major System Elements - Large System Assembly, Manned

transferring fluids in a low gravity environment, controlling both the pressure of the supply and receiver tanks and monitoring the process. A concept bipropellant system is shown in Fig. 3-7. This concept was based on the Flight Support System (FSS) interface with deployment, rotation, and jettison capabilities. The mechanisms are modular to provide fluid transfer and docking capabilities as needed for a specific mission. This particular concept shows a cylindrical propellant tank optimized in size for transporting liquids in the Orbiter payload bay.

3.4.2 Major System Elements

Included under the heading of bipropellant tanker are the major system elements shown in Fig. 3-8. The technology basic to the system is the ability to handle and transfer fluids in a micro-G environment. This includes both the long term and short term effects of storing propellants on-orbit, and dealing with the specific fluid related problems of extracting liquid from a mixed phase (liquid/gas) substance. Tanker interface with the servicer vehicle is important, and the ability to dock and manipulate the servicer to the spacecraft. Each of the system elements are described in terms of their requirements in the next section.

3.4.3 Identification of SAMS Application Development Needs

Associated with the major system elements described above are the associated subsystem technology requirements. Under docking and manipulation, the acquisition and alignment of the spacecraft is required with a means for soft and hard docking, mutual grounding, and reliable fluid coupling capability. The servicer vehicle will require power resources to accomplish the task, as well as thermal, guidance, and navigation subsystems. The avionics subsystem must have the necessary data handling capability to integrate the control, command and sensing systems. The propulsion system of the servicer must be capable of close proximity operations and orbital transfer manuevers. During proximity operations, strict control of contaminants must be maintained. In order to store the propellants, the capability of the propellant and pressurant in micro-G environments must be fully understood and defined.

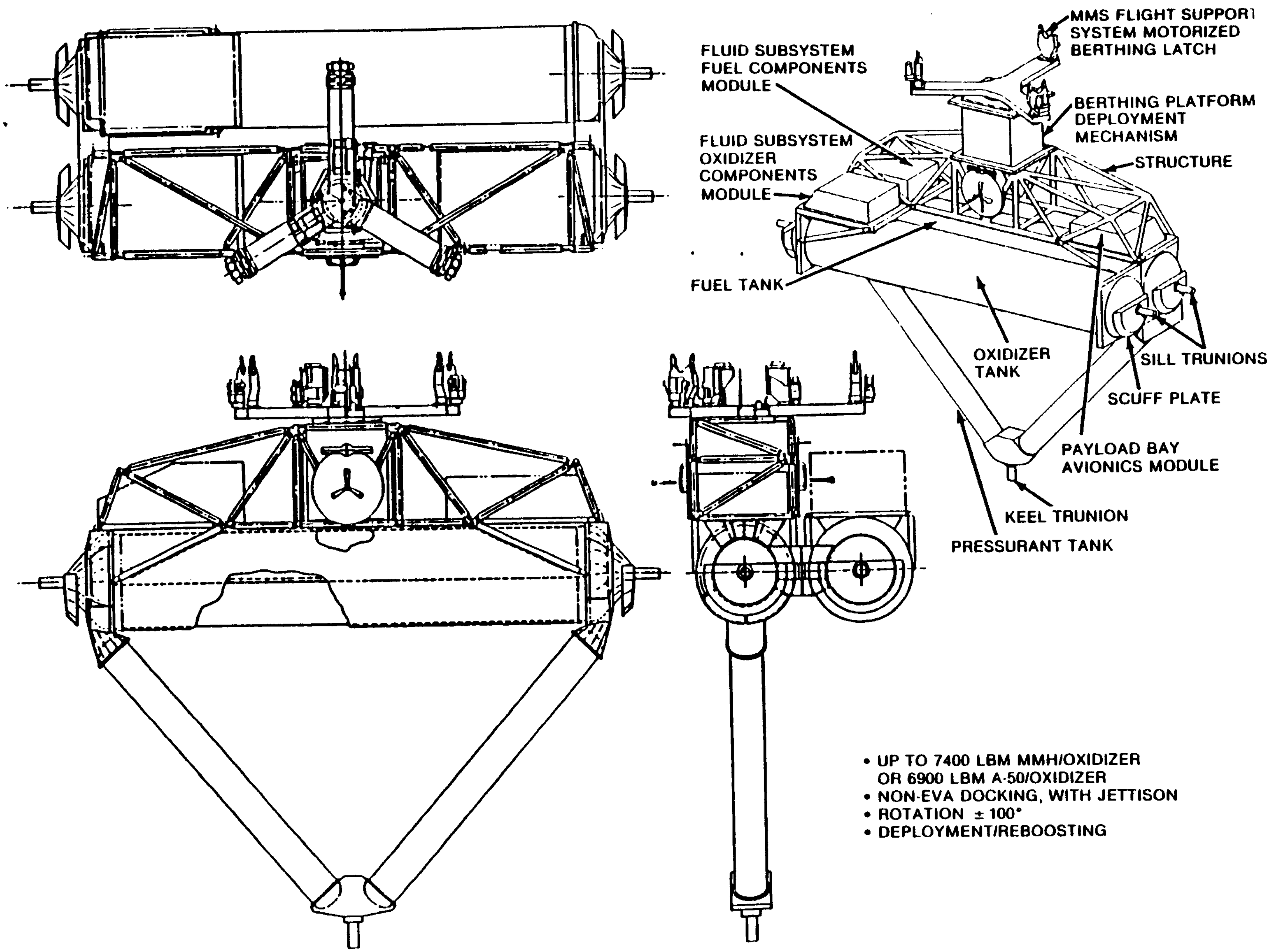
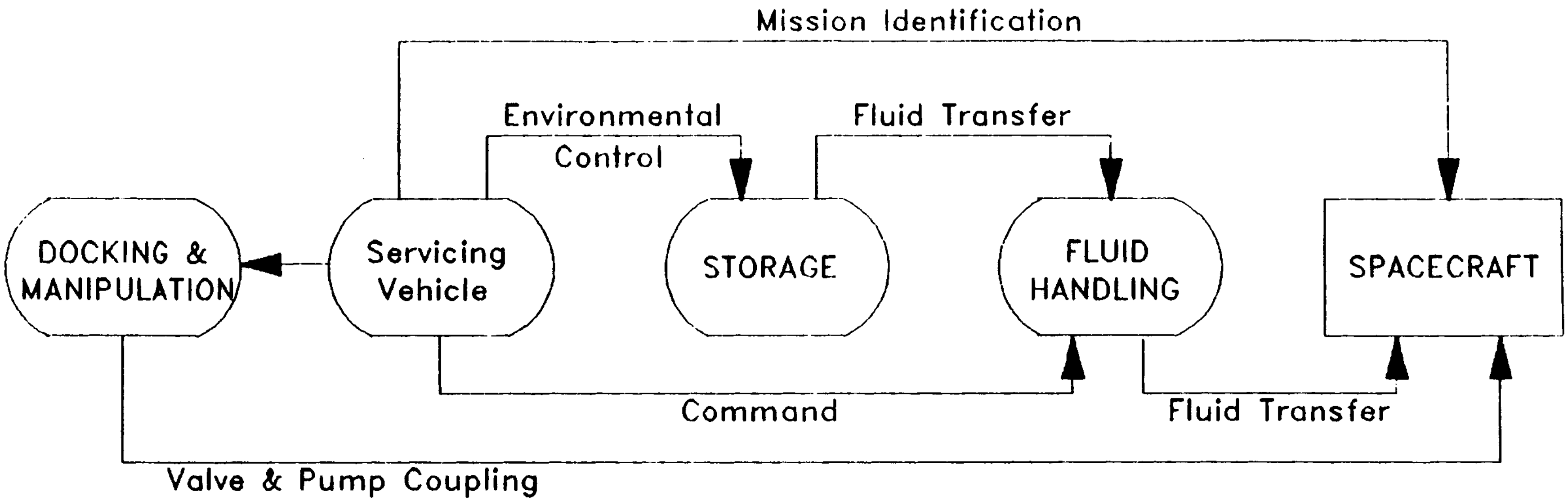


Fig. 3-7 Bipropellant Tanker Concept



REQUIREMENTS

Aquisition & Alignment Mechanical Connection Mutual Grounding	Power Thermal Guidance & Navigation Data Process Communication Command Propulsion Proximity Orbit Transfer Contaminant Control	Fuel Type capability Pressurant capability Environmental Control	Fuel Type: Separation Metering Contamination Control Physical Integration	Access Envelope Reference Fixtures Contamination Control Fuel & Pressurant Compatible Refuel OPS Mode Refuel Safeing Mutual Grounding

Fig. 3-8 Major System Elements - Bipropellant Tanker

Environmental control requirements must also be determined. The ability to transfer fluids will be based on an understanding of fluid seperation and metering technologies, contamination control, and the physical integration of the tanker fluid system with that of the spacecraft. Requirements placed on the spacecraft by the fluid transfer capability include definition of the access envelope, fuel and pressurant compatibility with that of the tanker, and the grounding paths required for mutual grounding.

3.5 CRYOGENIC TANKER SYSTEM

3.5.1 System Description - Cryogenic Tanker

The objective of cryogenic tanker development would be to provide economic and safe orbital fluid resupply capability to NASA, DoD, and commercial vehicles. The tanker must be able to permit fluid acquisition and transfer in low gravity and limit cryogen boil-off due to environmental heating. Boil-off management features, to minimize earth-to-orbit resupply costs, will include advanced multilayer insulation design concepts, vapor cooled shields, low conductance support structures, and refrigeration/reliquification systems. A tanker concept which could be attached to the OMV or Orbiter payload bay is shown in Fig. 3-9. It also includes 2 grapple fixtures for an RMS type end effector.

3.5.2 Major System Elements

The major system elements of the cryogenic tanker are shown in Fig. 3-10. The concept development program will have to prove compatibility of the tanker fluid system with that of the spacecraft. Docking and manipulation, as with the other technology areas, is a needed capability. Cryogen fluid transfer will require a fluid handling and storage capability with leak free coupling interfaces between the spacecraft and the servicing tanker. Special environmental control concerns accompany the design of the cryogenic tanker which seperate this technology from that of the bipropellant tanker, such as cool-down cryogen boil-off and venting. The tanker control architecture must interface with the fluid handling system to monitor temperature, pressure, and

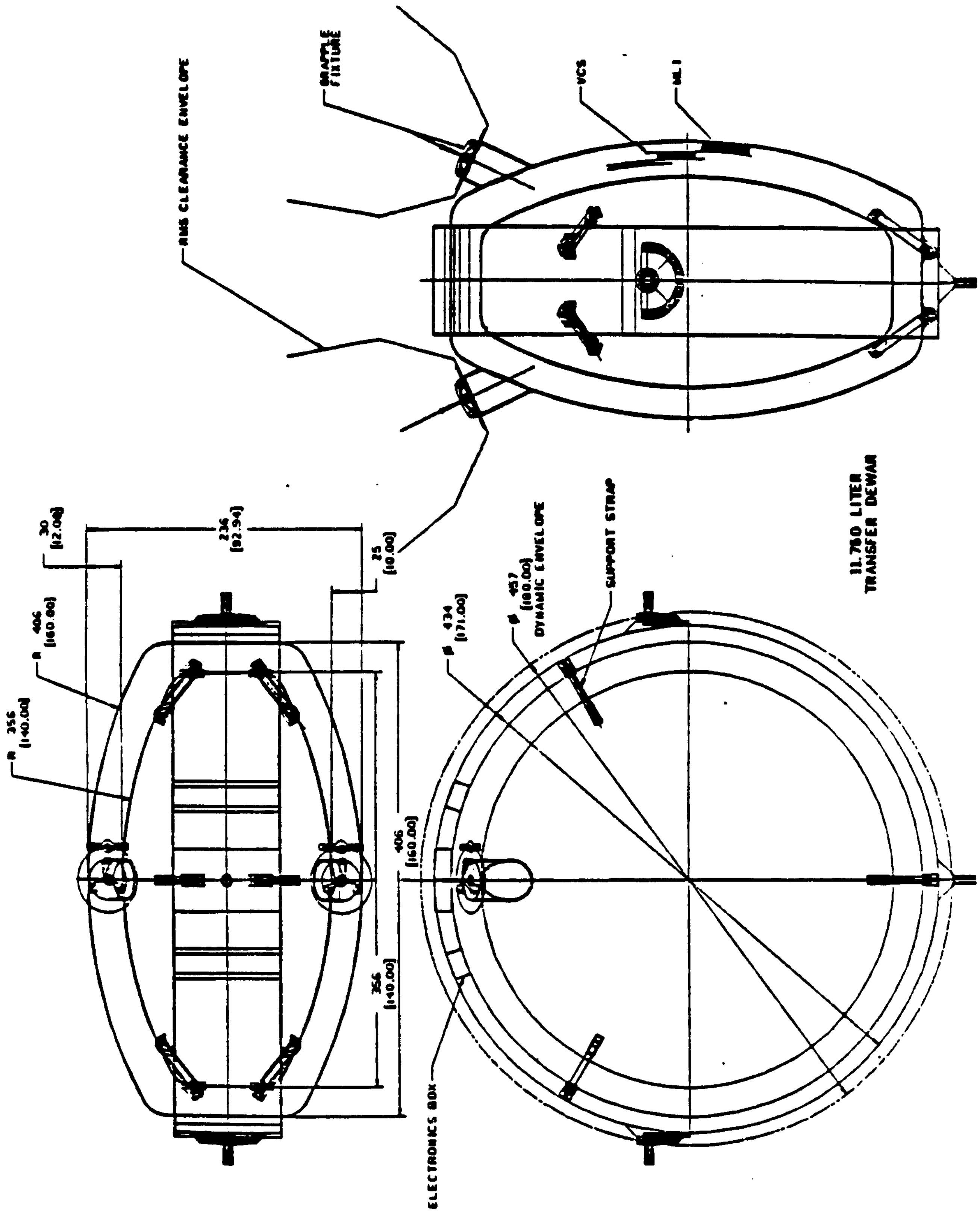
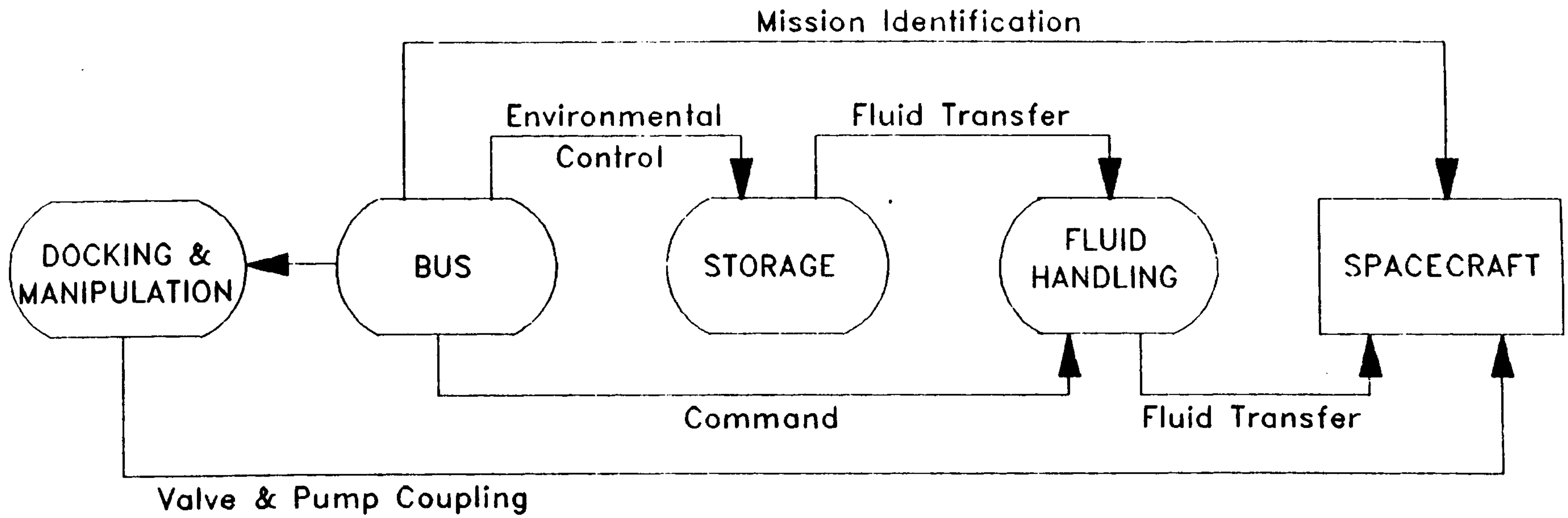


Fig. 3-9 Cryogenic Tanker Concept



REQUIREMENTS

Aquisition & Alignment Mechanical Connection Mutual Grounding	Power Thermal Guidance & Navigation Data Process Communication Command Propulsion Proximity Orbit Transfer Contaminant Control	Fluid Type capability Environmental Control Venting	Fluid Type: Separation Metering Contamination Control Physical Integration Thermal Compatibility Automatic Operations	Access Envelope Reference Fixtures Contamination Control Fluid Compatible OPS Mode Safeing Mutual Grounding

Fig. 3-10 Major System Elements - Cryogenic Tanker

mass transferred between the supply and receiving tanks. The command system must also include the capability to automatically shut down in case of anomaly conditions. After defining the major system elements required in a cryogenic tanker system, the subsystem requirements of each element were identified. The tanker system will have to be compatible with the spacecraft, which means access envelopes must be defined, and the contamination control requirements, safeing and mutual grounding methods, and fluid compatibility requirements must be determined. The tanker must be capable of storing multiple types of cryogenic fluids in an environmentally controlled tank and allow for venting of boil-off gases. Associated with the venting is contamination control requirements, which is of particular concern in the servicing of spacecraft with high precision and sensitive optical sensor systems. During transfer operations, the fluid must be monitored for temperature, pressure and mass quantity transfered. The acquisition of liquid from the vapor/liquid interphase will be necessary in the micro-G environments of space. Automatic operations, such as umbilical connection mechanisms are needed for remote resupply operations. The tanker must have its own control architecture which monitors and commands its thermal, power, guidance and navigation subsystems. High density and high speed data processing and communication will be needed, as well as a propulsion system which is able to perform both high precision proximity maneuvers, orbit transfer operations, and plane changes.

3.6 COMPLIMENTARY TECHNOLOGIES

In the previous sections, the four major systems required for SAMS capabilities on orbit were discussed. In addition to these, there is an underlying requirement for further development in associated complimentary technologies. Cost efficient transportation systems which can deliver heavier payloads to space are needed to support the SAMS capabilities. Advancements in technology needed to develop an advanced shuttle (STS II) or unmanned heavy lift launch vehicle have been addressed in many studies, including the Space Transportation Architecture Studies (STAS). Although considered to be a technology required to support SAMS, a transportation system proof of concept plan is considered to be beyond the scope of this concept development program and hence will not be discussed.

The complimentary technologies which are identified here are those which span the boundries of the major systems and whose development is not a requirement for the success of any major system. As the title implies, these technologies are those which will compliment and enhance future SAMS efforts. Included under this category are logistics modeling, EVA crew aids and specific EVA servicer functions not mentioned in the large system assembly or ORU changeout sections.

Because of the diversity of these proposed concept development candidates, no major system elements or requirements will be identified in this section. Further description of these candidates can be found in Section 5.5 of this volume.

SAMS

CANDIDATE SELECTION AND PRIORITIZATION

SECTION 4.0

Section 4.0

CONCEPT DEVELOPMENT PROGRAM (CDP) CANDIDATE SELECTION AND PRIORITIZATION

In the evaluation of CDP candidates, each major element of the previously discussed technology areas were assessed with regard to their mission significance and technical criticality. This assessment involved quantifying the degree of importance of the subsystem to the successful development of its associated technology area (i.e. large system assembly, tanker systems, or ORU change-out). Through the use of technical risk assessment methodology, a concept priority factor was assigned to each subsystem. This factor is a numerical measure of the subsystems criticality which enabled us to rank them accordingly. The following section describes the risk assessment methodology used in this analysis. The sections following discuss the results of the analysis for each of the SAMS CDP systems.

4.1 TECHNICAL RISK ASSESSMENT METHODOLOGY

Program risk involves three interrelated elements: technical impact, cost and schedule. To avoid the expenditure of dollars on programs which cannot meet minimum mission program requirements, risk analysis must be performed early in the program validation phase. In the case of concept development candidates, the objective of such analysis is to determine which technologies are critical to the successful development of a satellite servicing capability. This top-down approach promotes the evaluation of each system in regards to the goal of developing its prime technology area and focuses efforts on problems of greatest significance.

The technical risk associated with the proof of concept hardware and software items include their present state of maturity and the perceived degree of complexity. The concept development candidates were judged according to two major factors: technical criticality and mission criticality. Each hardware and software system was evaluated to determine what potential technical problems exist and the extent of these problems.

Technical criticality was obtained from the ratings given in Fig. 4-1 and 4-2 for the extent of potential problems associated with not developing the system to meet its minimum requirements. The factors were classified and averaged according to three problem categories:

$$TC = \frac{C_{MH} + C_{MS} + C_{CH}}{3}$$

where, CMH = Maturity of hardware
CMS = Maturity of software
CCH = Complexity of hardware

Another assessment, the mission criticality, considers the impact on the system when the system cannot meet its technical, cost, or schedule requirements. Mission criticality uses the values given in Fig. 4-3 and calculates the average of these factors:

$$TC = \frac{TI + CI + SI}{3}$$

where, TI = Technological impact
CI = Cost impact
SI = Schedule impact

The total impact of the subsystem is then calculated by the following equation:

$$\text{Total Impact} = TC + MC - (TC \times MC)$$

The following sections discuss the results of this analysis for each of the technology areas.

RATING	HARDWARE (C_{MH})	SOFTWARE (C_{MS})
0.1 (LOW)	Off-the-shelf items - no new hardware required	Existing, proven software or no new software required.
0.3	Minor redesign of proven hardware	Some slight change in existing S/W. Minor change in modules or lines of code
0.5	Technical feasibility established: change in design and performance reqts. of existing hardware	Major change in existing S/W modules/lines of code.
0.7	Undergoing exploratory development. Complex design and performance reqts. Technology available	New software. Software similar to existing programs.
0.9 (HIGH)	Very limited experience. Some research done. Significant change in state-of-the-art.	New software. Programs pushing state-of-the-art.

Figure 4-1 Technical Criticality - Hardware/Software Maturity

RATING	HARDWARE	SOFTWARE
0.1 (LOW)	Simple design. No changes reqd. or not applicable	Simple design. No changes reqd. or not applicable
0.3	Minor increase in complexity or performance requirements.	Minor changes in program complexity
0.5	Moderate increase in complexity or performance requirements.	Large increase in program complexity
0.7	Significant increase in complexity	Significant increase in program complexity. Major increase in modules.
0.9 (HIGH)	Extremely complex system.	Highly complex program. Very large data bases and complex, rapidly operating programs

Figure 4-2 Technical Criticality – Hardware/Software Complexity

RATING	TECHNICAL	COST	SCHEDULES
0.1 (LOW)	Minimal or no consequences.	Budget estimates not exceeded	Negligable impact to overall program
0.3	Some problems anticipated but easily corrected	Cost estimates exceed budget by 1% to 5%	Minor slip in schedule Some adjustment of milestones needed
0.5	Some reduction in technical performance	Cost estimates exceed budget by 5% to 20%	Moderate development schedule slip. Impact on item milestone with possible program impact
0.7	Significant degradation in technical performance	Cost estimates exceed budget by 20% to 50%	Subsystem development schedule slip
0.9	technical goals cannot be achieved	Cost estimates increase in excess of 50%	Large schedule slip that impacts program and/or has impact on system or technology area

Figure 4–3 Consequences of Failure – Mission Criticality

4.2 CRITICALITY EVALUATION

4.2.1 Criticality Evaluation - Remote ORU Change-out

Figure 4-4 shows the numerical results of the subsystem criticality evaluation. Based on this, the subsystems could be ranked in the following order. Those with the same criticality in our evaluation are shown below with the same prefacing number (i.e., sensors and docking):

1. Control System
   (Architecture, hardware, software)
2. Sensor Systems
   (Vision, tacile, proximity, fusion)
2. Docking and Alignment
4. Spacecraft
   (Compatibility, fault detection, safeing)
5. Command System and Workstation
6. ORU Compatability and Interfaces

As seen by the above, the criticality ranking of the ORU change-out subsystems is very close; although control system ranks well and above with a total impact figure of 0.98. The reason for such a high number can be explained by looking at what is incorporated in the factor.

In respect to technical criticality - the degree of maturity needed to bring the subsystem to the level required and its overall complexity, control systems again rank top of the list, followed by command/workstation systems, sensors and docking. This is because to the perceived amount of advancement in technology needed in these areas to bring them to the maturity level required is significant. For scheduling purposes, these subsystems should be developed and proofed as a priority, with parallel efforts in the other subsystems also ongoing but starting at a later date, as they won't need as much technical development.

SYSTEM ELEMENT	HARDWARE MATURITY	SOFTWARE MATURITY	COMPLEX HARDWARE	TECHNICAL CRITICALITY	TECHNICAL IMPACT	COST IMPACT	SCHEDULE IMPACT	MISSION CRITICALITY	TOTAL IMPACT
Command System and Workstation	0.7	0.8	0.7	0.73	0.7	0.5	0.5	0.56	0.88
Control System Architecture Hardware Software	0.9	0.9	0.8	0.86	0.9	0.8	0.8	0.83	0.98
Sensors Machine Vision Tactile Proximity Fusion	0.8	0.7	0.6	0.70	0.8	0.6	0.7	0.70	0.91
Actuators and End Effectors	0.6	0.6	0.6	0.60	0.6	0.6	0.7	0.63	0.85
ORU Compatibility and Interfaces	0.5	0.6	0.5	0.53	0.5	0.5	0.6	0.53	0.78
Spacecraft Compatibility Fault Detector Safeing	0.5	0.5	0.9	0.63	0.6	0.8	0.7	0.70	0.89
Docking and Alignment	0.7	0.8'	0.6	0.70	0.8	0.6	0.7	0.70	0.91

Figure 4-4 Criticality Evaluation – Remote ORU Change-out System

4.2.2 Criticality Evaluation - Large System Assembly

Figure 4-5 shows the numerical results of the subsystem criticality evaluation for manned large system assembly. The summary of the data in Fig. 4-5 is shown below in the subsystems rankings.

1. EVA Workstation
2. Utility Integration
3. Simulators/training
4. Heads-up Display
5. Neutral Bouyancy Research
6. Commonality
7. Alignment Tools
8. Voice Control System
9. Color Codings and Markings

For large system assembly, EVA workstation and utility integration ranked high in total impact. EVA workstations, although the hardware needn't be that complex, will require maturity of both the hardware and software that is significant. Utility integration technology is highest in rank with respect to technical criticality in the assembly of space structures. It's low cost, schedule and technical impact on the system result in a much lower mission criticality factor. It should be noted that although simulators and training have an overall low technical criticality (technology needn't advance much beyond present state-of-the-art), its mission criticality is very significant to the capability of assembling on-orbit. In order to gain cost effectiveness in operation, the crewmember must be well trained and knowledgeable of his task beforehand. This explains the high mission criticality of the neutral bouyancy research as well. Significant cost savings can be appreciated, however, through the use of a heads-up display which guides the crewmember step by step through the process at his own rate.

SYSTEM ELEMENT	HARDWARE MATURITY	SOFTWARE MATURITY	COMPLEX HARDWARE	TECHNICAL CRITICALITY	TECHNICAL IMPACT	COST IMPACT	SCHEDULE IMPACT	MISSION CRITICALITY	TOTAL IMPACT
Simulators/Training	0.3	0.1	0.5	0.30	. 0.9	0.9	0.9	0.9	0.93
Utility Integration	0.9	0.9	0.9	0.90	0.7	0.5	0.3	0.57	0.96
Voice Control System	0.5	0.5	0.9	0.63	0.5	0.5	0.3	0.43	0.79
Heads-Up Display	0.7	0.7	0.9	0.77	0.5	0.9	0.5	0.63	0.91
Color Codings, Markings	0.1	0.1	0.1	0.1	0.7	0.1	0.3	0.37	0.43
EVA Workstation	0.9	0.9	0.7	0.83	0.9	0.7	0.9	0.83	0.97
Alignment Tools	0.5	0.3	0.5	0.43	0.7	0.9	0.7	0.77	0.87
Commonality	0.3	0.3	0.3	0.30	0.7	0.9	0.9	0.83	0.88
Neutral Bouyancy Research	0.5	0.3	0.7	0.50	0.7	0.9	0.9	0.83	0.91

Figure 4-5 Criticality Evaluation – Large System Assembly

4.2.3 Criticality Evaluation - Bipropellant Tanker

Figure 4-6 shows the numerical results of the bipropellant tanker system's criticality evaluation. The subsystems could be ranked in according to their criticality in the following order (those subsystems with the same measure of criticality in our evaluation are shown below with the same prefacing number):

1. Fluid Handling
   (Auto-couple, valves, pumps, metering)
2. Docking and manipulation
3. Control Systems
   (Avionics, sensors)
4. Storage
   (Tanks, vents, environmental control)
4. Command System and Workstation
4. Servicer Vehicle
7. Spacecraft

The total impact evaluation of the subsystems involved in a bipropellant tanker system did not result in any one system of notable significance except for fluid handling. The technical criticality of this subsystem, because of the complexity of the hardware, was also the highest among the subsystem. Docking and manipulation requires the most development of maturity with respect to software. It is not surprising that fluid handling has the highest mission criticality. The technologies needed to handle fluids in the micro-G environment, however, are not expected to have significant cost or schedule impacts on the overall development of the bipropellant tanker system. Control systems and those relating to docking and manipulation will have technical impact if the software and hardware maturity requirement are not achieved.

4.2.4 Criticality Evaluation - Cryogenic Tanker

The cryogenic tanker has the same ranking of criticalities in its subsystems with that of the bipropellant tanker system as shown in Fig. 4-7. These rankings are as follows:

SYSTEM ELEMENT	HARDWARE MATURITY	SOFTWARE MATURITY	COMPLEX HARDWARE	TECHNICAL CRITICALITY	TECHNICAL IMPACT	COST IMPACT	SCHEDULE IMPACT	MISSION CRITICALITY	TOTAL IMPACT
Fluid Handling Auto Couple Valves Pumps Metering	0.7	0.7	0.8	0.73	0.8	0.7	0.7	0.73	0.93
Storage Tanks, vents Environ. Control	0.7	0.5	0.7	0.63	0.7	0.6	0.7	0.67	0.88
Control System Avionics Sensors	0.6	0.5	0.7	0.60	0.8	0.7	0.7	0.73	0.89
Command System Workstation	0.7	0.7	0.5	0.63	0.7	0.6	0.7	0.67	0.88
Servicer Vehicle	0.6	0.6	0.7	0.63	0.6	0.7	0.7	0.67	0.88
Spacecraft	0.6	0.5	0.7	0.60	0.6	0.7	0.7	0.67	0.87
Docking and Manipulation	0.7	0.8	0.6	0.70	0.8	0.6	0.7	0.70	0.91

Figure 4-6 Criticality Evaluation – Bipropellant Tanker

1. Fluid Handling
   (Auto-couple, valves, pumps, metering)
2. Docking and manipulation
3. Control Systems
   (Avionics, sensors)
4. Storage
   (Tanks, vents, environmental control)
4. Servicer Vehicle
7. Spacecraft

The criticality evaluation for the cryogenic tanker is identical to that of the bipropellant tanker with one exception: the hardware maturity required for fluid handling has increased. This is due to the special technology required to handle the extremely low temperatures of a cryogenic fluid. The fluid handling subsystem still ranks high in mission criticality as would be expected for a tanker system. Control systems and docking and manipulation systems show high technical impact as well because of their involvement in maneuvering to and interfacing with the satellite vehicle to be serviced.

SYSTEM ELEMENT	HARDWARE MATURITY	SOFTWARE MATURITY	COMPLEX HARDWARE	TECHNICAL CRITICALITY	TECHNICAL IMPACT	COST IMPACT	SCHEDULE IMPACT	MISSION CRITICALITY	TOTAL IMPACT
Fluid Handling Auto Couple Valves Pumps Metering	0.8	0.7	0.8	0.77	0.8	0.7	0.7	0.73	0.94
Storage Tanks, vents Environ. Control	0.7	0.5	0.7	0.63	0.7	0.6	0.7	0.67	0.88
Control System Avionics Sensors	0.6	0.5	0.7	0.60	0.8	0.7	0.7	0.73	0.89
Command System Workstation	0.7	0.7	0.5	0.63	0.7	0.6	0.7	0.67	0.88
Servicer Vehicle	0.6	0.6	0.7	0.63	0.6	0.7	0.7	0.67	0.88
Spacecraft	0.6	0.5	0.7	0.60	0.6	0.7	0.7	0.67	0.87
Docking and Manipulation	0.7	0.8	0.6	0.70	0.8	0.6	0.7	0.70	0.91

Figure 4-7 Criticality Evaluation – Cryogenic Tanker

SAMS

CANDIDATE DEVELOPMENT PLAN

SECTION 5.0

SECTION 5.0
CANDIDATE DEVELOPMENT PLANS

5.1 REMOTE ORU CHANGE-OUT SYSTEM

5.1.1 System Description

The ORU Change-out System is aimed at servicing spacecraft in orbits outside the range of the STS. This plan is based on developing the technologies, analysis and demonstrations necessary to support the development of an operational ORU Change-out system. The system would be composed of a remote servicer, a payload of orbit replacement units (ORUs), a command station, and a spacecraft available for servicing.

The plan includes the development of subsystem technology and performance of technical and operational studies. This leads to system level demonstrations on the ground. Based on successful ground tests and system level requirements definition studies, flight demonstrations are proposed which will prove operational system completion.

5.1.2 Subsystem Development

Subsystem development in the key technology areas is required as an initial step in the development of an ORU Change-out System demonstration. A road-map describing the over all development flow is shown in Fig. 5.1. The subsystems are listed according to their rank determined in the criticality assessment evaluation. The road map reflects a schedule meant to achieve ORU change-out system capability prior to 1995. Because of their impacts on the satellite vehicle programs, the docking, spacecraft compatibility and ORU compatibility are shown as a present consideration for any program requiring servicing by the mid 1990s. The key areas of development for the remote servicer include the control system, sensor system, docking system, actuators, and end effectors. There is also a need for associated developments in compatible ORUs, servicing compatible spacecraft, and command stations. The requirements for the development of those subsystems are described in more detail below.

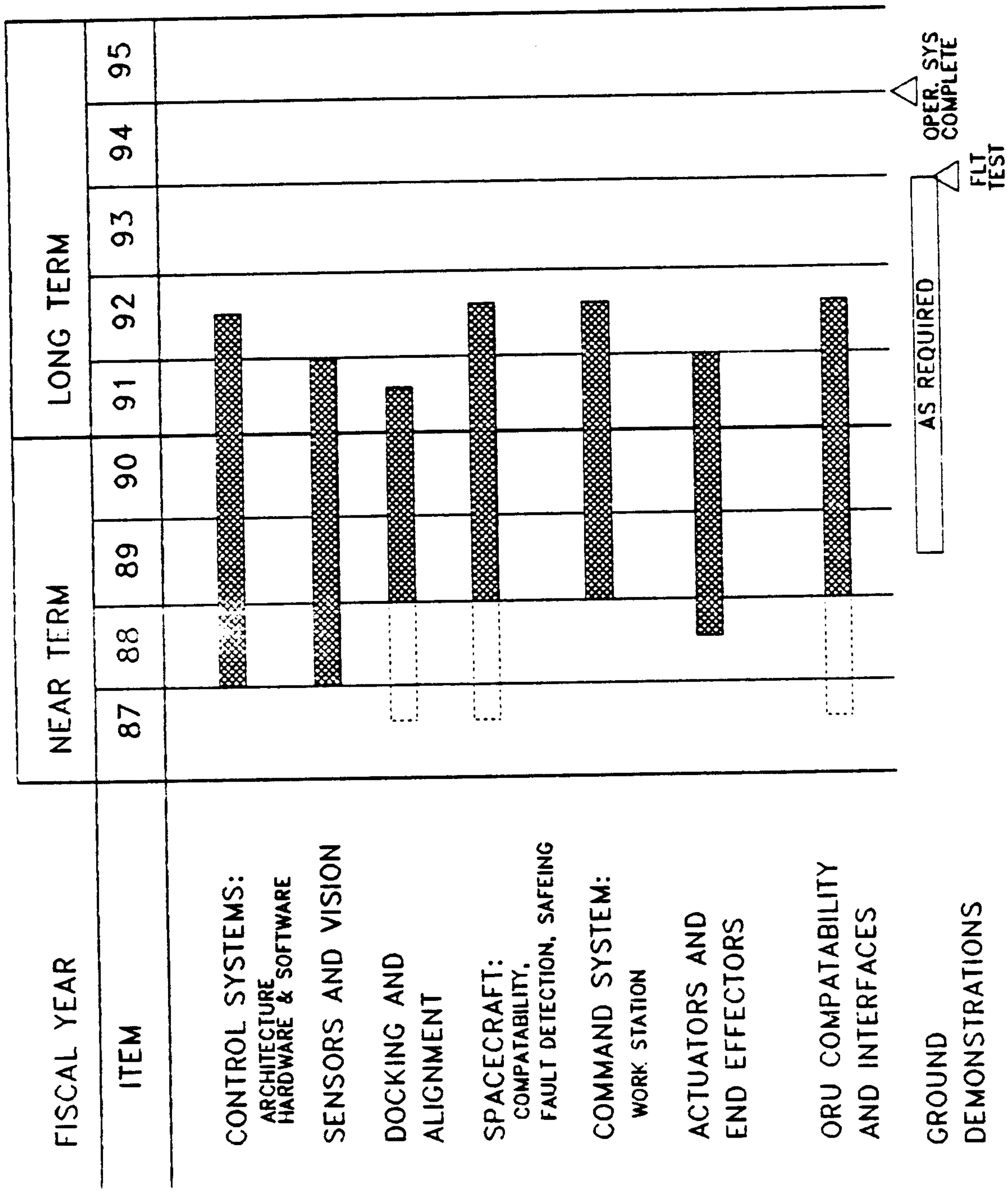


Figure 5-1 Remote ORU Change-out System Roadmap

5.1.2.1 Control System. Development efforts in this area are summarized in Fig. 5-2. Areas of development include the control system architecture that is compatible with telepresence, supervisory control, and ultimately with autonomous operation. Initial focus should be on the technologies required for telepresence and supervisory operations capability. Space processor hardware needed for initial operations must have the ability to be upgraded for enhanced operations as new technologies are developed. The required hardware needs to be identified and evaluated and the associated software should be specified, defined, and developed. Capabilities to be developed include lower hierarchical levels of control such as multi-arm operation with collision avoidance, navigation, camera focus, and tactile processing.

5.1.2.2 Sensor System. Another important element (also shown in Fig. 5-2) is the integration of the sensor and vision systems. Necessary sensors include video vision systems, range sensors, machine vision and targetting, proximity sensors, tactile sensors, and environmental sensors. These sensor systems must be linked to a higher level computational node which integrates the sensor data and translates it into commands for movement control and operator information. Bar codes are currently used to identify objects such as parts and ORUs, but current scanners read the codes without locating the marking tag. Through the use of vision systems, tags could be located and data on the ORUs present location, manipulation path, and target location could be transferred to the servicer command system. A sensor subsystem with both reading and locating capability will enable automated ORU and fixture handling to support ORU exchanges. The necessary data processing hardware and software requirements need to be evaluated in respect to the information needs, requirements, and processing architecture.

5.1.2.3 Docking System. Development of a spacecraft docking system may be derived through the adaption of hardware, control algorithms, and software from existing programs. Development areas include tracking, aquisition, final approach propulsion, grapple interface, sensor targeting, alignments, and latching included in mechanical and electrical interfaces. Development of a laser docking system which can track passive orbital target spacecraft with sufficient accuracy to enable soft docking with minimal thrusting near the

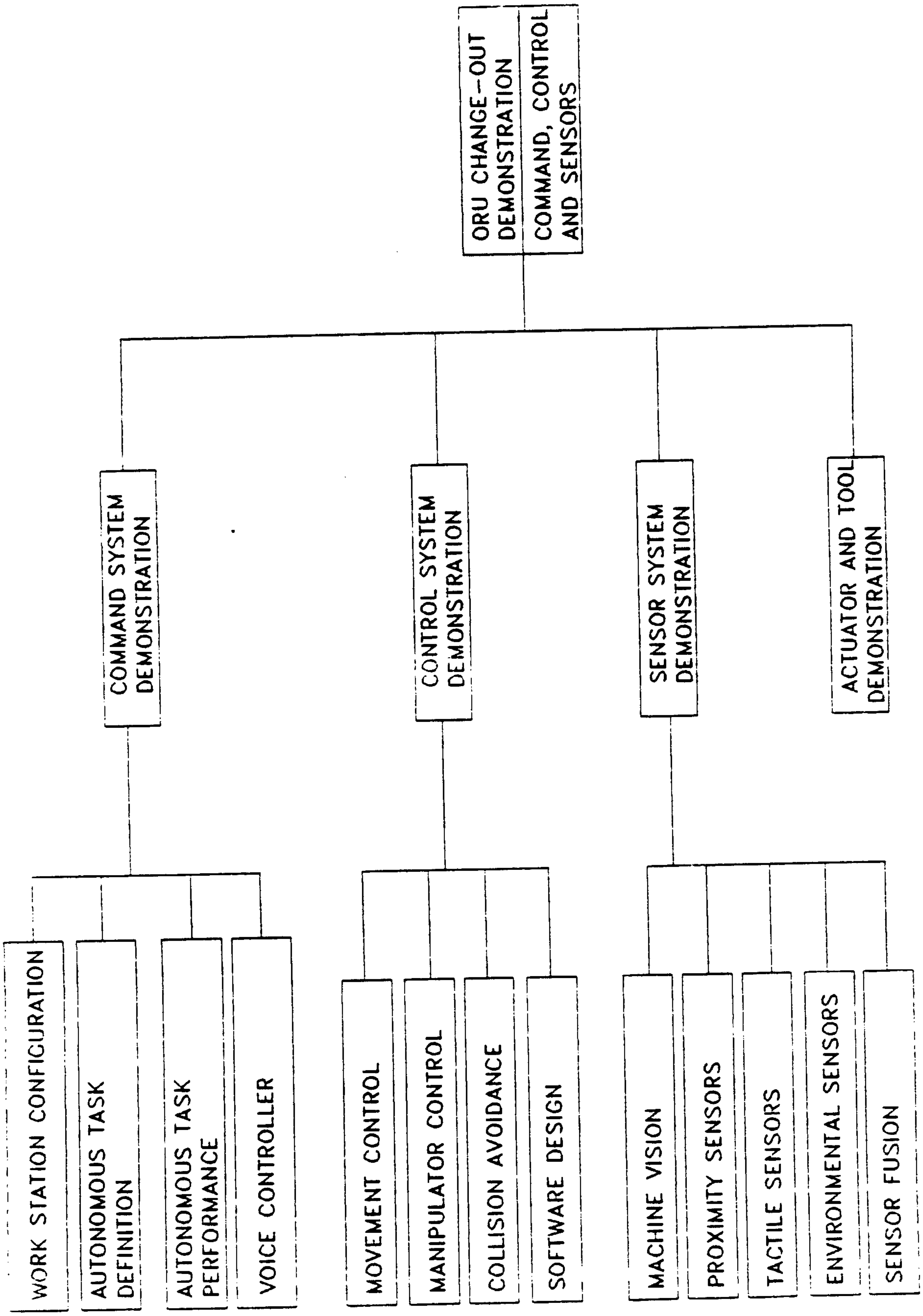


Figure 5-2 Remote ORU Change-out Development Task Flow Technology: Command, Control, and Sensors

vehicle is required. Also, a tumbling satellite recovery kit which could handle a wide range of recovery scenarios could be part of the modular servicer system, gaining the capability to be easily reconfigured to tailor to specific missions needs.

5.1.2.4 Actuators and End Effectors. Technological development of candidate remote operation arms is a future need for the accomplishment of SAMS (Fig. 5-3). Involving elements include arm structure, actuators, joints, modes of control, maximum tip speeds, and degrees of freedom. The development of a force-torque sensor for mounting on teleoperated arms would enhance servicing capabilities. The sensor would be linked to a graphics display of forces and torques with a data rate sufficient to give the operator a sense of real time. End effectors include grippers, simple tools, and devices.

5.1.2.5 Spacecraft Compatibility. Figure 5-3 also shows development and demonstration of spacecraft design compatibility. Successful ORU replacement requires design compatibility with the spacecraft envelope, ORU configuration and accessability, mechanical and thermal interfaces, electrical connectors, fluid couplings, and ORU fault detection. Spacecraft operational considerations need to be reviewed for design impacts including safing, control system shut down, and communications compatibility.

5.1.2.6 ORU Design. ORU design concepts need to be evaluated and demonstrated. Areas of effort include remote servicer compatibility, spacecraft compatibility, connector design for mechanical, electrical, and fluid interface, testing functions, and operational compatibility.

5.1.2.7 Command System. Design and operational requirements need to be evaluated for the operator control station definition. The control station includes all physical and cognitive interfaces between the machine and its operator. Expandibility with technological advancement from teleoperation and supervisory control to autonomous operation must be a consideration. Techniques for reducing the impacts of time delay on operator productivity need to be evaluated. The operator must be provided with the best possible means of receiving vision, tactile, and proximity sensor data from the remote

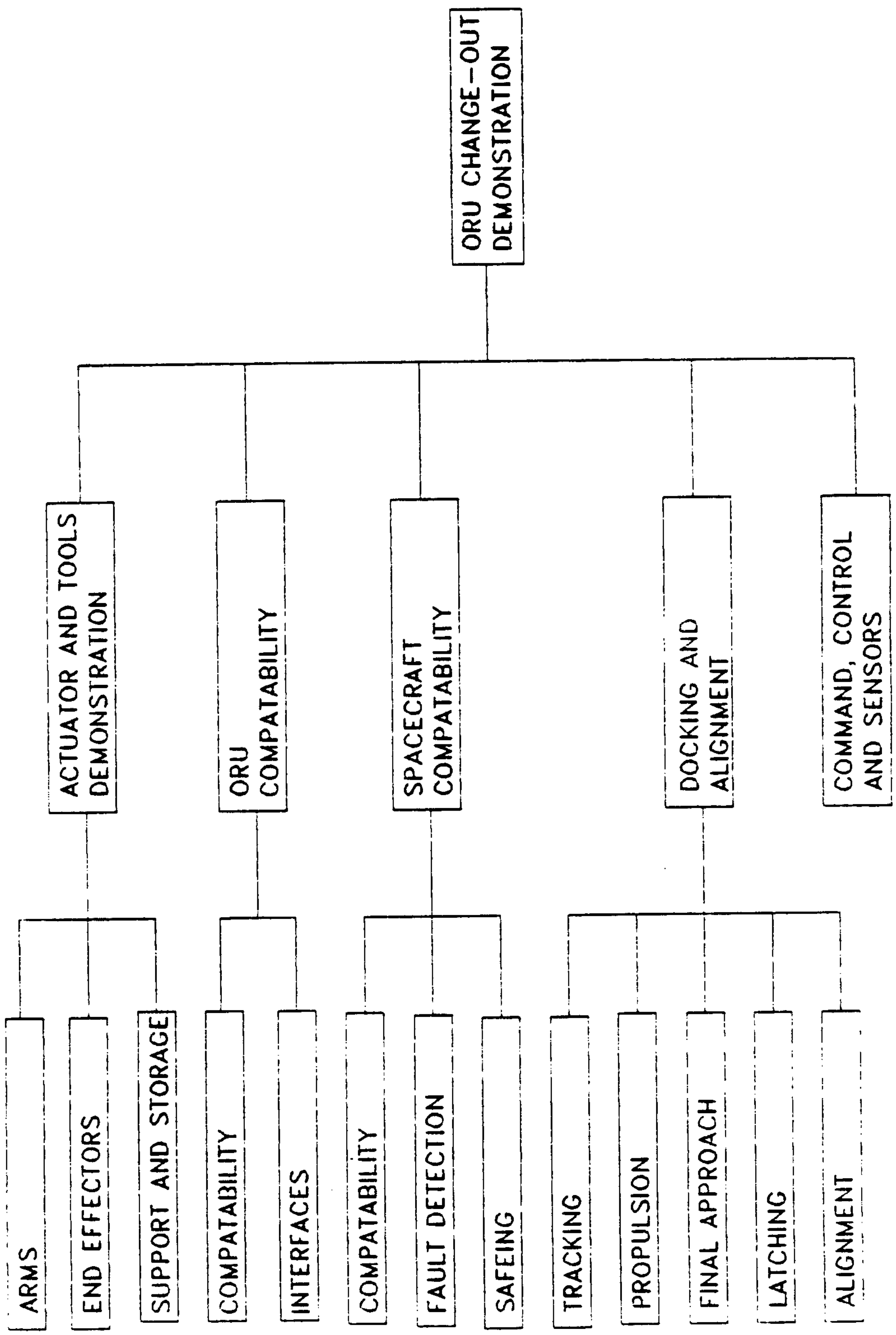


Figure 5-3 Remote ORU Change-out System Task Flow
Actuators, ORUs, Spacecraft, Docking

servicer including use of hands, feet, voice, and eye movements. In the case of teleoperated systems, this capability requires the ability to process data at high speed and high band-width. An emphasis on integrated systems and software development would be required, utilizing optical devices for increased reliability and minimizing noise in data transfer.

5.1.3 Analysis Tasks

Analysis tasks needed to provide system capability for ORU Change-out are outlined in Fig. 5-4. Areas include servicer, spacecraft, logistics, and operational requirements. The results of these analyses are needed to help focus the subsystem technology development and play a key role in defining requirements for system level demonstration and operational system development.

5.1.4 Demonstration Recommendations

System level demonstrations of ORU Changeout are a necessary step towards development of an operational system. One or more ground test system demonstrations are called for in the ORU Change-out technology roadmap Fig. 5-1. These demonstrations may include prototype or breadboard control system, sensor system, actuators and end effectors, and ORU modules. Tests will be conducted using mock-up and actual spacecraft hardware. An evolution in operator control systems from telepresence to supervisory control may be demonstrated. The ground tests should be conducted in realistic environments. This includes simulating the dynamic and range factors, lighting (sun, moon, earth, or stars), the zero refraction of a vacuum, plume effects, and thermal effects.

Based on success of these ground tests and definition of mission requirements, one or more flight test will be performed. A test system will be designed that can be deployed and retrieved by the STS. The system will be designed around a preferred spacecraft. The test system will be adapted from an existing 3 axis stabilized satellite vehicle bus selected on the basis of cost and mission significance for servicing.

SERVICER COMPATIBILITY REQUIREMENTS

- Servicer system level design capabilities
- Servicer propulsion requirements
- Environmental protection requirements for ORUs
- Tool standard interfaces for Automated and Robotic systems
- Control system architecture and software standards for servicers
- Evolution of telepresence, supervisory control, and autonomous operations

SPACECRAFT COMPATIBILITY STUDIES

- Functional analysis requirements for spacecraft design
- Spacecraft fault detection, safeing, and control system modification requirements

ORU COMPATIBILITIY INTERFACE ANALYSIS

- Standardization potential for interfaces
- Environmental control requirements on ORUs

LOGISTICS REQUIREMENTS

- Facility requirements and decision analysis
- Sparing availability modelling

Figure 5–4 Analysis Tasks – Remote ORU Change-out System

5.1.5 NASA/DOD Program Integration

This program complements and builds on the NASA programs to develop autonomous servicing capabilities. Major efforts include the Flight Telerobotic Servicer and the NASA Telerobotic Test Bed being worked on by JPL, GSFC, JSC, and Langley. OMV programs will also be integrated. In addition, the Air Force is sponsoring work in autonomy and sensors.

The SAMS effort differs fundamentally from the NASA effort in its operation regime, operator control requirements, and in spacecraft requirements and duty cycles.

5.1.6 Concept Description Work Sheets

The worksheets on candidate concepts associated with the ORU change-out technology area can be found in Appendix A, Section 1.0.

5.2 LARGE SYSTEM ASSEMBLY

5.2.1 System Description

The development of large space assemblies involve the evolvement of technologies related to multilevel orbital operating platforms on which both individual and cooperative payloads share the finite supporting resources of power supplies, communications, and navigation. Other major areas include on-orbit deployment, assembly and alignment of antennae and large optics systems. Demonstrations will proof and illustrate techniques and hardware designs that can significantly enhance manned assembly of large systems. Large system assembly simulations explore capabilities of new EVA hardware, compare assembly approaches, structural integration, and establish optimal task design and procedural planning. For purposes of this proof of concept analysis, a manned task orientation was assumed for large system assembly. This section, therefore, includes the evolution of EVA aids from minor tools and hardware to major support systems such as equipment tugs and robotic nurses. These technologies, however, could also be used in the other technology areas.

5.2.2 Subsystem Development

The effectiveness of operations in space assembly require advancement in the technologies related to the EVA equipment support and task design, manned workstation configurations, hardware interface definition, and assembly utility integration. A road map showing the overall development flow is shown in Fig. 5-5. The road map reflects the schedule needed to achieve large system assembly capability prior to 1995. Because of the amount of technical development required in the workstation and utility integration subsystems, these are shown with the longest spreads in the road map. Head-up displays, simulators, training, and neutral buoyancy are all interrelated and show similar 3 year development spreads. There is also additional needs for development of a logistics system which addresses the needs of parts supply in relation to the workstation and spacecraft campatability studies. Figure 5-6 shows the development tree for this technology area.

5.2.2.1 Workstations In the manual assembly of large structures/platforms, there comes a point where the human worker's performance can be greatly augmented through the assistance of a robotic nurse. Development of sensor, command and control systems for the man-machine interface can be in part derived from teleoperator technological developments mentioned in section 5.1. In addition, further human factors analysis and tests should be performed which demonstrate the task breakdown between man and machine, providing which are best done by whom. In general, equipment designed for use by simple automated systems can easily be adapted for utilization by humans, but equipment designed to take advantage of the human flexibility and dexterity cannot be easily adapted to simple automated mechanical systems. Hardware and systems designed to be utilized by simple automated mechanisms, therefore, can find near universal satellite vehicle application for future manned or remote utilization.

With more reliance on multi-funtionality, computer driven displays and multifunction command and control panels are required. Human/computer

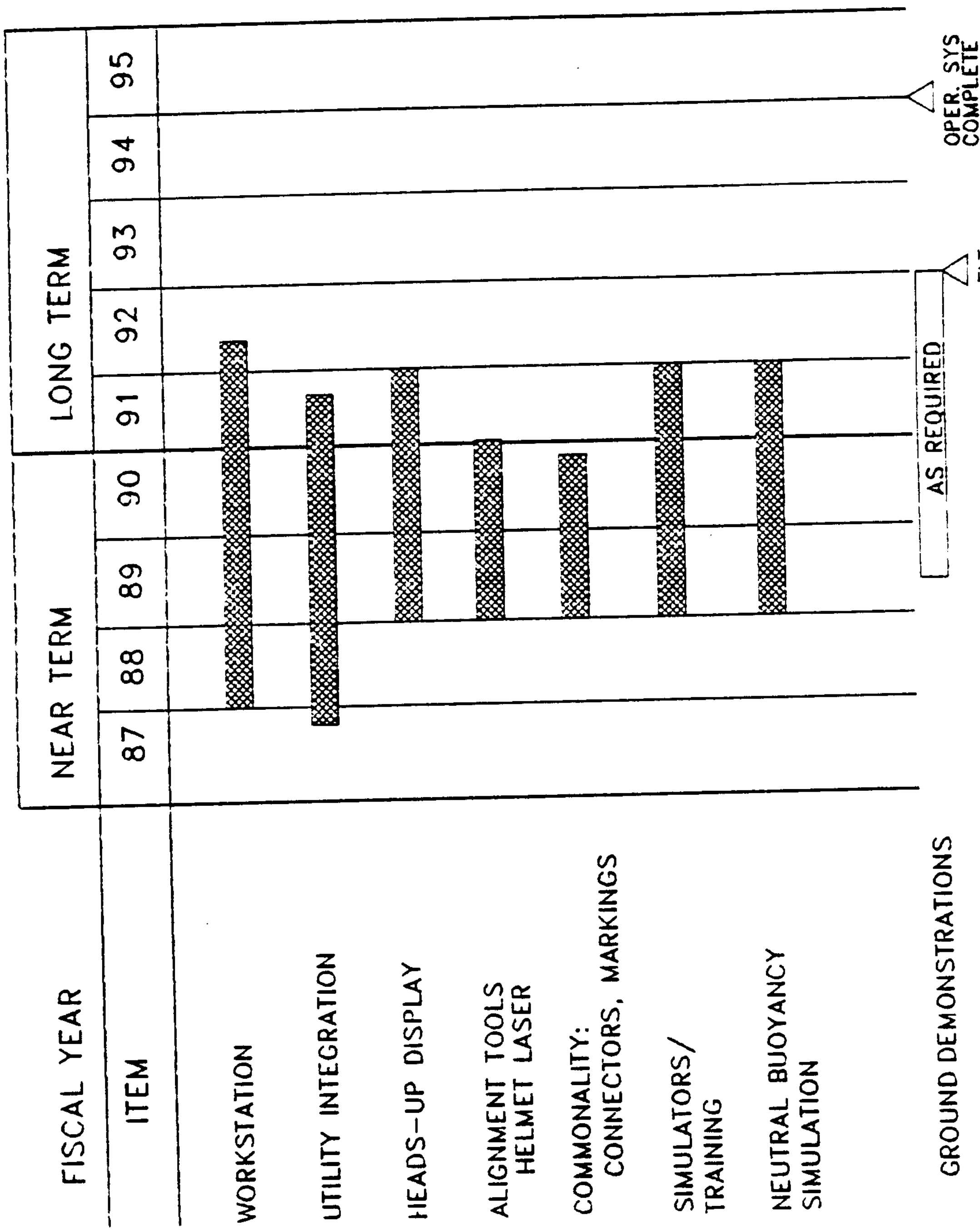


Figure 5-5 Large System Assembly Roadmap

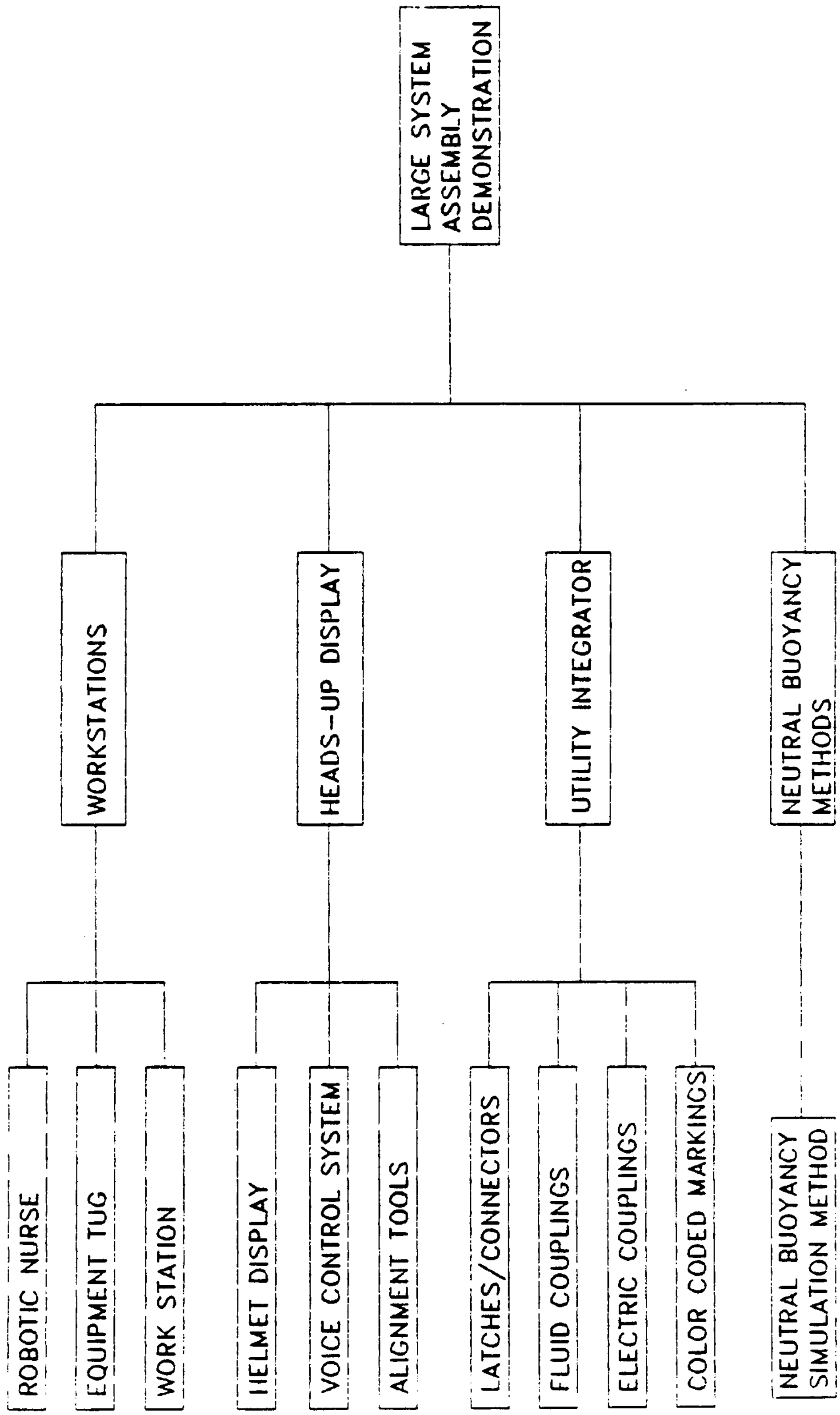


Figure 5-6 Large System Assembly – Development Tree

interaction, work environments experienced by the EVA crewman, and teleoperator habitat requirements must be evaluated.

While performing assembly at the workstation, the performance of the assemblier will be greatly enhanced if the supply of parts is continual and accessable. The transportation of parts from storage to the workstation could be accomplished through the use of an equipment tug. Propulsion, navigation, command and control technologies related to the development of such a vehicle must be addressed.

5.2.2.2 EVA Tools The assembly of complex systems requires a vast knowledge of the system's operating configuration and an understanding of the multitude of individual and different tasks necessary to make the system operational. The training required to perform space assembly could be greatly through the use of a helmet mounted display system. Heads-up displays inform the EVA crewmember of the required procedures through step-wise instruction augmented by video displays. Such a system would require human factors analysis to develop the helmet display, and technological development of a voice control system which would allow the assembler to the pace of assembly. Bar codings could be used to identify supply parts and transfer information to the assembler of part location and the required integration with utilities. The development of an EVA power-ratchet tool will also greatly enhance manned activity. The power tool should be programmable by the gloved EVA astronaut, giving them the capability of multiple torque levels, reversible directions, and variable speeds. Advancements in hardware and software to perform system checkout, precision alignment, and startup are required.

5.2.2.3 Utility Integration The assembly of large systems will require the integration of many utilities such as power, communication, thermal fluids, propulsion, and control systems into the structure of the orbital platform/vehicle. Vehicle configuration and interface compatibility require further technological advancement in zero-G fluid couplings, mechanical latching, and electrical connectors (optical or pin-type). To assist the crewmember in such utility system assembly, color coded or bar coded markings will be needed on all assembly parts.

5.2.2.4 Neutral Buoyancy Methods The proof of all man operations in space is best ground tested through neutral buoyancy simulation. Advancements in hardware technology which would best utilize the simulation of the zero gravity environment in neutral buoyancy should be evaluated. This would reduce the risk involved with operational use of the assembly system technologiues prior to actual flight qualification testing.

5.2.3 Analysis Tasks

Analysis tasks needed to provide operational capability of large system assembly are outlined in Fig. 5-7. Areas of possible analysis work include workplatform requirements, spacecraft compatibility studies into workplatform docking and assembly fixture interfaces, and logistics requirements of supportability and parts supply.

5.2.4 Demonstration Recommendations

System level demonstrations of Large System Assembly technologies are necessary to develop a feasible operational system. The technology roadmap of Fig. 5-5 shows the timeframe for these ground and flight-test demonstrations. Ground testing would be performed in the neutral buoyancy environment using mock-up spacecraft hardware. The demonstrations would include the utilization of a heads-up display system in a minor assembly task, utility integration procedures, and hardware prooftesting of new alignment aids such as a helmet laser. Different electrical connector and fluid coupling technologies could be evaluated using 1-G simulations or performed on actual spacecraft hardware.

Based on the success of these ground test and the definition of mission requirements, one or more flight tests will be performed. The on-orbit use of a helmet-mounted display system or helmet laser could occur either during individual technology demos in the shuttle payload bay or during assembly of a simple operating system requiring actual utility integration, system checkout, and startup.

WORK PLATFORM REQUIREMENTS

- ORU storage and conditioning requirements
- Work platform mobility power, storage, and habibat requirements

SPACECRAFT COMPATIBILITY STUDIES

- Docking and Assembly Fixture compatibility
- Interface compatibility: structural, thermal control, and command
- Operational mode evaluation including checkout, alignment, and startup

LOGISTICS

- Logistics facilities study
- "Sparing to availiability" model
- Supportability requirements for large space structures
- Space hardware support decision analysis

Figure 5-7 Analysis Tasks – Large System Assembly

5.2.5 NASA/DoD Program Integration

The large System Assembly program compliments and builds on the concurrent NASA programs to fully develop the related technologies. Major efforts currently on-going include the Space Station efforts currently in progress at JSC.

5.2.6 Concept Description Worksheets

The worksheets which fully describe the candidate program concepts for future technological development in the area of large system assembly can be found in Appendix A.2.

5.3 BIPROPELLANT TANKER SYSTEM

5.3.1 System Description

Because it is so expensive to build, launch and operate spacecraft, on-orbit refueling through the use of a bipropellant tanker is seen as a major element towards future SAMS capability. Design objectives should include modularity to gain flexibility in tanker sizing, maximized use of existing hardware, and low operation cost with short turnaround time. This would include minimizing the required interfaces (especially those computer related), and minimizing the need for ground support facilities. This technology area requires further development in subsystems such as propellant transfer, interface mechanisms, remote operations and contamination control.

5.3.2 Subsystem Development

Development of an operational bipropellant tanker requires further advancement in technologies related to fluid handling, fluid storage, umbilical design, command and control systems, and remote servicers. A roadmap showing the overall development flow is shown in Fig. 5-8 In order to achieve the capability to resupply propellant on orbit by the mid 1990s, fluid handling technology studies should begin as soon as possible. Control subsystem and

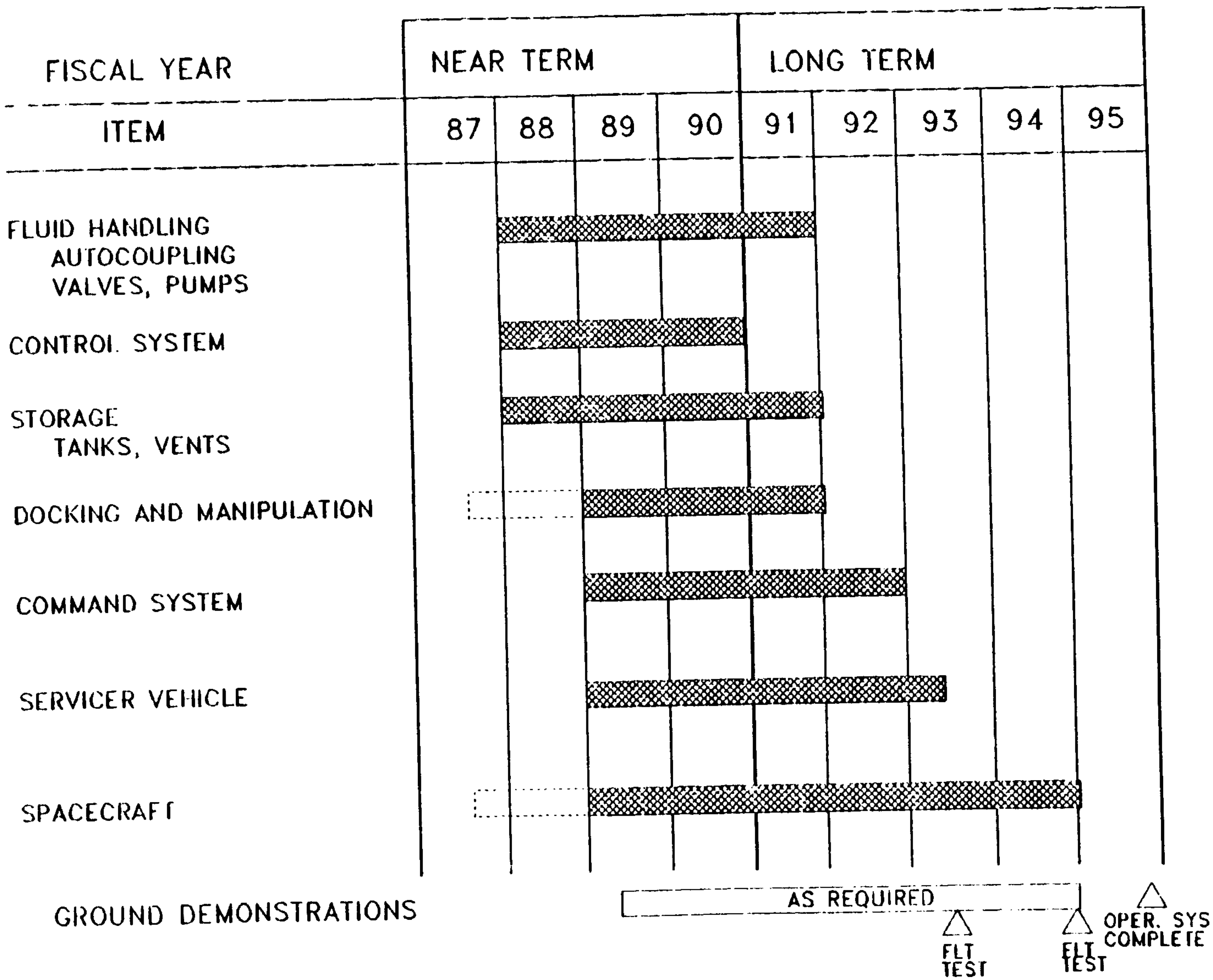


Figure 5-8 Bipropellant Tanker System Roadmap

lightweight storage tanks should also begin development as subsystems critical to this tanker system. The spacecraft and docking and manipulation areas are shown as requiring development soon because of the compatability needed with the vehicle which is to be serviced on orbit. Flight tests for this system should occur as soon as the servicer vehicle is operational and complete. Contamination control through proper spacecraft fluid and mechanical interfacing and strict adherance to environmental control requirements also must be further defined. Figure 5-9 shows the development tree of this technology area.

5.3.2.1 Fluid Handling

A key technology area for the development of the bipropellant tanker is the ability to efficiently and safely handle fluids in a zero-g environment. On-orbit refueling requires investigation into the problems associated with fluid transfer and propellant tank technology. Existing liquid propulsion systems can be used as a baseline from which such transfer systems will evolve. The first fluid transfer requirements will be the resupply of Earth storable propellants, since these will be required sooner and in greater quantities than other fluids. Regulated pressure-fed bipropellant systems can be resupplied by fill and vent at a constant receiver ullage pressure. The critical issue is gas liquid seperation to preclude liquid venting. Fluid transfer requires temperature monitoring and the ability to interrupt flow to permit the dissipation of heat generated by the adiabatic compression effects. Hardware development in the areas of micor-g valves, pumps, tank configuration, and leak-free fluid couplings would be required. A liquid acquisition device to insure liquid (versus gas) transfer to the receiving tank. Propellant mass gaging would be important to monmitor the mass quantity stored, transferred, and lost in the fluid transfer process. Trades analysis into transfer rates, fluid quantity gauging, pressurized transfer versus pumped fluid control, venting, and propellant pumping must be performed.

5.3.2.2 Storage Demonstration

Because of the extreme temperatures experienced by the candidate sytems,

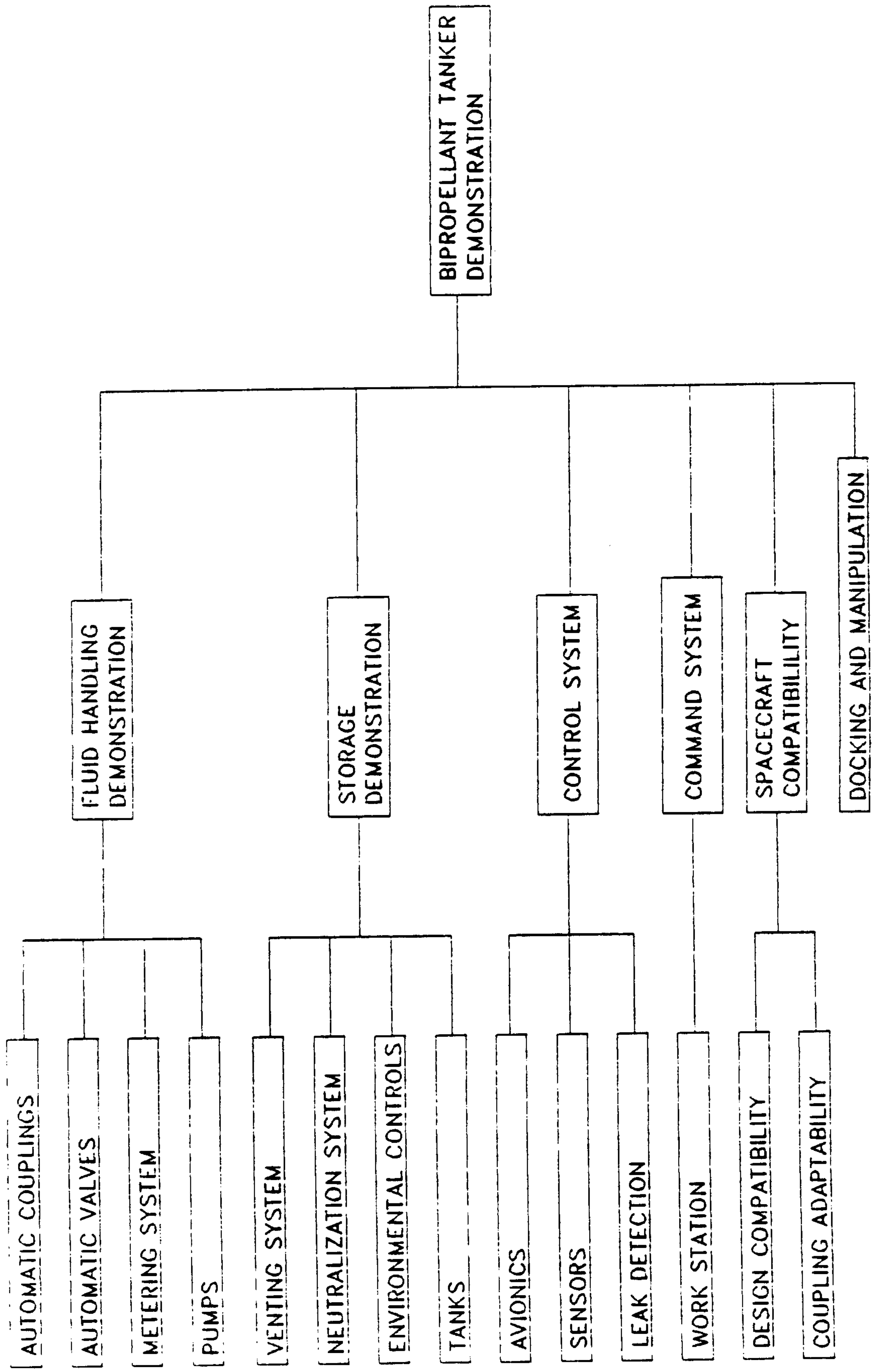


Figure 5-9 Bipropellant Tanker System Development Task Flow

storage components will require extensive analysis into the thermal control aspects of propellant transfer and storage. Fuel types and pressurants to be used, their capabilities, and compatability with the spacecraft propellant system must be evaluated. In addition, development of a disposal system for the decomposition of surplus liquid propellant and gas should be developed.

5.3.2.2 Control System

The control subsystem must be analyzed with respect to performance, cost and weight, maximizing system flexibility, reliability and safety. Fault isolation, monitoring, and system test and checkout capabilities must be investigated.

5.3..2.4 Command System

Telemetry, guidance, and navigation talkback systems to allow crew command with full system visibility through video or graphic display require development. System self test and health check results must be communicated to the operator to allow for reset of limit functions. Caution and warning interfaces to alert operator in the event of an anomalous condition also require developement.

5.3.2.5 Spacecraft Compatibility

Of special concern in the bipropellant tanker concept is the impact of contamination on the spacecraft which it is servicing due to propellant venting and leakage. Fuel resupply operations must meet the environmental control requirements and should be derived from future analysis in this area. The surfaces sensitive to contamination (mirrors, sensors, paints, thermal protection, etc) must be analyzed to determine the long and short term effects of contaminants which result from fluid resupply operations as well as propellants from the servicer propulsion system.
Associated to the refueling operation, the procedures for spacecraft safeing and mutual grounding must be defined. The spacecraft configuration analyses necessary to properly integrate refueling provisions and accessable interfaces

must be accomplished. Docking interface, manipulation and jettison mechanisms must be investigated.

5.3.3 Analysis Tasks

Analysis tasks needed to provide operational capability of the Bipropellant Tanker system are outlined in Fig. 5-10. Areas of future analysis work include servicer compatibility requirements involving contamination control, propulsion requirements, and control system architecture. Additionally, the spacecraft compatibility studies should involve the impacts of contaminants, grounding requirements, fuel compatability, and environmental control requirements. All systems analysis of servicing functions should consider the limited time availability for servicing due to nodal regression rates and multi-vehicle servicing requirements, then prepare concept design approaches in sufficient depth to enable trade studies an analyses. Trade studies should be performed to select the recommended approaches. Detail design work, including safety, reliability and producability analysis, and cost estimates for each of the recommended approaches. Finally, fabricate demonstration hardware to perform demonstrations.

5.3.4 Demonstration Recommendations

System level demonstrations are required to develop an operation Bipropellant tanker system. The technology roadmap shown in Fig. 5-8 gives the timeframes for these demonstrations. The tests will include mockup and actual flight hardware, including the use of a verification test article which would be used in both ground and flight tests. The article would be a subscale version of the orbital tanker system. The purpose of the test article would be to establish both the system and thermal performance of the design and to obtain long term system exposure effects.

Demonstrations will include the ground operation of the fluid transfer system with monitoring performed by associated control and command systems. Based on the success of these ground tests, further proofing of the concepts and designs will be accomplished through flight demonstrations. The on-orbit

SERVICER COMPATIBILITY REQUIREMENTS

- Contamination control requirements
- Servicer propulsion requirements
- Control system architecture and software standards

SPACECRAFT COMPATIBILITY STUDIES

- Contamination impacts study
- Spacecraft safeing, grounding, and refuel operations mode
- Fuel type capability and compatibility definition
- Fuel environmental control requirements definition

Figure 5-10 Analysis Tasks – Bipropellant Tanker System operation of a fluid transfer system will demonstrate zero-G transfer capabilities, monitoring, control and command system capabilities, as well as the docking and manipulation mechanism performance.

5.3..5 NASA/DoD Program Integration

The bipropellant tanker program compliments and builds on the concurrent NASA and Air Force programs to fully develop related technologies. Major efforts concurrently on-going include the NASA Orbital Spacecraft Consummables Resupply Study (OSCRS) and the NASA High Pressure Gas Supply Study.

5.3.6 Concept Description Worksheets

Worksheets which describe in detail the candidate program concepts to support future technological development in the Bipropellant tanker area can be found in Appendix A.3.

5.4 CRYOGENIC TANKER SYSTEM

5.4.1 System Description

The near term resupply of all categories of fluids, including the transfer and on-orbit storage of cyrogens, is essential for efficient space-based operations. Resupply of cryogens allows the system to remain on-orbit and have the life extended by having the fluids replenished. This precludes the need to bring the system back to ground for replenishment and relaunching. Fluid resupply, using a cryogenic tanker, therefore addresses the goal of reduced launch costs by an order of magnitude.

Cryogenic fluid quantities in the hundreds of thousands of pounds will be required to be resupplied in the next 20-year time period for propulsion, power, life support, laser reactants, nuclear particle beams, and other types of systems. This particular technology area focus represents an expansion of the cryogenic fluid storage and conditioning technical issues. There is currently no cryogenic liquid data for large tankage except for the superfluid helium storage data obtained from the IRAS mission. Specifically, the volumetric transfer efficiency of cryogens needs to be addressed.

5.4.2 Subsystem Development

Development of an operational cryogenic tanker requires further advancement in technologies related to fluid handling and storage, command and control systems, spacecraft compatability, and docking and manipulation. A roadmap for cryogenic tanker fluid transfer and resupply is shown in Fig. 5-11. In order to achieve the capability to resupply cryogens on orbit by the mid-1990s, development of fluid handling technologies related to cryogens in micro-G environments should be initiated as soon as possible. Related to this are the tanks which will store and environmentally control the fluid. As with all of the SAMS systems, should a program require servicing by the mid 1990s, effort should be expended now to insure the systems are fully compatible and properly interfaced. Flight tests should be run at the operational completion of the servicer vehicle and where spacecraft compatability is assured. Figure 5-12 shows the technology tree for this area.

5.4.2.1 Fluid Handling

The large quantities of fluid to be resupplied will require analysis into the actual quantity of fluid required to compensate for estimated transfer and cool-down losses. A pumping system which can adequately handle the required flow rates with maximum versatility and controlability to deal with the many operational scenarios must be developed and identified. Flow and mass gaging must be as accurate as possible. Mass gaging, for example, will be a key element of any transfer scenario and adequate instrumentation for gaging mass in zero-G does not exist. The application of cryogenics puts a special cold temperature requirement on any mass gaging system, and the gaging of both fluids and gases will be required. Design of orbital transfer couplings which consider safety, venting, and leak-checking requirements must be accomplished. Filtration is also extremely important in order to preclude malfunction of plugs, valves, burst disks and pump bearings. Other components from the cryogenic fluid management system such as flow meters, valves, and

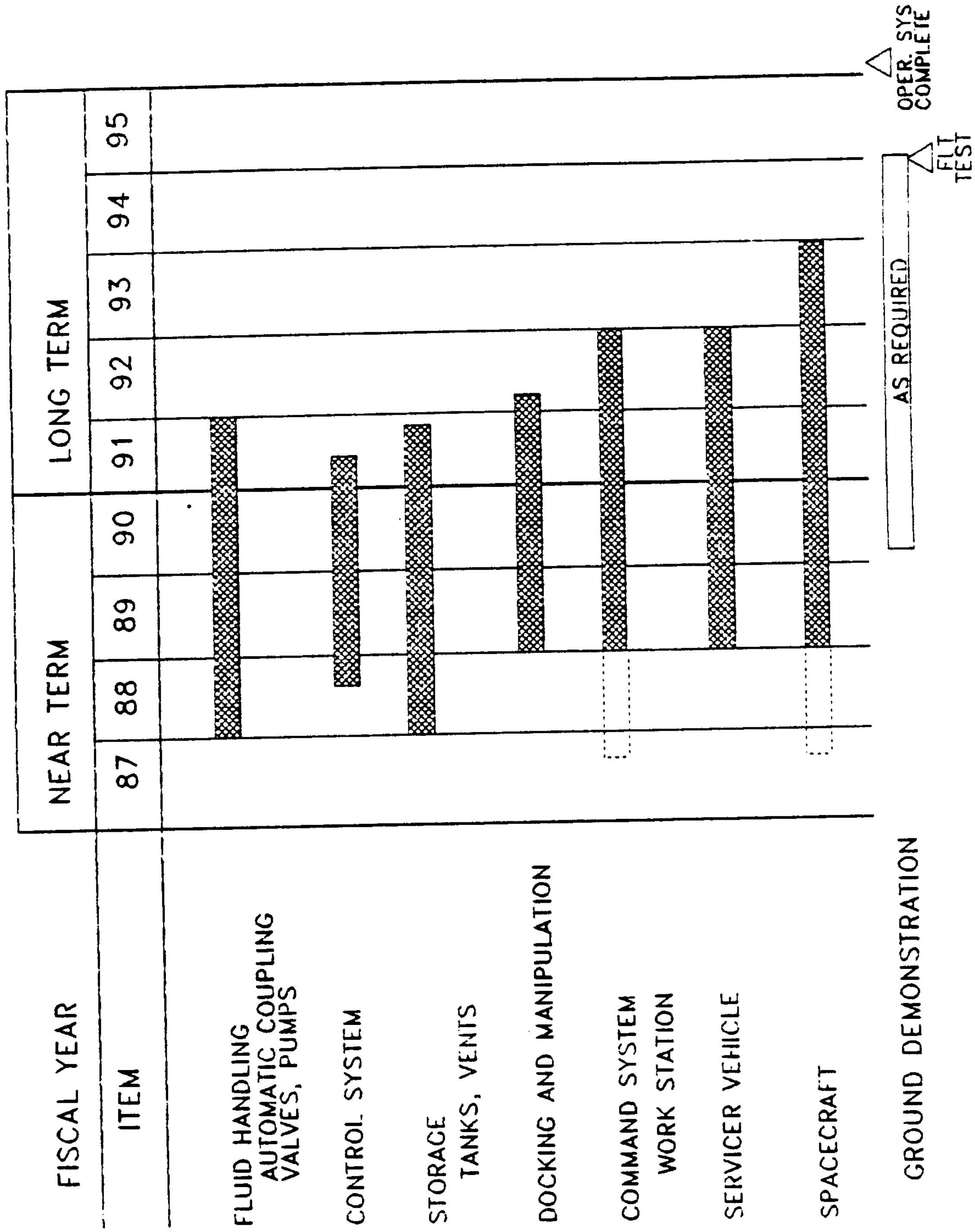


Figure 5–11 Cryogenic Tanker System Roadmap

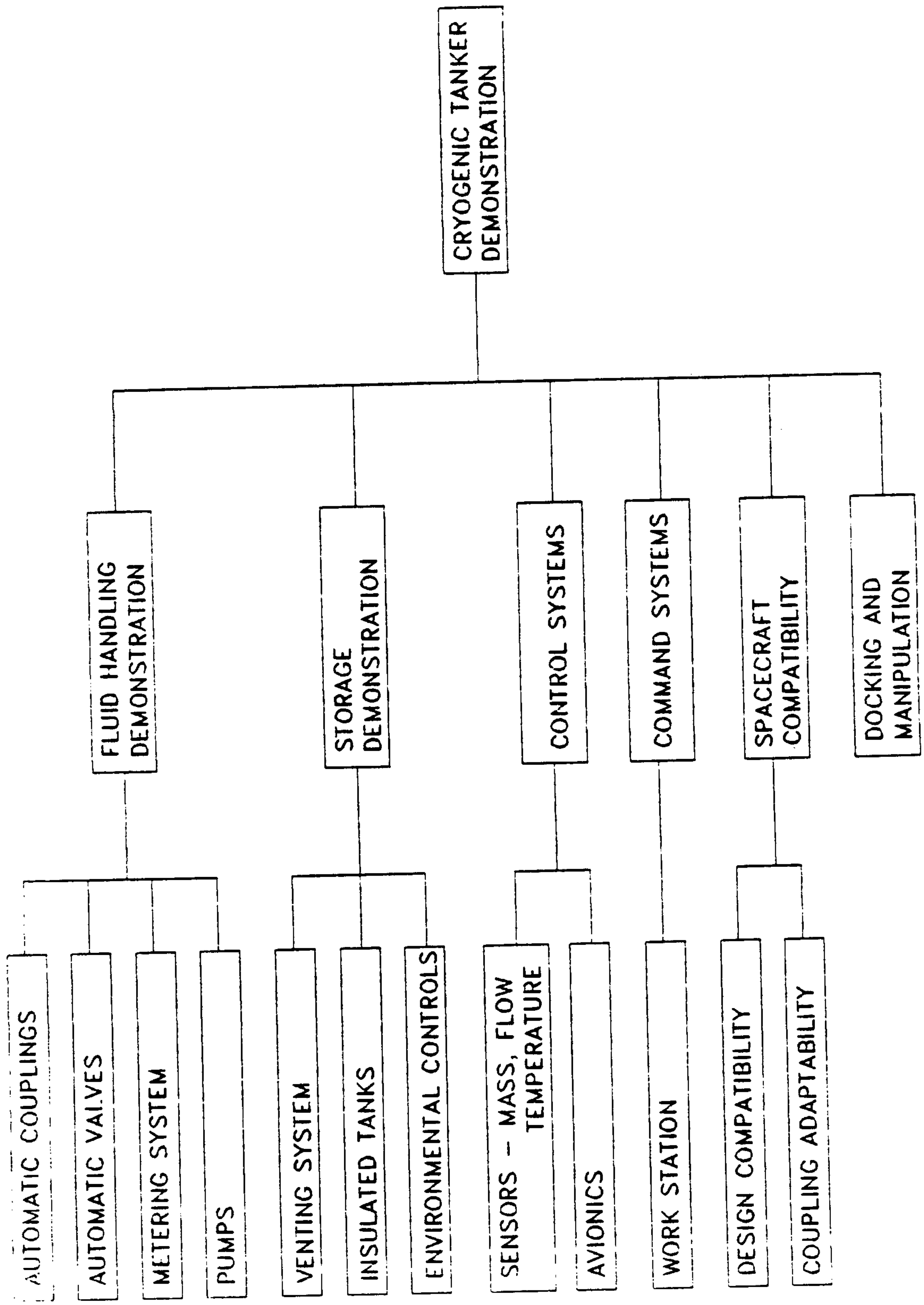


Figure 5-12 Cryogenic Tanker System Development Task Flow

service lines will also require evaluation. Hardware components which have previously been qualified or certified for flight use obviously have substantial advantage over untried components.

5.4.2.2 Fluid Storage

A large tank thermal control technical assessment is required to look at the thermal insulation aspects for long-term storage, including such problems as cryogen boil-off due to environmental heating. On-orbit hold time, which could be as long as nine months for extended scenarios, primarily reduces to a boil-off loss which must be factored into tank sizing. Of particular interest is the capability of the system to survive the launch environment. Lightweight, low pressure tankage will contribute to reductions in launch costs. Such materials such as lithium-aluminum should be investigated as ways to reduce launch cost and improve overall tanker mass fractions. Ground operations in which cryogen transfer is required are extremely costly, particularly as launch time approaches. System safety is a major consideration and must be thoroughly investigated. Venting problems in normal routing (operational) and maximal (contingency) operations must be investigated. Transfer line and tank chilldown and fill will require venting of cryogens to space, since transfer of the liquid through the higher temperature receiving lines will generate a vapor that must be vented overboard. Hardware designed to minimize vapor venting during charge, hold and venting operations will be necessary. Micro-G environments will cause liquid/vapor interphasing which will make liquid acquisition devices necessary to preclude the venting of liquids. All venting must satisfy safety criteria and mechanisms to do so must be developed. The required nonpropulsive venting, including rates and direction, must be designed to minimize hazards.

5.4.2.3 Command and Control Systems

The long intervals required to transfer large quantities of cryogens mandate that transfer operations be monitored by a computer in order to alleviate problems of crew fatigue. Other critical operations include emergency safeing and shutdown operations, by computer, which will not be delayed while waiting for crew response to an alarm and subsequent problem evaluation. Trades involving these decisions include required monitor sensitivity versus crew reaction time.

A critical subsystem to the cryogenic tanker will be the thermal control system, which includes studies into thermal control designs, methods, and associated hardware. It must be designed to ensure that interface temperatures and gradients are maintained within acceptable limits to keep thermal distortions within allowable tolerances. Designs should be evaluated with respect to reliability, flexibility, and safety. Other areas which require special attention are control of thermal distortion in docking mechanisms and structure, contamination control and monitoring, and pressure monitoring.

The requirements of the avionics subsytem include considerations of system reliability, possible operation independent of external supply of power, and interface to the tanker's control monitors. The data storage and transmission requirements must be evaluated in terms of quantity and architecture (including location of system control station).

5.4.2.4 Spacecraft Compatibility

Mechanical interfaces must be evaluated in terms of spacecraft safeing and grounding, structural integrity with regards to load paths and impact absorption. Docking interface, manipulation and jettison mechanisms must be defined. The interface must also involve electrical connectors for power, command, telemetry, and video relay. An umbilical connector carrier mechanism to provide remotely operated mate and demate is needed. The umbilical connection should have the capability of mate without the connector mechanism becoming ther secondary load path. Fluid couplings must consider contamination control, leak detection, safety, commonality, and compatibility.

5.4.3 Analysis Tasks

Analysis tasks needed to support cryogenic tanker technologies include configuration studies (CG, weight, length) to determine impact on launch vehicle performance. Tanker subsystems including fluid management, thermal control, structural, mechanical intefaces and electrical/avionics should be evaluated with respect to cost, safety, reliability, and design flexibility. Analysis into the required flow rates for resupply which consider the time limit due to nodal regression effects and satellite availability. A technical assessment of thermal insulation aspects for long term storage of cryogens should be performed. Contamination control and leak detection requirements must be analyzed with critical operation trades of monitor sensitivity versus crew reaction time to contingencies and emergencies. Spacecraft and servicer compatability studies are shown in Fig. 5-13.

5.4.4 Demonstration Recommendations

System level demonstrations are required to develop the cryogenic tanker system. The technology roadmap shown in Fig. 5-11 shows the timeframes for these demonstrations. The tests will include mockup and actual flight hardware, including the building of a verification test article which would be used both in ground and flight tests. The article would be a subscale version of the orbital tanker system. The purpose of the test article would be to establish both the system and thermal performance characteristics of the design and obtain long term system exposure effects. Demonstrations will include operation of the tanker test article in realistic environments while monitoring the performance of associated control and command systems, proximity operations systems, and docking and manipulation capabilities.

Further proofing of the systems involved in cryogen transfer involve flight tests which test the system in the zero-g environment, using cryogenic fluids to test emergency shutoff and monitoring systems, leak detection and contamination control.

5.4.5 NASA/DoD Program Integration

The Cryogenic Tanker program compliments and builds upon the concurrent NASA and Air Force programs to fully develop related technologies. Major efforts

SERVICER COMPATIBILITY REQUIREMENTS

- Contamination control requirements
- Thermal load environment and impacts
- Servicer propulsion requirements
- Control system architecture and software standards
- Compatibility of candidate cryogenic liquids for generic tanker design

SPACECRAFT COMPATIBILITY STUDIES

- Contamination impact studies
- Spacecraft safeing, grounding, and replenishment operations mode
- Cryogen environmental control requirements definition

Figure 5-13 Analysis Tasks – Cryogenic Tanker System on-going include the Tanker Concept Study, Tanker design and fabrication work at JSC, and the Cryogenic Fluid Mangement Experiment at Langley Research Center.

5.4.6 Concept Description Worksheets

The associated worksheets which describe the candidate program concepts to support the Cyrogenic tanker technology development can be found in Appendix A.4.

5.5 Complimentary Technologies

Complimentary technologies are those which could not easily be classified under any one of the four major SAMS functional systems identified earlier. These concept development candidates have applicabilities which span more than one system though are not required for successful demonstration of a SAMS major system. As a parallel effort to a system's development, however, they would compliment and enhance SAMS efforts. These complimentary technologies cover a wide range of capabilities including logistics facilities and sparing models, space hardware support, training methodology, suit technology, spacecraft software maintenance, coating rejuvination and surface cleaning. These technologies are briefly described in the following section. CDP candidate worksheets for these concepts can be found in Appendix A, section 5.0.

5.5.1 Logistics

Many logistics related studies could enhance SAMS capabilities on orbit. A logistics facilities study would analyze and consolidate facility requirements for space systems, including capabilities needed to support both DoD and NASA programs. Another logistically oriented complimentary technology would be the development of a facilities decision tree which would identify facility requirements due to hardware support needs of space-based assets, airborne support equipment, and space transportation systems.

A "sparing to availability" model should be developed to determine optimum spares requirements for space systems, especially Space Station and SDI constellation support. Models which translate the established system-level requirements into detailed qualitative and quantitative design requirements for proposed systems are in need of development. These requirements must then be evaluated for their effect on the supportability requirements for the proposed system.

5.5.2 Training and Simulation

To facilitate the design and development of SAMS Spacecraft and hardware, the development of an engineering and simulation laboratory dedicated to evaluate performance in a space environment could enhance the evolution of a common SAMS data base and standardization of hardware amongst programs. For training purposes the neutral buoyancy environment provides an excellent correlation to actual conditions experienced during EVA in space. A neutral buoyancy test program which proximizes the use of available facilities and hardware would be beneficial to the SAMS effort. Additionally, no program presently exists which establishes the training requirements for Mission Specialist Engineers MSE's). An in-depth analysis of crew and MSE training would assist in SAMS implementation.

5.5.3 Software Maintenance

Each maintenance concept option has specific mission and maintenance needs. Specific spacecraft mission scenarios will have differing requirements for speed, security provision, level of human interface, and degree of task complexity and difficulty. In order to facilitate and maximize the use of a multipurpose SAMS servicer across programs, a proof of concept program should be accomplished which provides a means to change software on-orbit and demonstrate new technological developments in this area.

5.5.4 EVA Suit Technlogies

Development of a quick reaction full-mobility Space Suit will require an in-depth evaluation of human performance requirements in a simulated weightless environment. A study to evaluate current suit capabilities using MSE's as test subjects could compare suit donning/doffing, translating, and work restraint operations. Additionally, a overgarment matrix system should be developed to adapt present Space Suits to the varying environmental and operational hazards including radiation, hydrazine contamination, differential pressure and nonventing suit requirements. A head positioning aiming system like that presently used by helicopter pilots could be further enhanced for applications in SAMS operations.

5.5.5 Coatings and Surfaces

A final technology area complimenting the SAMS functions on orbit would be the cleaning and rejuvinating of surfaces on-orbit. Optical surfaces are especially sensitive to contamination and degradation which negatively effect optical transmissivity. A proof of concept program to determine/develop cleaning equipment and supplies which cannot harm optical surfaces in any way would compliment the SAMS capability. Thermal coatings and surfaces are also a concern over long on-orbit durations due to micro-meteriod strikes or external contamination and could be part of this POC program or a seperate entity.

SAMS

INTEGRATED CONCEPT DEVELOPMENT PROGRAM

SECTION 6.0

6.0 Integrated Concept Development Program (CDP) Plan

6.1 Integrated Plan Approach

This study developed the analysis methodology, concept designs and the basis for cost benefits analysis through the application of the SAMS functional elements to derived design reference missions. An assumption in the development of this plan was that real programs would utilize these approaches thus reflecting the technology applicability shown in Fig. 3-1.

The purpose of the integrated CDP plan is to guide SAMS through the intermediate step between the study and operational capability. Since the time spans for IOC and FOC are indeterminant at this time a five year span (1988 to 1992) was selected as a reasonable time period for the development program. This decision was independant of schedule impacts resulting from program requiremets and may be changed to meet those requirements. The approach to the plan was to utilize this time period to perform tests which establish requirements; develop program, system and spacecraft requirements; integrate with flight hardware programs/developments; and provide opportunities to analyze and apply other government/ commercial technology developments to SAMS. Some candidates were determined to have little application in this near term period.

Each of the following sections present a proposed schedule and rough order magnitude (ROM) cost for plan implementation for the five SAMS application catagories. This will be followed by a summation of the proposed program cost.

6.2 Remote ORU Changeout

The remote ORU changeout CDP plan (Fig. 6-1) consists of three parallel efforts: A) SAMS/FTS ORU demonstration; B) ORU development; and C) Robotic Technology development.

The accelerated schedule for the Flight Telerobotic Servicer (FTS) development

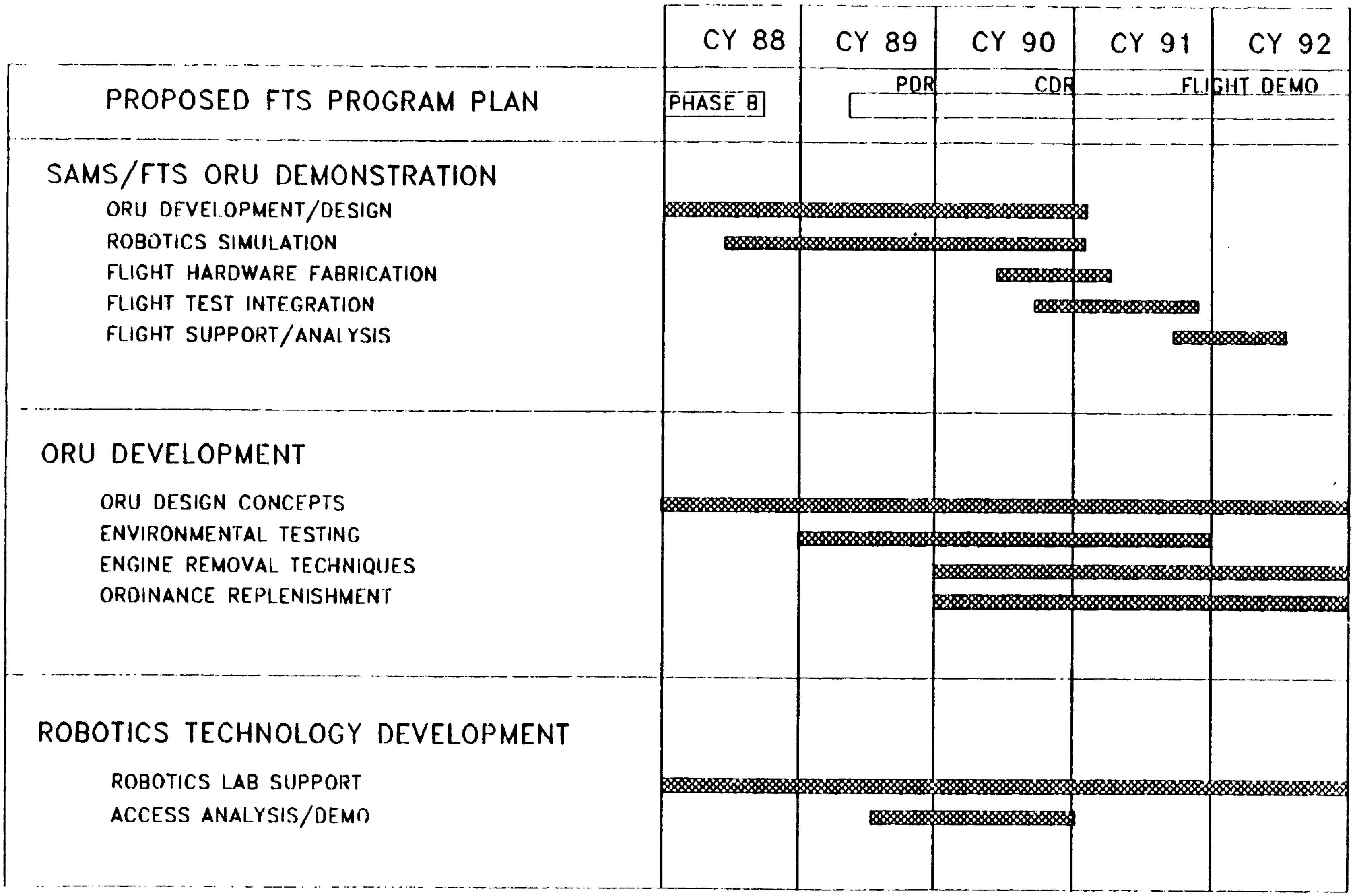


FIGURE 6-1 CDP PLAN - REMOTE ORU CHANGEOUT

provides an excellent opportunity to piggyback an ORU changeout experiment on the proposed demonstration in late 1991. Paralleling the proposed FTS schedule, SAMS would develop a concept ORU to be flown with the flight demonstration FTS hardware. This would allow a first hand evaluation of SAMS application of FTS. The proposed program includes the ORU integration/design; 1-G robotics simulations to develop interface and operational requirements; integration with FTS ground test; flight hardware fabrication; flight support and post flight analysis. The ROM cost is $15 M for the 4 1/2 year period.

The ORU development is an independent element for the development of the SAMS remote changeout interfaces and ORU requirements/designs. The emphasis is on the interaction of design and environmental test to establish and verify design requirements. . Parallel to this effort is the appliation of the design approaches to engine changeout and ordinance replenishment. The ROM cost is $8 M for five years.

The robotics technology development will support an on going robotic laboratory for the development of SAMS remote servicing requirements and techniques. It will also provide outside developers an opportunity to test their hardware and systems to meet SAMS requirements. This is also a means of developing remote servicing and robotics interface standards.

6.3 Large System Assembly

The plan proposed for the large system assembly (Figure 6-2) reflect an influence of EVA application.

The application of electronic documentation plays a leading role in this effort. Further developments in helmet mounted display developments will concentrate on the viewing material requirements and viewing techniques. As voice interaction control becomes more applicable to system control and operation voice, recognition systems must be developed to investigate responses to dynamic voice fluctuations. Finally the data storage requirements for dynamic electronic documentation systems will be evaluated. This effort is estimated to cost $5 M for the five year period.

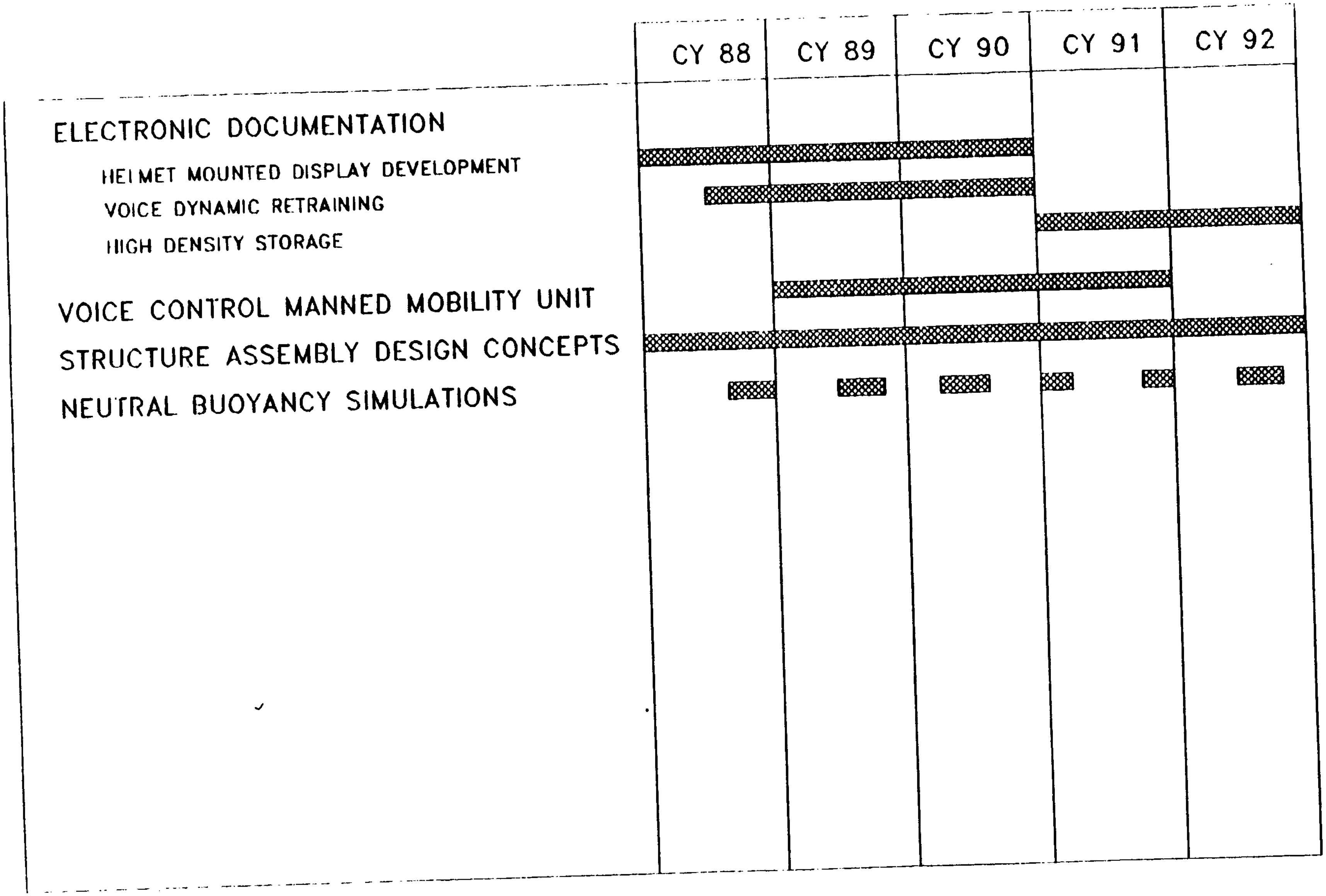


FIGURE 6–2 CDP PLAN – LARGE SYSTEM ASSEMBLY

The handling and movement of large structures requires the astronauts hands to be free. A voice actuated manned mobility unit (MMU) would free the astronauts hands from the controls. This program would develop the voice control system for the MMU and test in aneutral bouyancy simulation. The ROM cost is $10 M for three years.

An effort to develop structure assembly designs concepts should be initiated for SAMS application. This would be coupled with a neutral bouyancy simulation effort to test and evaluate the structural concepts. The Able Engineering lock assembly is a prime candidate for an early evaluation. The ROM cost of these programs are $8 M for structure attachment design and $3 M for supporting simulations over the five years.

6.4 Bipropellant and Cryogenic Tanker Systems

The plans for bipropellant tankers (Figure 6-3) and cryogenic tankers (Figure 6-4) are greatly influenced by on going NASA programs. Therefore, a level of effort activity to establish requirements and interfaces for these programs is most appropriate in the near term. This effort equates to a $15 M ROM for five years.

6.5 Complimentary Technologies

The complimentary technologies have application to varied aspects of SAMS development. Figure 6-5 presents a plan for the development of these technologies.

Little data is available on the effect of long duration space exposure on active system components. The purpose of this effort is to identify a candidate satellite(s) for capture; develop the rendezvous, capture, safing and earth return techniques; and disassemble the satellite for further analysis. The cost of this effort is $13 M not including the flight and support equipment costs. This assumes a 1991 capture flight.

Servicing in higher orbits introduce unique radiation environments to the

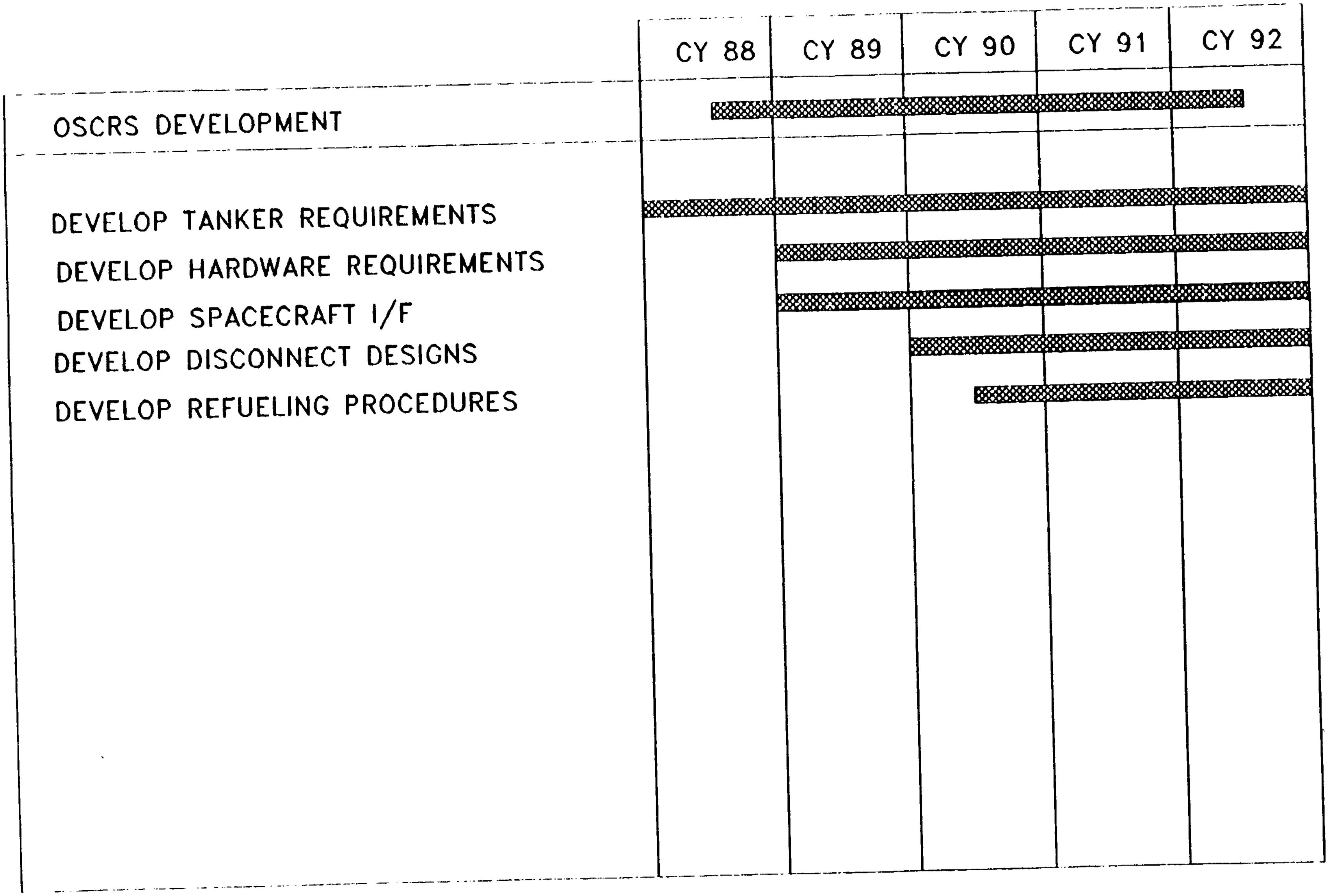


FIGURE 6–3 CDP PLAN – BIPROPELLANT TANKER SYSTEM

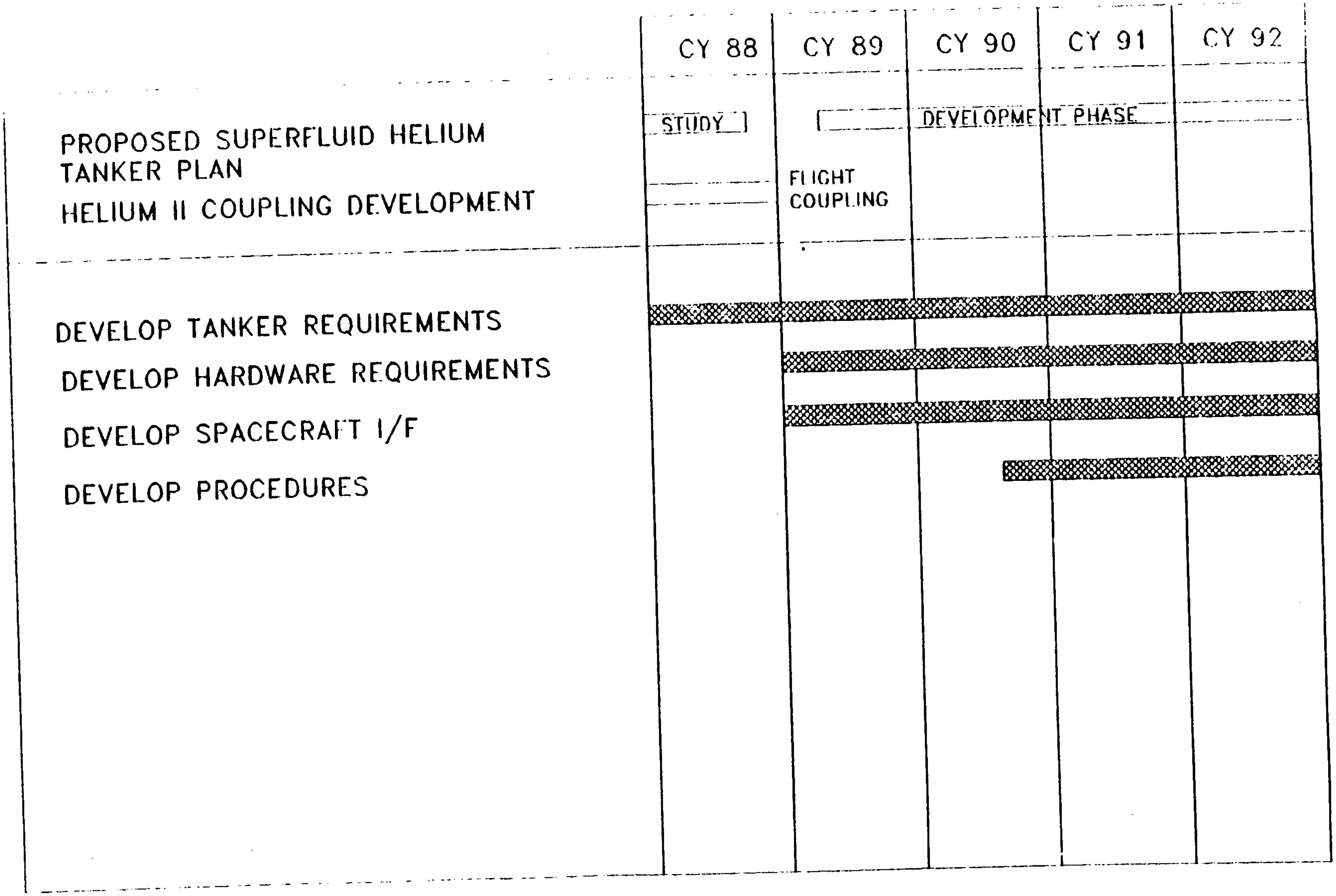


FIGURE 6-4 CDP PLAN – CRYOGENIC TANKER SYSTEM

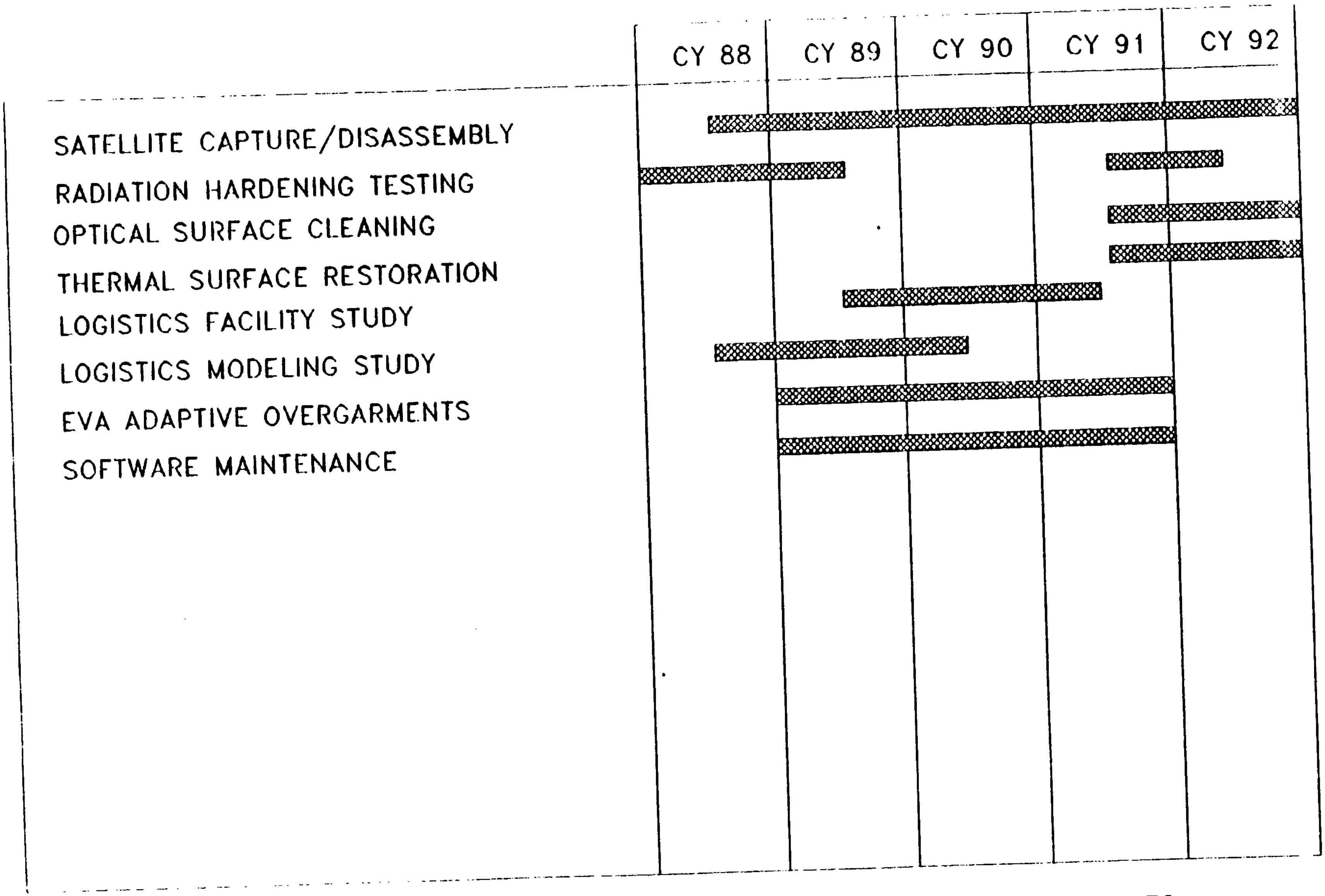


FIGURE 6–5 CDP PLAN – COMPLIMENTARY TECHNOLOGIES

task. This effort is aimed at testing and developing ORU requirements to survive in this environment. The cost ROM is $0.6 M.

Requirements for optical surface cleaning and thermal surface restoration could be derived utilizing the data obtained from the captured satellite. These efforts could be initiated in this program phase for $1.0 M total. This early timeframe could effectively be used to develop logistics facilities requirements and to standardize sparing and functional analysis modeling techniques. This effort could be initiated for $1.0 M.

An alternative to space suit redesign is the development of overgarments for radiation protection, hydrazine contamination control and suit vent contamination control. This $4.0 M program would define materials, fabricate to prototype designs and test for the environments for these three over garments.

Spacecraft software maintenance can best be effected by physical changeout and remote interaction. This proof of concept will develop and demonstrate design approaches and maintenance planning for Read Only Memory (ROM) and Random Access Memory (RAM) by application of the two maintenance concepts (i.e., physical maintenance and remote maintenance). The effort is $1.0 M over three years.

6.6 ROM Cost Summary

Table 6-1 is a summary of the ROM integrated CDP plan cost estimates. These are estimated costs and do not represent a formal proposal.

Table 6-1 INTEGRATED CDP PLAN ROM COST SUMMARY

TASK	ROM COST ($M)					
	CY88	CY89	CY90	CY91	CY92	Total
Remote ORU changeout:						
SAMS/FTS Demonstration	1.0	3.0	5.0	5.01	1.0	15.0
ORU Development	1.0	2.0	2.0	2.0	2.0	8.0
Robotics Technology Dev.	1.5	2.0	2.5	1.5	1.5	9.0
Large Structure Assembly:						
Electronic Documentation	1.0	1.0	1.0	1.0	1.0	5.0
Voice Control - MMU		2.0	4.0	4.0		10.0
Structure Attachment Design	1.0	2.0	2.0	2.0	1.0	8.0
N B Simulations	0.5	0.5	0.5	1.0	0.5	3.0
Bipropellant/Cryo Tanker Systems	3.0	3.0	3.0	3.0	3.0	15.0
Complimentary Technologies:						
Sat. Capture/Disassembly.	1.0	3.0	3.0	3.0	3.0	13.0
Radiation Hardening	0.3	0.1		0.1	0.1	0.6
Optical Surface Cleaning				0.2	0.3	0.5
Thermal Surface Restoration				0.2	0.3	0.5
Logistics Facility Study		0.2	0.2	0.2		0.6
Logistics Modeling Study	0.1	0.2	0.1			0.4
EVA Adaptive Overgarments		1.0	2.0	1.0		4.0
Software Maintenance		0.2	0.4	0.4		1.0
TOTAL	10.4	20.2	25.7	22.6	12.7	93.6

SAMS

APPENDICES

SECTION 1

SAMS CONCEPT DEVELOPMENT PROGRAM

CANDIDATE PROGRAM WORKSHEETS

REMOTE ORU CHANGE-OUT

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: ORU Grounding Requirements

BRIEF DESCRIPTION:

The introduction of additional voltage potentials to the work environment will effect spacecraft, servicer, robotics, and manned design requirements. In addition, little data is available in the following areas:

- o Connector - Power On requirements
- o Box grounding during transfer
- o Robot docking grounding requirements
- o Robot arm/ORU/spacecraft grounding requirements

This series of test/analyses to establish criteria for grounding during SAMS events.

CURRENT STATE OF DEVELOPMENT: No data available/No common approach.

RELATED PROGRAMS/STUDIES/DEVELOPMENTS: SCATHE

TECHNOLOGY NEEDS FOR THIS CONCEPT: Existing

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS:

- o Develop environment characteristics
- o Develop hardware requirements

ESTIMATED COST AND BASIS OF ESTIMATE:

2 million over two year

ESTIMATED SCHEDULE AND BASIS:

2 years

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE:

ESTIMATED CONSEQUENCE OF FAILURE:

CONTACT NAME: Tom Styczynski

TELEPHONE: 408-756-6671

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Satellite Capture/Disassembly

BRIEF DESCRIPTION:

Existing satellites, which have reached the end of their useful life, contain a wealth of information on the effects of long duration exposure to space environments. This program will be in three steps:

1) Identification and selection of candidate satellites
2) Developing rendezvous, capture, safing and earth return techniques which lead to plan execution.
3) Satellite disassembly and analysis, including historical record development.

CURRENT STATE OF DEVELOPMENT:

- STS atomic oxygen experiments
- Solar MAX Degradation Study
- LDEF return TBD
- WESTAR/Palapal status
- Space station debris concerns

RELATED PROGRAMS/STUDIES/DEVELOPMENTS: None

TECHNOLOGY NEEDS FOR THIS CONCEPT:

- Capture/Safing techniques

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS: Choose satellite, develop handling technique, simulation development

ESTIMATED COST AND BASIS OF ESTIMATE:

DDT&E $10 MIL EST. + STS Launch - high development cost of handling hardware disassembly/analysis $3 MIL - complete analysis + report

- 3 years from ATP to mission complete
- 1-1/2 years to disassemble - analyze - report

ESTIMATED SCHEDULE AND BASIS: TBD

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE: TBD

ESTIMATED CONSEQUENCE OF FAILURE: 0

CONTACT NAME: Tom Styczynski

TELEPHONE: 408-756-6671

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: EVA Inspector Robot (Flying Eye)

BRIEF DESCRIPTION:

To provide observational assistance to reduce human EVA for servicing, a largely autonomous free flyer which operates in the servicing task area to carry a camera or direct a light is needed. The concept consists of a flying unit which navigates and avoids obstacles autonomously. It also includes the home base support unit and command and control unit. Command and control would use speech recognition and CAD/CAM video directories.

CURRENT STATE OF DEVELOPMENT:

Concept identified. First level dynamic and autonomous navigation simulation developed.

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

TECHNOLOGY NEEDS FOR THIS CONCEPT:

Real time, rule-based path and task planner is needed - Approach and docking - Obstacle avoidance

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS:

Complete simulation - Conduct air-bearing table hardware/software development - Demonstrate on shuttle of Space Station - Operational status.

ESTIMATED COST AND BASIS OF ESTIMATE:

DDT&E - $20 Mil
Flight Hardware - $200M for 2 prototype units
Flight Software - $100 M

ESTIMATED SCHEDULE AND BASIS:

Path planner demonstrated 1988 - First integration of hardware and software 1990 - Functional prototype for demonstration 1992

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE: TBD

ESTIMATED CONSEQUENCE OF FAILURE: TBD

CONTACT NAME: Paul Meyer

TELEPHONE: 206-773-5562

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: OMV/OTV Main Engine Remove and Replace

BRIEF DESCRIPTION:

Provide capability to remove and replace OMV/OTV main engine. Due to the large number of projected flights main engine replacement will be a significant on-orbit maintenance problem

CURRENT STATE OF DEVELOPMENT:

Preliminary concepts - Maintenance platform - Tool kit - Maintenance procedures

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

TECHNOLOGY NEEDS FOR THIS CONCEPT:

Leakproof valves and disconnects - Artificial Intelligence (AI) and robotics technologies to support procedural advisory systems and human EVA replacement systems

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS:

Modularize OMV/OTV main engines - OTV/OMV ORU packages common - Fuel disconnects prevent leaks or spills

ESTIMATED COST AND BASIS OF ESTIMATE: TBD

ESTIMATED SCHEDULE AND BASIS: TBD

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE:

ESTIMATED CONSEQUENCE OF FAILURE:

CONTACT NAME: George Reid

TELEPHONE: 206-773-5180

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Preventative and Corrective Ordinance Resupply

BRIEF DESCRIPTION:

Provide capability for satellite ordinance resupply on a scheduled and unscheduled basis in space. Provide safing, handling, checkout, and arming capability.

CURRENT STATE OF DEVELOPMENT:

No work conducted

RELATED PROGRAMS/STUDIES/DEVELOPMENTS: TBD

TECHNOLOGY NEEDS FOR THIS CONCEPT:

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS: TBD

ESTIMATED COST AND BASIS OF ESTIMATE: TBD

ESTIMATED SCHEDULE AND BASIS: TBD

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE: TBD

ESTIMATED CONSEQUENCE OF FAILURE:

CONTACT NAME: Lowell Wiley

TELEPHONE: 206-773-5239

(APPEND ANY ADDITIONAL AVAIULABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Rendezvous and Dock with Uncooperative Spacecraft

BRIEF DESCRIPTION:

Develop the control techniques and the grapple/docking hardware to attach and dock to an uncooperative stable satellite. This capability is required to recover near term satellites which require repair, servicing, or return.

- o Demonstrate auto docking/berthing with cooperative satellite.
- o Develop/demo design method/hardware.

CURRENT STATE OF DEVELOPMENT:

Limited experience has been gained with the Shuttle-orbiter.

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

MSFC - Tumbling Satellite Study

TECHNOLOGY NEEDS FOR THIS CONCEPT:

The key technology required is the close approach control and grapple techniques.

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS: Model and perform software similations - Design and test spacecraft grapple and docking hardware - Design and test simulated satellite in orbit with Shuttle.

ESTIMATED COST AND BASIS OF ESTIMATE: $10M

ESTIMATED SCHEDULE AND BASIS: 3 years

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE: TBD

ESTIMATED CONSEQUENCE OF FAILURE: TBD

CONTACT NAME: Lowell Wiley

TELEPHONE: 206-773-3779

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Spacecraft Maintenance/Servicing Access Provisions

BRIEF DESCRIPTION:

Development of remote activated hardware for moving solar arrays and antennas out of the way to improve maintenance and servicing access.

CURRENT STATE OF DEVELOPMENT: Concepts and hardware technology available.

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

TECHNOLOGY NEEDS FOR THIS CONCEPT: Technology available

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS: Develop concepts - Design, fabricate and test prototypes - Perform ground demonstration.

ESTIMATED COST AND BASIS OF ESTIMATE: $2 Mil

ESTIMATED SCHEDULE AND BASIS: 2 years

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE: TBD

ESTIMATED CONSEQUENCE OF FAILURE: TBD

CONTACT NAME: Gerald Julien

TELEPHONE: 206-773-1894

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Remove and Replace SAMS ORU's

BRIEF DESCRIPTION:

Provide a capability and a means to allow an EVA crewmember to remove and replace failed SAMS orbital replacement units (ORU's) with one tool. The tool will not require excessive workload on the crewmember and will not require SAMSS modular spacecraft ORU's that have been designed for replacement with teleoperated our autonomous robotic systems. The new tool will be light weight and replace the module servicing tool currently in the satellite servicing tool inventory.

CURRENT STATE OF DEVELOPMENT: Preliminary SAMSS concept.

RELATED PROGRAMS/STUDIES/DEVELOPMENTS: GSFC lightweight module tool

TECHNOLOGY NEEDS FOR THIS CONCEPT:

New light weight tool with high torque capabilities
Standard satellite ORU design

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS: Develop SAMSS ORU concept - Design ad fabricate developmental hardware - Refine SAMS EVA procedures - Schedule NBS or WETF and demonstrate capability

ESTIMATED COST AND BASIS OF ESTIMATE: $5 Mil

ESTIMATED SCHEDULE AND BASIS: 3 years

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE: TBD

ESTIMATED CONSEQUENCE OF FAILURE: TBD

CONTACT NAME: Lowell Wiley

TELEPHONE: 206-773-3779

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Autonomous Servicing/Maintenance in High Earth Orbit (HEO)

BRIEF DESCRIPTION:

A relataively autonomous robot servicer will refuel and replace ORU's on HEO satellites (satellites which were designed with this objective). A series of demonstrations to validate this concept are shown on the attached pages. These include a software simulation of the dynamics and commands control system, a ground demonstration of automated refueling/ORU exchange, and finally, a demonstration of refueling/ORU exchange in ORU space (co-orbiting with the shuttle).

CURRENT STATE OF DEVELOPMENT:

Preliminary conceptual designs of services; real-time, autonomous path planning and obstacel avoidance demonstrated in Boeing "flying eye" demonstration

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

Khatib control of robot manipulators (Stanford); "automated" fuel coupling conceptual design (Fairchild)

TECHNOLOGY NEEDS FOR THIS CONCEPT:

Autonomous path planning, autonomous "mission planning.

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS: Mission analysis; Conceptual design of servicer pre-prototype; Coding of robot command & control algorithms; Fabrication of servicer pre-prototype; conceptual des. of an operations prototype; Fabrication of prototype; Ground an on-orbit demonstration.

ESTIMATED COST AND BASIS OF ESTIMATE: $500M Flight Hardware

ESTIMATED SCHEDULE AND BASIS: After "Flying Eye" Development

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE: TBD

ESTIMATED CONSEQUENCE OF FAILURE: TBD

CONTACT NAME: Chris Dunmier

TELEPHONE: 206-773-3416

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Teleoperation Demo of a High Earth Orbit (HEO) Satellite Servicing Robot

BRIEF DESCRIPTION:

Teleoperation of a robot in HEO can be demonstrated in 1-G and Low Earth Orbit (LEO) demonstrations. In the 1-G case, an operator will teleoperate a ground based preprototype servicer to exchange an ORU on a test satellite. In the LEO case, the shuttle would release a prototype servicer and a test satellite from the payload bay, and an operator on board the shuttle would teleoperate the servicer in exchanging an ORU.

CURRENT STATE OF DEVELOPMENT:

Teleoperation of mechanical arms is well established technology. Conceptual studies of robot servicer design underway.

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

Real-time robot control algorithms at Stanford ("Khatib control").

TECHNOLOGY NEEDS FOR THIS CONCEPT:

Real-time control of robot arms.

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS: Mission analyses, preliminary conceptual design, design and fabrication of pre-prototype, design and fabrication of space qualified prototype.

ESTIMATED COST AND BASIS OF ESTIMATE: $100Mil for Ground Demonstration

ESTIMATED SCHEDULE AND BASIS: 4 years Ground Demonstration

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE: TBD

ESTIMATED CONSEQUENCE OF FAILURE: TBD

CONTACT NAME: Chris Dunmier

TELEPHONE: 206-773-3416

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Spacecraft ORU Replacement Interface Concept

BRIEF DESCRIPTION:

Concept, design, and verify ORU replacement interface concept that are compatible with robotic, teleoperator, and EVA maintenance techniques. This includes mechanical engagement/alignment and elect/and fluid interface connect/disconnect.

CURRENT STATE OF DEVELOPMENT:

SAMS study is developing initial concepts, development will proceed in th second phase of the study.

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

NASA/Goddard multi-mission modular spacecraft (MMS) is the first operating on-orbit maintainable satellite system. ORU standardization activities are the key.

TECHNOLOGY NEEDS FOR THIS CONCEPT:

Maintainable system is required that operated robotically or by teleoperation, or both.

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS:
- o Develop concept
- o Demonstrate concepts

ESTIMATED COST AND BASIS OF ESTIMATE: 15M

ESTIMATED SCHEDULE AND BASIS: 3 years

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE: TBD

ESTIMATED CONSEQUENCE OF FAILURE: TBD

CONTACT NAME: Lowell Wiley

TELEPHONE: 206-773-5239

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Rendezvous, Approach, and Docking Concept Demo for a Robot Servicer

BRIEF DESCRIPTION:

A robot satellite servicer (such as a modified Orbit Maneuvering Vehicle (OMV)) operating on Geosynchronous (GEO) based satellites will need to autonomously approach and dock with target satellites. Communication delays to a ground or LEO based human operator makes the traditional teleoperated docking procedure impractical. Rendezvous and docking would be demonstrated in LEO in close proximity to Shuttle-orbiter.

CURRENT STATE OF DEVELOPMENT:

Algorithm development for "automated docking" underway at Jet Propulsion Labs (JPL)

RELATED PROGRAMS/STUDIES/DEVELOPMENTS: See above

TECHNOLOGY NEEDS FOR THIS CONCEPT:

Automated docking algorithms, grappling fixture "grabbers".

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS: Automated doking software development, software simulation of process (dynamics and conrol), 0-G lab demo, co-orbit with Shuttle demo (in LEO).

ESTIMATED COST AND BASIS OF ESTIMATE: $150M

ESTIMATED SCHEDULE AND BASIS: 4 years

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE: TBD

ESTIMATED CONSEQUENCE OF FAILURE: TBD

CONTACT NAME: Chris Dumire

TELEPHONE: 206-773-3416

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: ORU Replacement Demonstration

BRIEF DESCRIPTION:

To demonstrate full scale (on-orbit) spacecraft ORU maintenance under actual operational conditions.

CURRENT STATE OF DEVELOPMENT:

This is dependent upon the successful completion of the following technology elements: robotic ORU replacement concepts; design and develop test system; deploy system on-orbit; perform on-orbit demo.

RELATED PROGRAMS/STUDIES/DEVELOPMENTS: TBD

TECHNOLOGY NEEDS FOR THIS CONCEPT:

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS:

ESTIMATED COST AND BASIS OF ESTIMATE:

ESTIMATED SCHEDULE AND BASIS:

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE:

ESTIMATED CONSEQUENCE OF FAILURE:

CONTACT NAME: Lowell Wiley

TELEPHONE: 206-773-3779

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Post Maintenance On-orbit Spin Balance

BRIEF DESCRIPTION:

Demonstrate on-orbit spin balancing of satellite prior to deploying spacecraft back on-orbit after replacing Apogee Kick Motor (AKM)

CURRENT STATE OF DEVELOPMENT:

A launch spin table is developed for Shuttle-orbiter. This requirement can probably be inegrated into that unit by adding instrumentation and controls.

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

TECHNOLOGY NEEDS FOR THIS CONCEPT: Technology exists

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS: Define methods and design requirements - Develop and test prototype table. Design and qualify production table.

ESTIMATED COST AND BASIS OF ESTIMATE: $20 Mil based on shared mission with existing hardware

ESTIMATED SCHEDULE AND BASIS: 20 months

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE: TBD

ESTIMATED CONSEQUENCE OF FAILURE: TBD

CONTACT NAME: Lowell Wiley

TELEPHONE: 206-773-5239

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: ORU Replacement

BRIEF DESCRIPTION:

Develop a proof of concept (POC) system that is deployed/retrieved by the Shuttle/Orbiter. The principal elements of the POC system are:

1 Remote/autonomous servaicer,
2 Demonstration spacecraft,
3 ORU Spacecraft provisions,
4 Docking system.

The POC test system should be adapted to an existing 3 axis stablized spacecraft bus. The POC would simulate the high orbit servicing cases but performed in LEO in the vicinity of the Shuttle/Orbiter under ground control and ground monitoring (a minimum of two POC test systems would be required) (a zero G demo system should complement development).

CURRENT STATE OF DEVELOPMENT:

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

TECHNOLOGY NEEDS FOR THIS CONCEPT:

Autonomous robotics technology advancement is required for refinement of ORU exchange activities.

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS:
- Develop remote/autonomous servicer ground demo sys.
- Develop a remote/autonomous servicer POC system.
- Develop demonstration spacecraft with ORU provisions.
- Develop servicer/spacecraft docking system.
- Perform orbiter launched/retrieved POC demo.

ESTIMATED COST AND BASIS OF ESTIMATE:

ESTIMATED SCHEDULE AND BASIS:

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE:

ESTIMATED CONSEQUENCE OF FAILURE:

CONTACT NAME: Raj N. Gounder

TELEPHONE: 206-773-8863

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Inertial Upper Stage (IUS) Servicer Platform Development

BRIEF DESCRIPTION:

Use a modified IUS Equipment Support Section (ESS) to prove the concept of the Servicing Platform. For proof of concept, the maneuverability and manipulation capability of a platform must be demonstrated. IUS has sufficient attitude control and avionics capability to enable proof of concept. The requirements would include addition of remote manipulatort systems to the IUS and TV cameras to enable a remote (Shuttle) manned interface. Astronauts could control the operation through the command uplink capability of IUS.

CURRENT STATE OF DEVELOPMENT:

IUS in its current configuration (without solid rocket motors) would be very adaptable. The requirement is addition of battery power for extended operations and a means of transporting it to orbit. Remote manipulators and TV monitor systems exist (RMS).

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

We have investigated applications of IUS as a platform for SDI experiments.

TECHNOLOGY NEEDS FOR THIS CONCEPT: None

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS: Select remote manipulator system, select remote monitor system, select ASE concept for transport, define experinemt to enable power and RCS sizing.

ESTIMATED COST AND BASIS OF ESTIMATE:

Remote manipulator system and monitor systems are TBD. IUS modifications (ASE, structure, qualification) is $30 million, based on a comparable IUS program.

ESTIMATED SCHEDULE AND BASIS:

Schedule for IUS modifications is 30 to 36 months based on comparable type changes on other projects.

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE: Low

ESTIMATED CONSEQUENCE OF FAILURE: Unknown

CONTACT NAME: Raj N. Gounder

TELEPHONE: 206-773-8863

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: IUS Servicer Platform Development (Cont'd)

KEY TECHNOLOGY ISSUES:

1. High to low-level control integration (integrated blackboard architecture with both manipulater/mobility control.
2. Predictive target acquisition for both manipulator and mobility control.
3. 3-D image-understanding for dynamic target acquisition.
4. Highly dexterous wrist control.
5. Highly precise thrust vector control.
6. Distributed processing architecture for contract net control.

SECTION 1

SAMS CONCEPT DEVELOPMENT PROGRAM

CANDIDATE PROGRAM WORKSHEETS

REMOTE ORU CHANGE-OUT

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: ORU Grounding Requirements

BRIEF DESCRIPTION:

The introduction of additional voltage potentials to the work environment will effect spacecraft, servicer, robotics, and manned design requirements. In addition, little data is available in the following areas:

- o Connector - Power On requirements
- o Box grounding during transfer
- o Robot docking grounding requirements
- o Robot arm/ORU/spacecraft grounding requirements

This series of test/analyses to establish criteria for grounding during SAMS events.

CURRENT STATE OF DEVELOPMENT: No data available/No common approach.

RELATED PROGRAMS/STUDIES/DEVELOPMENTS: SCATHE

TECHNOLOGY NEEDS FOR THIS CONCEPT: Existing

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS:

- o Develop environment characteristics
- o Develop hardware requirements

ESTIMATED COST AND BASIS OF ESTIMATE:

2 million over two year

ESTIMATED SCHEDULE AND BASIS:

2 years

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE:

ESTIMATED CONSEQUENCE OF FAILURE:

CONTACT NAME: Tom Styczynski

TELEPHONE: 408-756-6671

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Satellite Capture/Disassembly

BRIEF DESCRIPTION:

Existing satellites, which have reached the end of their useful life, contain a wealth of information on the effects of long duration exposure to space environments. This program will be in three steps:

1) Identification and selection of candidate satellites
2) Developing rendezvous, capture, safing and earth return techniques which lead to plan execution.
3) Satellite disassembly and analysis, including historical record development.

CURRENT STATE OF DEVELOPMENT:

- STS atomic oxygen experiments
- Solar MAX Degradation Study
- LDEF return TBD
- WESTAR/Palapal status
- Space station debris concerns

RELATED PROGRAMS/STUDIES/DEVELOPMENTS: None

TECHNOLOGY NEEDS FOR THIS CONCEPT:

- Capture/Safing techniques

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS: Choose satellite, develop handling technique, simulation development

ESTIMATED COST AND BASIS OF ESTIMATE:

DDT&E $10 MIL EST. + STS Launch - high development cost of handling hardware disassembly/analysis $3 MIL - complete analysis + report

- 3 years from ATP to mission complete
- 1-1/2 years to disassemble - analyze - report

ESTIMATED SCHEDULE AND BASIS: TBD

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE: TBD

ESTIMATED CONSEQUENCE OF FAILURE: 0

CONTACT NAME: Tom Styczynski

TELEPHONE: 408-756-6671

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: EVA Inspector Robot (Flying Eye)

BRIEF DESCRIPTION:

To provide observational assistance to reduce human EVA for servicing, a largely autonomous free flyer which operates in the servicing task area to carry a camera or direct a light is needed. The concept consists of a flying unit which navigates and avoids obstacles autonomously. It also includes the home base support unit and command and control unit. Command and control would use speech recognition and CAD/CAM video directories.

CURRENT STATE OF DEVELOPMENT:

Concept identified. First level dynamic and autonomous navigation simulation developed.

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

TECHNOLOGY NEEDS FOR THIS CONCEPT:

Real time, rule-based path and task planner is needed - Approach and docking - Obstacle avoidance

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS:

Complete simulation - Conduct air-bearing table hardware/software development - Demonstrate on shuttle of Space Station - Operational status.

ESTIMATED COST AND BASIS OF ESTIMATE:

DDT&E - $20 Mil
Flight Hardware - $200M for 2 prototype units
Flight Software - $100 M

ESTIMATED SCHEDULE AND BASIS:

Path planner demonstrated 1988 - First integration of hardware and software 1990 - Functional prototype for demonstration 1992

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE: TBD

ESTIMATED CONSEQUENCE OF FAILURE: TBD

CONTACT NAME: Paul Meyer

TELEPHONE: 206-773-5562

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: OMV/OTV Main Engine Remove and Replace

BRIEF DESCRIPTION:

Provide capability to remove and replace OMV/OTV main engine. Due to the large number of projected flights main engine replacement will be a significant on-orbit maintenance problem

CURRENT STATE OF DEVELOPMENT:

Preliminary concepts - Maintenance platform - Tool kit - Maintenance procedures

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

TECHNOLOGY NEEDS FOR THIS CONCEPT:

Leakproof valves and disconnects - Artificial Intelligence (AI) and robotics technologies to support procedural advisory systems and human EVA replacement systems

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS:

Modularize OMV/OTV main engines - OTV/OMV ORU packages common - Fuel disconnects prevent leaks or spills

ESTIMATED COST AND BASIS OF ESTIMATE: TBD

ESTIMATED SCHEDULE AND BASIS: TBD

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE:

ESTIMATED CONSEQUENCE OF FAILURE:

CONTACT NAME: George Reid

TELEPHONE: 206-773-5180

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Preventative and Corrective Ordinance Resupply

BRIEF DESCRIPTION:

Provide capability for satellite ordinance resupply on a scheduled and unscheduled basis in space. Provide safing, handling, checkout, and arming capability.

CURRENT STATE OF DEVELOPMENT:

No work conducted

RELATED PROGRAMS/STUDIES/DEVELOPMENTS: TBD

TECHNOLOGY NEEDS FOR THIS CONCEPT:

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS: TBD .

ESTIMATED COST AND BASIS OF ESTIMATE: TBD

ESTIMATED SCHEDULE AND BASIS: TBD

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE: TBD

ESTIMATED CONSEQUENCE OF FAILURE:

CONTACT NAME: Lowell Wiley

TELEPHONE: 206-773-5239

(APPEND ANY ADDITIONAL AVAIULABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Rendezvous and Dock with Uncooperative Spacecraft

BRIEF DESCRIPTION:

Develop the control techniques and the grapple/docking hardware to attach and dock to an uncooperative stable satellite. This capability is required to recover near term satellites which require repair, servicing, or return.

- o Demonstrate auto docking/berthing with cooperative satellite.
- o Develop/demo design method/hardware.

CURRENT STATE OF DEVELOPMENT:

Limited experience has been gained with the Shuttle-orbiter.

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

MSFC - Tumbling Satellite Study

TECHNOLOGY NEEDS FOR THIS CONCEPT:

The key technology required is the close approach control and grapple techniques.

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS: Model and perform software similations - Design and test spacecraft grapple and docking hardware - Design and test simulated satellite in orbit with Shuttle.

ESTIMATED COST AND BASIS OF ESTIMATE: $10M

ESTIMATED SCHEDULE AND BASIS: 3 years

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE: TBD

ESTIMATED CONSEQUENCE OF FAILURE: TBD

CONTACT NAME: Lowell Wiley

TELEPHONE: 206-773-3779

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Spacecraft Maintenance/Servicing Access Provisions

BRIEF DESCRIPTION:

Development of remote activated hardware for moving solar arrays and antennas out of the way to improve maintenance and servicing access.

CURRENT STATE OF DEVELOPMENT: Concepts and hardware technology available.

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

TECHNOLOGY NEEDS FOR THIS CONCEPT: Technology available

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS: Develop concepts - Design, fabricate and test prototypes - Perform ground demonstration.

ESTIMATED COST AND BASIS OF ESTIMATE: $2 Mil

ESTIMATED SCHEDULE AND BASIS: 2 years

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE: TBD

ESTIMATED CONSEQUENCE OF FAILURE: TBD

CONTACT NAME: Gerald Julien

TELEPHONE: 206-773-1894

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Remove and Replace SAMS ORU's

BRIEF DESCRIPTION:

Provide a capability and a means to allow an EVA crewmember to remove and replace failed SAMS orbital replacement units (ORU's) with one tool. The tool will not require excessive workload on the crewmember and will not require SAMSS modular spacecraft ORU's that have been designed for replacement with teleoperated our autonomous robotic systems. The new tool will be light weight and replace the module servicing tool currently in the satellite servicing tool inventory.

CURRENT STATE OF DEVELOPMENT: Preliminary SAMSS concept.

RELATED PROGRAMS/STUDIES/DEVELOPMENTS: GSFC lightweight module tool

TECHNOLOGY NEEDS FOR THIS CONCEPT:

New light weight tool with high torque capabilities
Standard satellite ORU design

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS: Develop SAMSS ORU concept - Design ad fabricate developmental hardware - Refine SAMS EVA procedures - Schedule NBS or WETF and demonstrate capability

ESTIMATED COST AND BASIS OF ESTIMATE: $5 Mil

ESTIMATED SCHEDULE AND BASIS: 3 years

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE: TBD

ESTIMATED CONSEQUENCE OF FAILURE: TBD

CONTACT NAME: Lowell Wiley

TELEPHONE: 206-773-3779

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Autonomous Servicing/Maintenance in High Earth Orbit (HEO)

BRIEF DESCRIPTION:

A relataively autonomous robot servicer will refuel and replace ORU's on HEO satellites (satellites which were designed with this objective). A series of demonstrations to validate this concept are shown on the attached pages. These include a software simulation of the dynamics and commands control system, a ground demonstration of automated refueling/ORU exchange, and finally, a demonstration of refueling/ORU exchange in ORU space (co-orbiting with the shuttle).

CURRENT STATE OF DEVELOPMENT:

Preliminary conceptual designs of services; real-time, autonomous path planning and obstacel avoidance demonstrated in Boeing "flying eye" demonstration

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

Khatib control of robot manipulators (Stanford); "automated" fuel coupling conceptual design (Fairchild)

TECHNOLOGY NEEDS FOR THIS CONCEPT:

Autonomous path planning, autonomous "mission planning.

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS: Mission analysis; Conceptual design of servicer pre-prototype; Coding of robot command & control algorithms; Fabrication of servicer pre-prototype; conceptual des. of an operations prototype; Fabrication of prototype; Ground an on-orbit demonstration.

ESTIMATED COST AND BASIS OF ESTIMATE: $500M Flight Hardware

ESTIMATED SCHEDULE AND BASIS: After "Flying Eye" Development

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE: TBD

ESTIMATED CONSEQUENCE OF FAILURE: TBD

CONTACT NAME: Chris Dunmier

TELEPHONE: 206-773-3416

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Teleoperation Demo of a High Earth Orbit (HEO) Satellite Servicing Robot

BRIEF DESCRIPTION:

Teleoperation of a robot in HEO can be demonstrated in 1-G and Low Earth Orbit (LEO) demonstrations. In the 1-G case, an operator will teleoperate a ground based preprototype servicer to exchange an ORU on a test satellite. In the LEO case, the shuttle would release a prototype servicer and a test satellite from the payload bay, and an operator on board the shuttle would teleoperate the servicer in exchanging an ORU.

CURRENT STATE OF DEVELOPMENT:

Teleoperation of mechanical arms is well established technology. Conceptual studies of robot servicer design underway.

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

Real-time robot control algorithms at Stanford ("Khatib control").

TECHNOLOGY NEEDS FOR THIS CONCEPT:

Real-time control of robot arms.

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS: Mission analyses, preliminary conceptual design, design and fabrication of pre-prototype, design and fabrication of space qualified prototype.

ESTIMATED COST AND BASIS OF ESTIMATE: $100Mil for Ground Demonstration

ESTIMATED SCHEDULE AND BASIS: 4 years Ground Demonstration

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE: TBD

ESTIMATED CONSEQUENCE OF FAILURE: TBD

CONTACT NAME: Chris Dunmier

TELEPHONE: 206-773-3416

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Spacecraft ORU Replacement Interface Concept

BRIEF DESCRIPTION:

Concept, design, and verify ORU replacement interface concept that are compatible with robotic, teleoperator, and EVA maintenance techniques. This includes mechanical engagement/alignment and elect/and fluid interface connect/disconnect.

CURRENT STATE OF DEVELOPMENT:

SAMS study is developing initial concepts, development will proceed in th second phase of the study.

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

NASA/Goddard multi-mission modular spacecraft (MMS) is the first operating on-orbit maintainable satellite system. ORU standardization activities are the key.

TECHNOLOGY NEEDS FOR THIS CONCEPT:

Maintainable system is required that operated robotically or by teleoperation, or both.

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS:
- o Develop concept
- o Demonstrate concepts

ESTIMATED COST AND BASIS OF ESTIMATE: 15M

ESTIMATED SCHEDULE AND BASIS: 3 years

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE: TBD

ESTIMATED CONSEQUENCE OF FAILURE: TBD

CONTACT NAME: Lowell Wiley

TELEPHONE: 206-773-5239

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Rendezvous, Approach, and Docking Concept Demo for a Robot Servicer

BRIEF DESCRIPTION:

A robot satellite servicer (such as a modified Orbit Maneuvering Vehicle (OMV)) operating on Geosynchronous (GEO) based satellites will need to autonomously approach and dock with target satellites. Communication delays to a ground or LEO based human operator makes the traditional teleoperated docking procedure impractical. Rendezvous and docking would be demonstrated in LEO in close proximity to Shuttle-orbiter.

CURRENT STATE OF DEVELOPMENT:

Algorithm development for "automated docking" underway at Jet Propulsion Labs (JPL)

RELATED PROGRAMS/STUDIES/DEVELOPMENTS: See above

TECHNOLOGY NEEDS FOR THIS CONCEPT:

Automated docking algorithms, grappling fixture "grabbers".

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS: Automated doking software development, software simulation of process (dynamics and conrol), 0-G lab demo, co-orbit with Shuttle demo (in LEO).

ESTIMATED COST AND BASIS OF ESTIMATE: $150M

ESTIMATED SCHEDULE AND BASIS: 4 years

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE: TBD

ESTIMATED CONSEQUENCE OF FAILURE: TBD

CONTACT NAME: Chris Dumire

TELEPHONE: 206-773-3416

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: ORU Replacement Demonstration

BRIEF DESCRIPTION:

To demonstrate full scale (on-orbit) spacecraft ORU maintenance under actual operational conditions.

CURRENT STATE OF DEVELOPMENT:

This is dependent upon the successful completion of the following technology elements: robotic ORU replacement concepts; design and develop test system; deploy system on-orbit; perform on-orbit demo.

RELATED PROGRAMS/STUDIES/DEVELOPMENTS: TBD

TECHNOLOGY NEEDS FOR THIS CONCEPT:

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS:

ESTIMATED COST AND BASIS OF ESTIMATE:

ESTIMATED SCHEDULE AND BASIS:

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE:

ESTIMATED CONSEQUENCE OF FAILURE:

CONTACT NAME: Lowell Wiley

TELEPHONE: 206-773-3779

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Post Maintenance On-orbit Spin Balance

BRIEF DESCRIPTION:

Demonstrate on-orbit spin balancing of satellite prior to deploying spacecraft back on-orbit after replacing Apogee Kick Motor (AKM)

CURRENT STATE OF DEVELOPMENT:

A launch spin table is developed for Shuttle-orbiter. This requirement can probably be inegrated into that unit by adding instrumentation and controls.

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

TECHNOLOGY NEEDS FOR THIS CONCEPT: Technology exists

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS: Define methods and design requirements - Develop and test prototype table. Design and qualify production table.

ESTIMATED COST AND BASIS OF ESTIMATE: $20 Mil based on shared mission with existing hardware

ESTIMATED SCHEDULE AND BASIS: 20 months

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE: TBD

ESTIMATED CONSEQUENCE OF FAILURE: TBD

CONTACT NAME: Lowell Wiley

TELEPHONE: 206-773-5239

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: ORU Replacement

BRIEF DESCRIPTION:

Develop a proof of concept (POC) system that is deployed/retrieved by the Shuttle/Orbiter. The principal elements of the POC system are:

1 Remote/autonomous servaicer,
2 Demonstration spacecraft,
3 ORU Spacecraft provisions,
4 Docking system.

The POC test system should be adapted to an existing 3 axis stablized spacecraft bus. The POC would simulate the high orbit servicing cases but performed in LEO in the vicinity of the Shuttle/Orbiter under ground control and ground monitoring (a minimum of two POC test systems would be required) (a zero G demo system should complement development).

CURRENT STATE OF DEVELOPMENT:

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

TECHNOLOGY NEEDS FOR THIS CONCEPT:

Autonomous robotics technology advancement is required for refinement of ORU exchange activities.

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS:
- Develop remote/autonomous servicer ground demo sys.
- Develop a remote/autonomous servicer POC system.
- Develop demonstration spacecraft with ORU provisions.
- Develop servicer/spacecraft docking system.
- Perform orbiter launched/retrieved POC demo.

ESTIMATED COST AND BASIS OF ESTIMATE:

ESTIMATED SCHEDULE AND BASIS:

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE:

ESTIMATED CONSEQUENCE OF FAILURE:

CONTACT NAME: Raj N. Gounder

TELEPHONE: 206-773-8863

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Inertial Upper Stage (IUS) Servicer Platform Development

BRIEF DESCRIPTION:

Use a modified IUS Equipment Support Section (ESS) to prove the concept of the Servicing Platform. For proof of concept, the maneuverability and manipulation capability of a platform must be demonstrated. IUS has sufficient attitude control and avionics capability to enable proof of concept. The requirements would include addition of remote manipulatort systems to the IUS and TV cameras to enable a remote (Shuttle) manned interface. Astronauts could control the operation through the command uplink capability of IUS.

CURRENT STATE OF DEVELOPMENT:

IUS in its current configuration (without solid rocket motors) would be very adaptable. The requirement is addition of battery power for extended operations and a means of transporting it to orbit. Remote manipulators and TV monitor systems exist (RMS).

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

We have investigated applications of IUS as a platform for SDI experiments.

TECHNOLOGY NEEDS FOR THIS CONCEPT: None

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS: Select remote manipulator system, select remote monitor system, select ASE concept for transport, define experinemt to enable power and RCS sizing.

ESTIMATED COST AND BASIS OF ESTIMATE:

Remote manipulator system and monitor systems are TBD. IUS modifications (ASE, structure, qualification) is $30 million, based on a comparable IUS program.

ESTIMATED SCHEDULE AND BASIS:

Schedule for IUS modifications is 30 to 36 months based on comparable type changes on other projects.

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE: Low

ESTIMATED CONSEQUENCE OF FAILURE: Unknown

CONTACT NAME: Raj N. Gounder

TELEPHONE: 206-773-8863

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: IUS Servicer Platform Development (Cont'd)

KEY TECHNOLOGY ISSUES:

1. High to low-level control integration (integrated blackboard architecture with both manipulater/mobility control.
2. Predictive target acquisition for both manipulator and mobility control.
3. 3-D image-understanding for dynamic target acquisition.
4. Highly dexterous wrist control.
5. Highly precise thrust vector control.
6. Distributed processing architecture for contract net control.

APPENDIX A

SECTION 2.0

SAMS CONCEPT DEVELOPMENT PROGRAM

CANDIDATE PROGRAM WORKSHEETS

LARGE SYSTEM ASSEMBLY

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Voice Dynamic Retraining

BRIEF DESCRIPTION:

This capability enables voice templates of the user to be automatically updated in real-time thus increasing the reliability of voice recognition. Introduce this capability to voice recognition devices when used by the crew as a means to perform information access from the electronic documentation system.

CURRENT STATE OF DEVELOPMENT:

Few voice recognizers have the capability to automatically update their stored voice templates of the user in real-time.

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

TECHNOLOGY NEEDS FOR THIS CONCEPT: None know to date.

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS:

ESTIMATED COST AND BASIS OF ESTIMATE:

ESTIMATED SCHEDULE AND BASIS:

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE:

ESTIMATED CONSEQUENCE OF FAILURE:

CONTACT NAME: Anne Schur

TELEPHONE: 612/782-7395

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Intelligent Trainers

BRIEF DESCRIPTION:

Capability to provide knowledge of the system being serviced and maintained by crew. Thus crew will be able to problem solve and improvise when in a situation which they have "never done before."

CURRENT STATE OF DEVELOPMENT:

None can represent students' knowledge or the model they have of the device or system.

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

TECHNOLOGY NEEDS FOR THIS CONCEPT:

Computer should support graphics and a variety of continuous input devices.

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS:

ESTIMATED COST AND BASIS OF ESTIMATE:

ESTIMATED SCHEDULE AND BASIS:

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE:

ESTIMATED CONSEQUENCE OF FAILURE:

CONTACT NAME: Anne Schur

TELEPHONE: 612/782-7395

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: High Density Storage

BRIEF DESCRIPTION:

This technology is a compact durable software storage medium. Its utility to electronic documentation for SAMS application will be investigated and demonstrated as (a) single storage medium and (b) as storage medium in conjunction with others.

CURRENT STATE OF DEVELOPMENT:

- o Drexler card has read-only capability. Read and write capability expected 1988.
- o Compact discs

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

Fast developing storage medium in development by commercial USA and Japanese vendors. Honeywell currently holds license to use Drexler card technology and is investigating its application to electronic documentation.

TECHNOLOGY NEEDS FOR THIS CONCEPT:

Read and write capability is preferable, but read-only and read-only write-once capability will also be useful.

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS:

ESTIMATED COST AND BASIS OF ESTIMATE:

ESTIMATED SCHEDULE AND BASIS:

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE:

ESTIMATED CONSEQUENCE OF FAILURE:

CONTACT NAME: Anne Schur

TELEPHONE: 612/782-7395

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Smart Diagnostics

BRIEF DESCRIPTION:

An expert system assists the crewmember performing troubleshooting and maintenance.

CURRENT STATE OF DEVELOPMENT:

Many available. The number which have true knowledge based systems is small but is growing.

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

TECHNOLOGY NEEDS FOR THIS CONCEPT:

Equipment capable of supporting graphics, high level programming language, alternate input devices. Access to subject matter expert(s).

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS:

ESTIMATED COST AND BASIS OF ESTIMATE:

ESTIMATED SCHEDULE AND BASIS:

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE:

ESTIMATED CONSEQUENCE OF FAILURE:

CONTACT NAME: Anne Schur

TELEPHONE: 612/782-7395

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Portable Job Performance Aids

BRIEF DESCRIPTION:

Provide job performance aiding and training capabilities to crew.

CURRENT STATE OF DEVELOPMENT:

See prior and current technology review deliverables.

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

See prior and current technology review deliverables.

TECHNOLOGY NEEDS FOR THIS CONCEPT:

Software architecture to handle huge amount of information. Information processing.

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS:

ESTIMATED COST AND BASIS OF ESTIMATE:

ESTIMATED SCHEDULE AND BASIS:

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE:

ESTIMATED CONSEQUENCE OF FAILURE:

CONTACT NAME: Anne Schur

TELEPHONE: 612/782-7395

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Voice Actuated Control of MMU

BRIEF DESCRIPTION:

Provide capability to evaluate the potential utilization of a voice actuated control maneuvering system for the manned maneuvering unit (MMU). The MMU will be maneuvered in six degrees-of-freedom by the utilization of voice actuated commands. This system would allow the MMU hand controllers to remain in the stowed configuration and allow hands free for 2-handed servicing tasks and manual translation operations).

CURRENT STATE OF DEVELOPMENT:

Voice recognition cards are available. Microprocessors for controlling system are available. Neutral Buoyancy (NBS) MMU is available.

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

TECHNOLOGY NEEDS FOR THIS CONCEPT: Interface card

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS:
Develop interface card - Develop control software - Assemble system - Conduct NBS tests

ESTIMATED COST AND BASIS OF ESTIMATE: $10M

ESTIMATED SCHEDULE AND BASIS: 3 years

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE:

ESTIMATED CONSEQUENCE OF FAILURE:

CONTACT NAME: Bob Horne

TELEPHONE: 773-5564

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Large Structure Attachment Method Evaluation

BRIEF DESCRIPTION:

Provide the capability to evaluate methods for attaching large structures to satellites as part of the servicing process. Possible attachment points include docking fittings or special attachment points built into the satellite. Candidate procedures for attachment include the remote manipulator system (RMS) or the use of the capabilities of EVA astronauts. The subject of this study is to investigate the procedures required of extravehicular activity (EVA) astronauts to attach a trus structure to a pressurized module using one or two of the attachment techniques mentioned above.

CURRENT STATE OF DEVELOPMENT:

- o Neutral Buoyancy System (NBS) hardware is available at Boeing-Huntsville
- o NBS procedures available

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

TECHNOLOGY NEEDS FOR THIS CONCEPT: None

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS: o Schedule NBS or WETF (If WETF is used, hardware must be shipped from Boeing-Huntsville)

ESTIMATED COST AND BASIS OF ESTIMATE: $500K

ESTIMATED SCHEDULE AND BASIS: 6 months

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE:

ESTIMATED CONSEQUENCE OF FAILURE:

CONTACT NAME: Richard Gates

TELEPHONE: 773-5179

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Maneuvering Enclosure Unit (EVA Pod)

BRIEF DESCRIPTION:

Satellite servicing when the satellites are in polar or high altitude orbits requires a robust enclosure unit for human EVA when the ;servicing needs are frequent and repetitive EVA versatility is needed. An enclosure unit which combines features of the current Shuttle EMU and MMU with advanced robotics manipulator-end-effector technology is needed.

CURRENT STATE OF DEVELOPMENT: Concept identified

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

TECHNOLOGY NEEDS FOR THIS CONCEPT:

Manipulator and end effector, Obstacle avoidance, Tactile feedback and force feedback.

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS:

End effector design and demonstration - Manipulator design and demonstration - Obstacle avoidance development - Integrated prototype demonstration.

ESTIMATED COST AND BASIS OF ESTIMATE:

Hardware $150M for 2 prototype units
Software $100M

ESTIMATED SCHEDULE AND BASIS: (Based on immediate start)

End effector/manipulator demonstrated (1993)
Obstacle evidence integrated into demo (1995)
Integrated prototype units ready for demo (1996)

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE:

ESTIMATED CONSEQUENCE OF FAILURE:

CONTACT NAME: Paul Meyer

TELEPHONE: 773-5562

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Remove/Repair/Replace Mechanical/Structural Components

BRIEF DESCRIPTION:

To provide the capability for an EVA crewmember to remove, repair, or replace mechanical components such as solar panels, antennas and satellite structure.

CURRENT STATE OF DEVELOPMENT:

Preliminary SAMSS concept

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

TECHNOLOGY NEEDS FOR THIS CONCEPT:

Std. satellite appendage hinge and actuator design reqmts. - Structural repair reqmts. - Standard satellite tool requirements.

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS:

Develop SAMS concept - Design and fabricate developmental hardware - Refine SAMS EVA procedures - Schedule NBS or WETF and demonstrate capability.

ESTIMATED COST AND BASIS OF ESTIMATE: TBD

ESTIMATED SCHEDULE AND BASIS: TBD

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE:

ESTIMATED CONSEQUENCE OF FAILURE:

CONTACT NAME:

TELEPHONE:

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: EVA Assisted Servicing Tools

BRIEF DESCRIPTION:

Develop tools to provide the capability for a EVA crewmember to service satellites with depleted fuel supplies. The capability allows the EVA crewmember to be in a remote location during toxic fuel transfer operations.

CURRENT STATE OF DEVELOPMENT:

Preliminary SAMS concept.

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

TECHNOLOGY NEEDS FOR THIS CONCEPT:

Standardize servicing tools and equipment
Standardize satellite fuel transfer interface equipment

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS:

Develop SAMS concept - Design and fabricate developmental hardware - Refine SAMS EVA procedures - Schedle NBS or WETF and demonstrate capability

ESTIMATED COST AND BASIS OF ESTIMATE: TBD

ESTIMATED SCHEDULE AND BASIS: TBD

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE:

ESTIMATED CONSEQUENCE OF FAILURE:

CONTACT NAME:

TELEPHONE:

(APPEND ANY ADDITIONAL AVAILABLE DATA)

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APPENDIX A

SECTION 3.0

SAMS CONCEPT DEVELOPMENT PROGRAM

CANDIDATE PROGRAM WORKSHEETS

BIPROPELLANT TANKER SYSTEM

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Propellant Transfer

BRIEF DESCRIPTION:

Develop capability to refuel SV remotely. Dut to the satety related problems of the fuel, equipment and procedures need to be developed to eliminate fuel leaks and spills.

CURRENT STATE OF DEVELOPMENT:

Prototype triple seal values have been built.
Propellant transfer was demonstrated on STS.
Tools are available in current STS tools kits.

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

TECHNOLOGY NEEDS FOR THIS CONCEPT:

Refueling station - Leakproof disconnect - Develop robotic system to remove man from loop

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS:

Complete valve design - Develop leak and spill proof disconnects - Develop refueling procedures - Evolve to robotics capability

ESTIMATED COST AND BASIS OF ESTIMATE: $200M

ESTIMATED SCHEDULE AND BASIS: 6 years

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE:

ESTIMATED CONSEQUENCE OF FAILURE:

CONTACT NAME: George Reid

TELEPHONE: 773-5180

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Spacecraft Propellant/Pressurant Servicing Demonstration

BRIEF DESCRIPTION:

Demonstrate near term propellant/pressurant servicing with a simulated spacecraft structural replica incorporating on-orbit spacecraft system features. This demo will simulate GEO operations.

CURRENT STATE OF DEVELOPMENT:

The servicing interfaces have been developed and tested.

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

TECHNOLOGY NEEDS FOR THIS CONCEPT:

Software controlled robotic servicing control hardware technology must be developed.

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS:

Design and develop on-oribt simulator; Demonstrate operation in ground demonstration; Test in Shuttle-orbiter bay simulating GEO operation.

ESTIMATED COST AND BASIS OF ESTIMATE: $20M

ESTIMATED SCHEDULE AND BASIS: 3 years

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE:

ESTIMATED CONSEQUENCE OF FAILURE:

CONTACT NAME: Lowell Wiley

TELEPHONE: 773-5239

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SECTION 4.0

SAMS CONCEPT DEVELOPMENT PROGRAM

CANDIDATE PROGRAM WORKSHEETS

CRYOGENIC TANKER SYSTEM

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Cryogenic Replenishment

BRIEF DESCRIPTION:

On-orbit resupply of subcritical cryogenic fluids (propellants, reactants, coolants, and life-support fluids) depends on special techniques for acquiring and transferring fluids on low gravity, controlling the pressure of both the supply and receiver tanks, and monitoring the process. For efficient resupply, improvements in tankage and thermal control systems will be needed.

CURRENT STATE OF DEVELOPMENT:

Candidate systems have been analyzed and ground-tested. Low-G tests of reasonable scale and duration have not been performed.

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

Cryogenic Fluid Management Flight Experiment (CFMFE): Proposed by NASA-LeRC, this is an integrated orbital test and demonstration of these technologies. Other component technology development programs are underway, planned, or proposed.

TECHNOLOGY NEEDS FOR THIS CONCEPT:

Improved thermal protection, tank pressure control, pressurization, liquid acquisition, childown, transfer, tank fill, and monitoring systems.

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS:
(1) Ground-based development and demonstration of component technologies.
(2) Development and orbital test of the CFMFE.

ESTIMATED COST AND BASIS OF ESTIMATE:

STEP (1) = \$ 35M (estimated total cost of currently-unfunded component development programs)
STEP (2) = \$267M (from NASA-LeRC briefing - not yet funded; needs support and augmentation)

\$302M Total

ESTIMATED SCHEDULE AND BASIS:

Technologies will be developed and demonstrated in space by end of 1992 if funds are allocated as proposed.

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE: 1%

ESTIMATED CONSEQUENCE OF FAILURE:

If proposed techniques prove unworkable, less efficient/desirable methods are available (e.g., propulsive settling of fluids)

CONTACT NAME: Raj N. Grounder

TELEPHONE: 773-8863

(APPEND ANY ADDITIONAL AVAILABLE DATA)

APPENDIX A

SECTION 5.0

SAMS CONCEPT DEVELOPMENT PROGRAM

CANDIDATE PROGRAM WORKSHEETS

COMPLIMENTARY TECHNOLOGIES

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Logistics Facilities Study

BRIEF DESCRIPTION: This study will analyze and consolidate logistics facility requirements for space systems. The study will identify current capabilities for both DoD and NASA, and develop plans and procedures for optimizing depot support to space systems.

CURRENT STATE OF DEVELOPMENT:

Studies have been conducted on KSC capabilities and future needs, but studies to date have not considered sharing resources/capabilities between NASA and DoD.

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

Space Station, OSSA Payloads

TECHNOLOGY NEEDS FOR THIS CONCEPT: N/A

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS:

Analyze existing capabilities, consolidate requirements, establish areas of responsibility, share resources/capabilities, prepare plans and procedures.

ESTIMATED COST AND BASIS OF ESTIMATE:

3 Man-year effort - similar logistics analysis experience.

ESTIMATED SCHEDULE AND BASIS:

1 Year - similar logistics analysis experience.

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE: N/A

ESTIMATED CONSEQUENCE OF FAILURE:

CONTACT NAME: T. Palguta

TELEPHONE: (205)837-1800

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: "Sparing to Availability" Model

BRIEF DESCRIPTION:

The model determines optimum spares requirements for space systems through consideration of the following factors: unit cost, critically, failure rate, quality, location, weight, volume, redundancy, packaging, repair turnaround time, levels of fault detection/isolation, unique subsystem criteria, maintenance mission frequency and capability.

CURRENT STATE OF DEVELOPMENT:

Generic models are available.

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

Space Station

TECHNOLOGY NEEDS FOR THIS CONCEPT: N/A

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS:

Develop a generic model, analyze special space system considerations, tailor model for application to different categories of space systems.

ESTIMATED COST AND BASIS OF ESTIMATE:

1 Man-year effort - similar logistics analyses

ESTIMATED SCHEDULE AND BASIS:

1 Year - similar model developments

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE:

ESTIMATED CONSEQUENCE OF FAILURE:

CONTACT NAME: T. Palguta

TELEPHONE: (205)837-1800

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Functional Analysis and Requirements Allocation Modeling

BRIEF DESCRIPTION:

Involves the translation of established system-level requirements into detailed qualitative and quantitative design requirements for the proposed system. This preliminary analysis will be used to modify the design requirements to meet the supportability resources available.

CURRENT STATE OF DEVELOPMENT:

Proven conceptually, however the methods and models used to accomplish the result seem to raise controversy. There are techniques accepted by DoD and others by NASA.

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

MIL-STD-1388-1A/2A, MIL-STD 765B, MIL-STD-721C
MIL-STD-785B, HST Reliability (SPATEL) model.

TECHNOLOGY NEEDS FOR THIS CONCEPT:

Continue refinement of part stress analysis failure predictions. The ability to qualify and highlight stress in components is a continuing technology effort.

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS:

Include supportability as a major criteria at PDR. Establish methods and responsibilities for government and contractor management organizations.

ESTIMATED COST AND BASIS OF ESTIMATE:

2 Man-Year effort - similar logistics studies.

ESTIMATED SCHEDULE AND BASIS:

1 Year - similar logistics studies.

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE: N/A

ESTIMATED CONSEQUENCE OF FAILURE:

CONTACT NAME: Will Bradley

TELEPHONE: (205)837-1800

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Functional Analysis and Requirements Allocation Modeling

BRIEF DESCRIPTION:

Involves the translation of established system-level requirements into detailed qualitative and quantitative design requirements. These requirements must then be evaluated for their effect on the supportability requirements for the proposed system. This preliminary analysis will be used to modify the design requirements to meet the supportabilty resources available.

CURRENT STATE OF DEVELOPMENT:

Proven conceptually, however the methods and models used to accomplish the result seem to raise controversy. There are techniques accepted by DoD and others by NASA.

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

MIL-STD-1388-1A/2A, MIL-STD-765B, MIL-STD-721C
MIL-STD-795B, HST Reliability (SPATEL) model.

TECHNOLOGY NEEDS FOR THIS CONCEPT:

Continue refinement of part stress analysis failure predictions. The ability to qualitify and highlight stress in compoents is a continuing technology effort.

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS:

Include supportability as a major criteria at PDR. Establish methods and responsibilities for government and contractor management organizations.

ESTIMATED COST AND BASIS OF ESTIMATE:

2 Man-year effort - similar logistics studies.

ESTIMATED SCHEDULE AND BASIS:

1 Year - similar logistics studies.

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE: N/A

ESTIMATED CONSEQUENCE OF FAILURE:

CONTACT NAME: Will Bradley

(APPEND ANY ADDITIONAL AVAILABLE DATA)

TELEPHONE: (205)837-1800

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Facilities Decision Tree for Space Hardware Support

BRIEF DESCRIPTION:

This concept uses the same approach to identification of facility requirements as conventional methods except that it adds considerations for hardware support requirements for items used in a space environment and adds additional considerations for the two exceptions to conventional facilities selection and design, space transport system and orbital platform servicing facilities.

CURRENT STATE OF DEVELOPMENT:

The groundrules are identified, normal facilities considerations are outlined and additional peculiar aspects for space support facility requirements have been identified. The decision tree is in the process of becoming part of a computer model which will be used as a tool for facility decisions.

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

The Hubble Space Teslescope, some preliminary work on AXAF, and the Space Station studies provide the basis for this effort.

TECHNOLOGY NEEDS FOR THIS CONCEPT:

Design of the orbital maneuvering vehicle, heavy cargo lifting vehicle, and concept finalization for a space logistic support modules.

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS:

1. Refine requirements for space hardware support facilities.
2. Computer cost estimates for space peculiar facility requirements.
3. Update conventional facility cost drivers.
4. Assign degradation factors and tradeoffs which apply to use of existing facilities.

ESTIMATED COST AND BASIS OF ESTIMATE: 1 Man-year effort - similar logistics analyses.

ESTIMATED SCHEDULE AND BASIS: 1 Year - similar logistics analysis.

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE:

ESTIMATED CONSEQUENCE OF FAILURE:

CONTACT NAME: L. Rizzo

(APPEND ANY ADDITIONAL AVAILABLE DATA)

TELEPHONE: (205) 837-1800

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Space Environment Simulation and Engineering Laboratory

BRIEF DESCRIPTION:

LMSC proposes to develop an engineering and simulation laboratory dedicated to designing and analyzing SAMS spacecraft/hardware and performance in a space environment. Computer aided engineering and analytical simulation technologies will be evaluated an integrated into a common data base. Spacecraft performance and operational scenarios will be displayed on a large color graphic wall screen. As a minimum, analytical capabilities will include structural analysis, thermal analysis, rigid body controllability, orbit analysis, timeline analysis, six degree of freedom simulation, solar pressure environment loading analysis, mechanism analysis, inertia properties, docking analysis, plume impingement, ECLSS and solid modeling analysis.

CURRENT STATE OF DEVELOPMENT:

LMSC can provide the engineering and simulation facility. Computer aided engineering and analytical simulation technology need integration into a common data base. Software, Hardware and display screen will need to be procured.

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

Space Station

TECHNOLOGY NEEDS FOR THIS CONCEPT: None

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS:
1. Establish requirements.
2. Develop facility and integrate software/hardware.
3. Design and develop test and simulation run.

ESTIMATED COST AND BASIS OF ESTIMATE:

$1.6 Mil; estimate $500K in software/hardware costs, remainder for system engineering and integration.

ESTIMATED SCHEDULE AND BASIS:

Two years. Similar LMSC development activity.

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE: N/A

ESTIMATED CONSEQUENCE OF FAILURE: N/A

CONTACT NAME: Tony Lusting

(APPEND ANY ADDITIONAL AVAILABLE DATA)

TELEPHONE: (408) 756-8332

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Neutral Buoyancy Test Program

BRIEF DESCRIPTION:

Space Shuttle crew training, EVA hardware evaluation and procedures development are activites which are conducted using neutral buoyancy simulations. This environment provides an excellent correlation to the actual conditions one experiences during EVA in space. NASA astronauts are required to complete some 44 courses in EVA operations and acquire some 50+ hours of EVA suit time before qualified to represet EVA technology. The MSE SAMS integration team would benefit significantly by undertaking a similar program. The purpose of this PDC is to develop and conduct a SAMS neutral buoyancy test program which maximizes the use of the available facilities and hardware. Recommended SAMS concepts will be evaluated and tested during this program.

CURRENT STATE OF DEVELOPMENT:

Facilities exist for NB testing. Existing NB hardware configuration requires modification to SAMS concepts. New hardware design concepts will be selected and tested to maximize benefits to SDI and related programs.

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

Space Station, ESA, STS EVA flights.

TECHNOLOGY NEEDS FOR THIS CONCEPT:

Current and those identified in the SAMSS.

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS:
1. Develop NB test program.
2. Design, develop and manufacture NB test hardware.
3. Conduct tests and evaluate results.

ESTIMATED COST AND BASIS OF ESTIMATE:

$2.1 Mil, based upon 20 NB tests for a minimum period of one week each.

ESTIMATED SCHEDULE AND BASIS:

Two years; Scheduled tests could use two neutral buoyancy facilities.

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE: N/A

ESTIMATED CONSEQUENCE OF FAILURE: N/A

CONTACT NAME: Tony Lustig

(APPEND ANY ADDITIONAL AVAILABLE DATA)

TELEPHONE: (408) 756-8332

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Mission Specialist Engineering (MSE) SAMS Training Development

BRIEF DESCRIPTION:

AS the SAMS concept reaches the operational phase the Air Force will require a staff of key people to follow the implementation of program requirements. The MSE's can play a key role in this implementation if their training is enhanced to develop the necessary skills . The purpose of this POC is to do an in-depth analysis of crew/MSE training to establish new training requirements to assist in SAMS implementation.

CURRENT STATE OF DEVELOPMENT:

MSE training seems limited and pragmented resulting in a high MSE turnover.

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

MSE Training manual

TECHNOLOGY NEEDS FOR THIS CONCEPT:

Analysis

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS: Obtain training documentation, interview all MSE's (past/ current)

ESTIMATED COST AND BASIS OF ESTIMATE:

$500K to complete a review of training status and direct training = 2 men for 1 year + travel

ESTIMATED SCHEDULE AND BASIS:

1 year from ATP

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE: 0

ESTIMATED CONSEQUENCE OF FAILURE:

SAMS concept will have not internal AF review capability

CONTACT NAME: Thomas F. Styczynski

TELEPHONE: 408/756-6671

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Develop Standards for Suited Subject Force/Reach

BRIEF DESCRIPTION:
The force/reach data in various NASA/Government Standards documents is outdated and often conflicting. This POC will develop a single standard based on strict test criteria which will incompass the requirements established on the attachment. The results of this test will reduce spacecraft and ORU design constraints by establishing a firm criteria for loads. (Cont. next page)

CURRENT STATE OF DEVELOPMENT:

Current criteria out dated RIF NASA JSC 10615-MSFC512A

RELATED PROGRAMS/STUDIES/DEVELOPMENTS: None

TECHNOLOGY NEEDS FOR THIS CONCEPT:

Current and new technology suits.

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS:

- o Define criteria
- o Design tests
- o Develop simulation hardware
- o Establish schedule for activity integration

ESTIMATED COST AND BASIS OF ESTIMATE:

$2 M for ground test and analysis
- o Flight test equate to extra cost?NB + KC135 GFE

ESTIMATED SCHEDULE AND BASIS:

2 years - for ground test and analysis
+ 2 years - flight TRST option

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE: 0

ESTIMATED CONSEQUENCE OF FAILURE:

SAMS requires standardization of data.

CONTACT NAME: Thomas E. Styczynski

TELEPHONE: 408/756-6671

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

BRIEF DESCRIPTION: (Cont'd)

Suited subject Force/Reach Standard Development

Test Requirements Criteria

- o Test subjects must represent a propullation of 5th to 95th percentile males and females *
- o Test results must show correlation between IG, OG and neutral buoyancy data
- o The loads data must record the following characteristics for suited and unsuited subjects in IG, OG and NB environments
  - Hand grip
  - Finger grip
  - Foot forces
  - Foot restraint under worn loads
  - Force durations
- o Design loads for ORU's must record the following characteristics
  - Mass versus handling characteristics
  - Impact loads produced by crew/robot
  - Crew aid attachment loads
  - Robotic interface loads
- o Develop criteria for inadverdant crew damage
- o Establish crew/ORU tether loads
- o Establish a firm policy for analysis versus TRST to safety factors.

*Range subjects to cost trade

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Spacecraft Software Maintenance

BRIEF DESCRIPTION:

The spacecraft software maintenance proof of concept will address two maintenance concepts for changing/enhancing/maintaining software after deployment into space:

(1) physical software maintenance:
  (a) through removal/replacement of software ORUs by an EVA maintenance team
  (b) through physical computer interface with the spacecraft via a computer interface port with the Orbiter
(2) remote software maintenance:
  (a) through a communications link between the spacecraft and the space station maintenance facility
  (b) through a communications link between the spacecraft and dedicated earth bound software maintenance facility

Each of these software maintenance concepts provide specific mission and maintenance benefits, but are driven by the architecture and characteristics of the spacecraft's computer memory.

Read Only Memory (ROM) and Random Access Memory (RAM) characteristics of the software are the determining factors which drive the maintenance approach. ROM software can be "powered down" and is "hard wired", such that the software can not be erased or changed unless physically replaced. ROM is slow is processing and occupies much more physical space than RAM, but is designed for mission critical software for fail operation/fail safe measures. RAM, on the other hand, is faster is processing capabilities and can be changed through telecommunication, but if "powered down" the software is not retained. Currently, spacecraft download ROM into RAM to expedite processing, and maintain the ROM in case of system failure for safety and further mission operation. The means for maintenance of software will be based around these memory attributes.

This proof of concpet will develop and demonstrate design approaches and maintenance planning for ROM and RAM by application of the two defined maintenance concepts (i.e., physical maintenance and remote maintenance):

ROM

ROM will require physical maintenance through ORU change out capability. To date, no spacecraft has been designed with this capability. The ROM software currently is subjected to extensive testing prior to deployment. If errors are discovered after deployment they are worked around, if possible, by RAM, and no enhancements are capable of being made. This proof of concept will analyses the spacecrat ROM configurations and design an ORU to accommodate ROM for EVA removal and replacement. Additional maintenance procedures, requirements and specifications will be defined for this type of software maintenance.

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Spacecraft Software Maintenance (Cont'd)

RAM

RAM can be altered through physical or remote maintenance techniques. To date, RAM is changed through telecommunication links (remote maintenance technique), but has not been changed via physical hardware replacement or data link interface. This proof of concept will analye RAM and present the maintenance planning and design for changing RAM by: (1) physical ORU changeout; (2) physical Orbiter interface via a computer data port link-up; (3) remote space station maintenance facility telecommunications: and (4) earth bound maintenance facility telecommunications.

Each of the maintenance concept options have specific mission and maintenance attributes. These attributes may be the determining factor in maintenance concept selection for specific spacecraft mission scenarios. The attributes are: cost; speed; secruity provision; level of human interface; degree of difficulty; and mission risk. Table 1-1 shows these attributes in relationship to the maintenance concept options.

This proof of concept program will provide new means for changing software on-orbit, and demonstrate valid and new technology. From these concepts, specific software design requirements and specifications will be defined and maintenance scheduling, planning, and scenarios developed.

CURRENT STATE OF DEVELOPMENT:

Lockheed has conducted preliminary analysis for physical software maintenance for ROM, and technology exists for RAM maintenance.

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

MILSTAR spacecraft segment and related classified programs have anlysed this maintenance concept dilema.

TECHNOLOGY NEEDS FOR THIS CONCEPT:

(1) software ORU design; (2) software architecture structuring; (3) software design for maintainability.

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Spacecraft Software Maintenance (Cont'd)

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS:

(1) Review of current spacecraft software configuration/architectures.
(2) Formulate maintenance requirements/specifications.
(3) Defined a maintainable software architecture/configuration concept.
(4) Develop an ORU design to support ROM maintenance.
(5) Develop RAM interface methodologies for physical and remote maintenance.
(6) Update requirements and specifications.
(7) Address system integration and interface demands.
(8) Create small module examples to demonstrate maintenance concept.
(9) Demonstrate concepts.
(10) Test and validate demonstration resultants.
(11) Summarize and update maintenance requirements/specifications.

ESTIMATED COST AND BASIS OF ESTIMATE:

ESTIMATED SCHEDULE AND BASIS:

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE: LOW

ESTIMATED CONSEQUENCE OF FAILURE: LOW

CONTACT NAME:

TELEPHONE:

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Evaluation of EVA Space Suit Capabilities using KC-135

BRIEF DESCRIPTION:

Development of a quick reaction full-mobility Space Suit will require an indepth evaluation of human performance requirements in a simulated weightless environment. The KC-135 aircraft provides the capability to achieve simulated O-G by flying through a Keplerian Trajectory. The subject of this study is to evaluate existing Space Suit capabilities and using MSE's as test subjects and conduct performance measurement tests on the KC-135. The EMU, ZPS and utilizing AX-5 Space Suits. Candidate tests include comparison of suit donning/doffing, translating, EVA work restraint operations and use of manipulative hand controls.

CURRENT STATE OF DEVELOPMENT:

- o EMU, ZPS and AX-5 are available from NASA centers. Airlock and EVA work stations are available from Lockheed.
- o Manipulative hand control task board needs development.

RELATED PROGRAMS/STUDIES/DEVELOPMENTS: Space Station

TECHNOLOGY NEEDS FOR THIS CONCEPT: None

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS: o Schedule KC-135 flight with availability of space suits.

ESTIMATED COST AND BASIS OF ESTIMATE:

$500K; Experience on recent KC-135 flights.

ESTIMATED SCHEDULE AND BASIS:

9 months; KC-135 flight/suit use schedule

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE: Individual dependent

ESTIMATED CONSEQUENCE OF FAILURE: None

CONTACT NAME: Tony Lustig

TELEPHONE: (408)756-8332

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Mission Adaptive Overgarment Matrix System

BRIEF DESCRIPTION:

Consists of a matrix of garments which are worn over the EVA pressure enclosure. Each of the mission adaptive overgarment configurations would accommodate a specific hazard. Currently identified overgarments include:

- o Radiation protection overgarment
- o Hydrazine contamination protection overgarment
- o (Differential pressure) nonventing overgarment

Each overgarment would be compatible with (or integral to) the thermal insulation overgarment.

CURRENT STATE OF DEVELOPMENT: See attached.

RELATED PROGRAMS/STUDIES/DEVELOPMENTS: See attached.

TECHNOLOGY NEEDS FOR THIS CONCEPT: See attached.

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS: See attached.

ESTIMATED COST AND BASIS OF ESTIMATE: See attached.

ESTIMATED SCHEDULE AND BASIS: See attached.

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE: See attached.

ESTIMATED CONSEQUENCE OF FAILURE: See attached.

CONTACT NAME: William Elkins

TELEPHONE: (415)962-9800

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Radiation Protection Overgrament (forms a component of the mission adaptive overgarment matrix system).

BRIEF DESCRIPTION:

The radiation protection overgarment consists of a separate woven metal (perhaps monel or tungsten) garment which is donned separately over the EVA pressure suit. The overgarment provides protection to the EVA crewmember at GEO and/or polar orbit.

CURRENT STATE OF DEVELOPMENT:

- o Some conceptual work exists from past suit development programs.

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

- o Various GEO and polar radiation studies
- o Various EVA suit development programs

TECHNOLOGY NEEDS FOR THIS CONCEPT:

- o Woven metal technologies

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS:
- o Define materials/construction
- o Prototype design/fab
- o Compability/mobility/radiation protection/stowage tests & eval's
- o Define radiation protection requirement

ESTIMATED COST AND BASIS OF ESTIMATE:

$1 M - Engineering estimate

ESTIMATED SCHEDULE AND BASIS:

18 mo. - Engineering estimate

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE: Low

ESTIMATED CONSEQUENCE OF FAILURE: EVA restricted to LEO, or use of all metal hard suit required.

CONTACT NAME: William Elkins

TELEPHONE: (415) 962-9800

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Hydrazine Contamination Overgarment (forms a component of the mission adaptive overgarment matrix system).

BRIEF DESCRIPTION:

The hydrazine contamination overgarment consists of a separate impermeable garment which is donned separately over the EVA pressure suit. The overgarment is made of such materials that will not degrade from contact with hydrazine. Its purpose is to provide the EVA crewmember protection against hydrazine contamination during EVA duel transfer operations.

CURRENT STATE OF DEVELOPMENT:

- o Technology available from similar terrestrial applications

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

- o Hazardous materials clean-up technologies

TECHNOLOGY NEEDS FOR THIS CONCEPT:

- o Nonmetallic materials technology

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS:

- o Materials survey/selection
- o Prototype design and fab
- o Compatibility/mobility/stowage evaluations

ESTIMATED COST AND BASIS OF ESTIMATE: $0.5 M - Engineering

ESTIMATED SCHEDULE AND BASIS: 12 mo. - Engineering estimate

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE: LOW

ESTIMATED CONSEQUENCE OF FAILURE: Fuel transfer restricted to unmanned modes or highly reliable fuel transfer system required.

CONTACT NAME: William Elkins

TELEPHONE: (415)962-9800

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: (Differential Pressure) Nonventing Overgarment (forms a component of the mission adaptive overgarment matrix system).

BRIEF DESCRIPTION:

Manned EVA servicing in close proximity with sensitive sensing instrumentation can seriously degrade operation of such equipment due to contaminants typically vented from the EVA pressure suit. While regenerative nonventing breathing and cooling systems are under current development, suit leakage (typically 100 cc/min) would continue to pose a hazard. The nonventing overgarment addresses this problem by providing an impermeable barrier over the pressure suit. The leaked gas retained by the overgarment would then be removed by an ancillary vaccum/compressor/gas storage subsystem either remotely located (interfaced with the suit through an umbilical) or as an attachment to the PLSS.

CURRENT STATE OF DEVELOPMENT:

- o Some conceptual definition from past suit development programs.
- o Development can be derived from current penumatics technology

RELATED PROGRAMS/STUDIES/DEVELOPMENTS: o Past suit development programs

TECHNOLOGY NEEDS FOR THIS CONCEPT: o Pneumatics technology

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS:

- o Interface/compatibility/mobility/stowage
- o Generate system requirements/definition
- o Engineering development of vacuum/compressor subsystem
- o Prototype design/fab

ESTIMATED COST AND BASIS OF ESTIMATE: $2.5 M - Engineering estimate

ESTIMATED SCHEDULE AND BASIS: 24 mo. - Engineering estimate

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE: Low/Medium

ESTIMATED CONSEQUENCE OF FAILURE: Manned EVA servicing in proximity to contaminant sensitive equipment would be restricted.

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(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Head Position Sensing System (HPSS) and Servo Loop Control of Lighting/TV and HMD Targeting

BRIEF DESCRIPTION:

Use of current state of the art (helicopter head positon aiming systems) for servo positioning lighting and TV suit mounted systems. Lights will use photo sensitive feedback from head mounted unit to control intensity of the work area. HPSS can also be used to target areas of the HMD in conjunction with voice direction to expand areas of interest.

CURRENT STATE OF DEVELOPMENT: Technology is available from other applications.

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

Current lighting system mounted to shuttle EMU

TECHNOLOGY NEEDS FOR THIS CONCEPT:

Servo control systems for position - helmet mounted and head mounted inductance sensing devices, servoed miniature TV.

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS:

- Prototype design, fab test
- Simulated orbital light environment and test

ESTIMATED COST AND BASIS OF ESTIMATE:

$500,000 - $1,000,000 - Engineering estimate

ESTIMATED SCHEDULE AND BASIS:

One year - Engineering estimate

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE: Low

ESTIMATED CONSEQUENCE OF FAILURE: None

CONTACT NAME: William Elkins

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(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Radiation Hardening Testing

BRIEF DESCRIPTION:

Implementation of servicing and assembly in polar and geostationary orbits introduce unique radiation environments. The effects on the module (box) may be quite different between and environment protected by structure (i.e., inside an equipment section bay) and fully exposed to the space environment (i.e., exposed connectors, vent screens). The purpose of this test is to expose boxes, modules, components, etc. to these high radiation levels and establish new criteria for radiation hardening design.

CURRENT STATE OF DEVELOPMENT:

Current hardening techniques may not be effective in the exposure required to complete SAMS tasks

RELATED PROGRAMS/STUDIES/DEVELOPMENTS: Unknown

TECHNOLOGY NEEDS FOR THIS CONCEPT: Radiation Laboratory

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS:

- o Determine effects on most suceptable components
- o Build hardwar with ole/new technology
- o Establish radiation hardening guidelines

ESTIMATED COST AND BASIS OF ESTIMATE:

$250 K = 3 man years performed in a year to a years and a half time period in an academic environment

ESTIMATED SCHEDULE AND BASIS:

One to one and one half years from ATP.

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE: 0

ESTIMATED CONSEQUENCE OF FAILURE:

Module designs may not meet SAMS requirements.

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(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Clean Optical Surfaces

BRIEF DESCRIPTION:

To provide a capability and means to clean optical surfaces when degradation exceeds optical transmissivity requirements. Cleaning equipment and supplies cannot scratch or, in any way, effect the optical quality of the optics or disturb any of the surface coatings.

Removal transparent coatings should be considered as an alternative to manual cleaning.

CURRENT STATE OF DEVELOPMENT:

Preliminary concept.

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

TECHNOLOGY NEEDS FOR THIS CONCEPT:

Cleaning material that will not damage optical qualities -
Removable/disposable sacrifical surfaces design to absorb most of the mech. damage or staining that cannot otherwise be avoided.

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS:

Develop new cleaning material - Develop removable surface material - Conduct 1-g tests

ESTIMATED COST AND BASIS OF ESTIMATE: TBD

ESTIMATED SCHEDULE AND BASIS: TBD

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE:

ESTIMATED CONSEQUENCE OF FAILURE:

CONTACT NAME:

TELEPHONE:

(APPEND ANY ADDITIONAL AVAILABLE DATA)

SAMS POC PROGRAM CANDIDATE CONCEPT WORKSHEET

CONCEPT NAME: Rejuvenate Thermal Control Coatings & Surfaces

BRIEF DESCRIPTION:

Provide EVA capability to rejuvenate/repair/remove or replace thermal control coatings/covers and surfaces. Capability is required due to the possibility of micro-meteriod strikes or external contamination damage to thermal protection material.

CURRENT STATE OF DEVELOPMENT:

Removal and replacement of simulated space station thermal protective blankets was demonstrated by BAC in the MSFC NBS.

RELATED PROGRAMS/STUDIES/DEVELOPMENTS:

TECHNOLOGY NEEDS FOR THIS CONCEPT:

Develop coating materials and processes

OUTLINE DEVELOPMENT EFFORT REQUIRED:

MAJOR STEPS:

Evaluate BACMSFC test results; Develop EVA procedures to replace large blankets; schedule NBS or WETF; demonstrate capability of EVA replacement of large thermal blanket; evaluate/develop & demonstrate other repair methods

ESTIMATED COST AND BASIS OF ESTIMATE: TBD

ESTIMATED SCHEDULE AND BASIS: TBD

RISK ESTIMATE: ESTIMATED PROBABILITY OF FAILURE:

ESTIMATED CONSEQUENCE OF FAILURE:

CONTACT NAME:

TELEPHONE:

(APPEND ANY ADDITIONAL AVAILABLE DATA)