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SAMSS: AN IN-PROGRESS REVIEW OF THE SPACECRAFT ASSEMBLY, MAINTENANCE, AND SERVICING STUDY

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ABSTRACT

SAMSS is a combined NASA/DOD/SDIO effort to define and verify the most cost effective approach to spacecraft servicing, as an alternative to replacement, in the 1990's and beyond. The intent of the study is to assess the servicing of satellites in all orbit regimes. Elements of a space servicing infrastructure are developed and cost estimations are generated. In the latter stages of the study technology readiness is assessed and proof of concept demonstrations are identified. Products of the study will offer spacecraft program offices various options for their consideration in extending the lifetime of space systems. Fluid resupply is one portion of the servicing aspect of the study and includes cryogenic fluid resupply. Within this area cryogenic propellants for orbital transfer vehicles are seen as the most significant driver for the 2000 epoch.

Contract Number F04701-86-C-0032

SAMSS Introduction

SAMSS objective

Determine and demonstrate the most cost-effective approach to enable servicing, assembly, and maintenance of spacecraft in all orbit regimes

SAMSS roots

- 1983 DOD policy for servicing spacecraft
- Skylab demonstrated that man can do good work in space
- Every manned spaceflight (U.S. and U.S.S.R.) has seen the crew involved in repairs, adjustments, and changes
- The advent of NASA/DOD high-value satellites
- A need to do something to reduce the cost of space operations

SAMSS Programmatics

SAMSS is a joint AFSD/SDIO/NASA effort

Project monitor

Capt. Joseph Wong, Air Force Space Division, Plans and Advanced Programs

Length of study

28 February 1986 to 12 June 1987

Contractors

TRW

Grumman Space Systems
McDonnell Douglas Astronautics
Booz Allen and Hamilton
Advanced Technology, Inc.

Lockheed

Boeing Aerospace
Honeywell
Illinois Institute of Technology
Carnegie-Mellon
Life Support Systems

SAMSS Approach

DEFINE CONCEPTS

- SERVICING HARDWARE
- SPACECRAFT DESIGNS
- DESIGN REFERENCE MISSIONS
- SCENARIOS

EVALUATE BENEFITS

- MORE MISSION FLEXIBILITY
- PREPLANNED PRODUCT IMPROVEMENT
- LESS SATELLITE COMPONENTS REDUNDANCY
- REDUCED COST OF SPACE MISSIONS
- EXTENDED LIFETIME
- OPERATIONAL CONTINUITY
- ENHANCED SCIENCE
- ENHANCED PAYLOAD PERFORMANCE

CONCEPTUAL DESIGN

- HOW TO DESIGN SERVICEABLE SPACECRAFT
- LIST OF HARDWARE, TOOLS, SUPPORT EQUIPMENT FOR PROJECT MANAGERS
- RESULTS OF TRADES ON HOW TO PERFORM MISSIONS

PROOF OF CONCEPT PLAN

- SUGGESTED NEAR-TERM TEST AND DEMONSTRATION
- VERIFY TECHNOLOGIES
- VERIFY NEW HARDWARE

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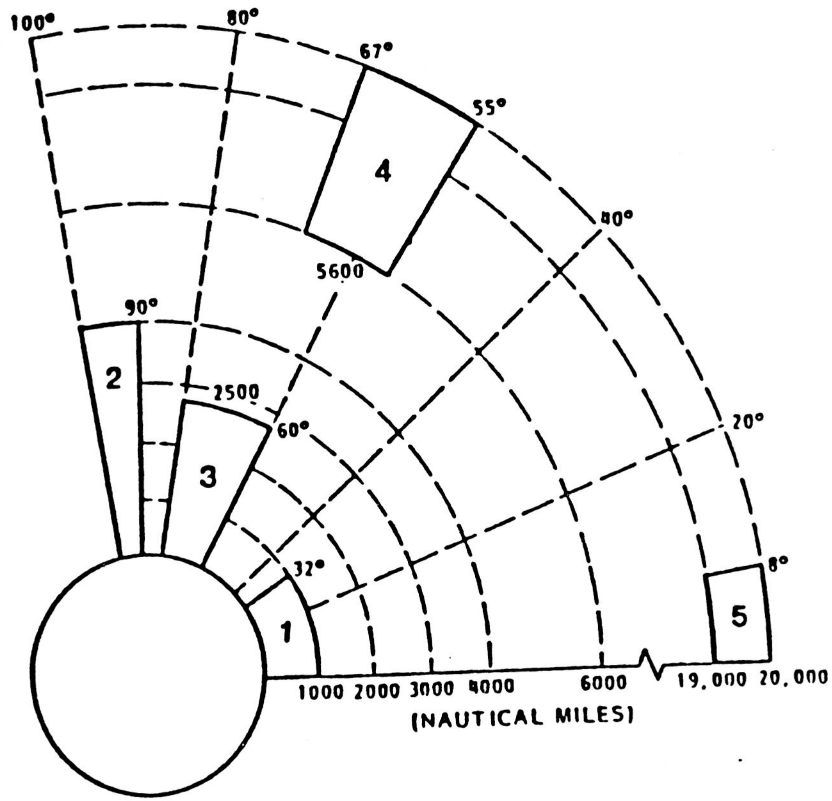
TRW DRM MISSION GROUPINGS

The specific design reference missions (DRM's) have been grouped here to highlight orbital considerations relative to the mission activities. The purpose of this is to illustrate the requirements for accomplishing the SAMS operations for each DRM. It is based on these requirements that the mission scenarios and summaries were constructed.

The scenario summaries for each of the DRM's highlight the mission timeline, transporation considerations, the role of man, required SAMS elements and any identified areas associated with logistics issues for performing the specific SAMS operations. The major logistics issues resulting from the mission analyses deal with personnel requirements, transporation, supply and required facilities.

SERVICING MISSIONS BY LOCATIONS (1990-2010)

LOCATION	SPACECRAFT	SERVICING MISSIONS	%
1 LEO	• 1 SPACE STATION • 7 FREE FLYERS • 1 INCL. FAC.	467	40
2 POLAR	• 2 MET SATS • 5 EARTH OBS PLATFORMS • 1 SPACE ENVIRON PLATFORM	188	14
3 AND 4 MID TO HIGH INCLINATIONS; LOW TO HIGH ALT	• 20 FREE FLYERS • TBD SDI SPACECRAFT	528	41
5 GEO	• 3 COMM SATS • 2 FREE FLYERS • TBD SDI SPACECRAFT	43 TBD	5
			100%



DRM MISSION SUMMARY

DRM NO.	MISSION DESCRIPTION
1	LEO SERVICING, SINGLE S/C, HIGH INCL., REMOTE OPS
2	LEO MAINTENANCE, SINGLE S/C, HIGH INCL., REMOTE OPS
3	LEO ASSEMBLY, LARGE SINGLE S/C, LOW INCL., CREW/ROBOTIC COMBO.
4	EMERGENCY SERVICING & MAINTENANCE IN LEO, SINGLE S/C, MID INCL., MANNED OPS
5	HEO SERVICING & MAINT., MULT. S/C, SUPERSYNC ORBIT, REMOTE OPS
6	GEO SERVICING & MAINT., MULT. S/C, LEO STAGED, REMOTE OPS
7	LEO ASSEMBLY, MULT. S/C, MID INCL., STAGING FAC., CREW/ROBOTIC OPS
8	DEPOT SERVICING & MAINT., MULT. S/C, MID INCL., STAGING FAC., CREW/ROBOTIC COMBO
9	EMERGENCY SERVICING & MAINT. IN GEO, SINGLE S/C, LEO STAGED, ROBOTIC OPS
10	ROUTINE SERVICING & MAINT. IN GEO, MULT. S/C, LEO STAGED, ROBOTIC OPS
11	ASSEMBLY IN GEO, LARGE SINGLE S/C, MANNED ASSEMBLY FAC, CREW/ ROBOTIC COMBO

SAMS INFRASTRUCTURE (Circa 2010)

Illustrated here is one concept of how the total SAMS Architecture/Infrastructure might look in the year 2010. SAMS would be fully operational, with missions in all of the DRM areas.

The Space Station would serve as the primary SAMS base. The servicing equipment would be stored there, along with spares and servicing facilities for the servicers. The station is shown with its servicing facility enclosure extended. It contains a Customer Servicing Facility with substantial assembly and servicing capabilities.

The assembly and overhaul station is necessary for the sucessful completion of the SDI satellite overhaul, roughly fifteen years after the first need for just the assembly operation.

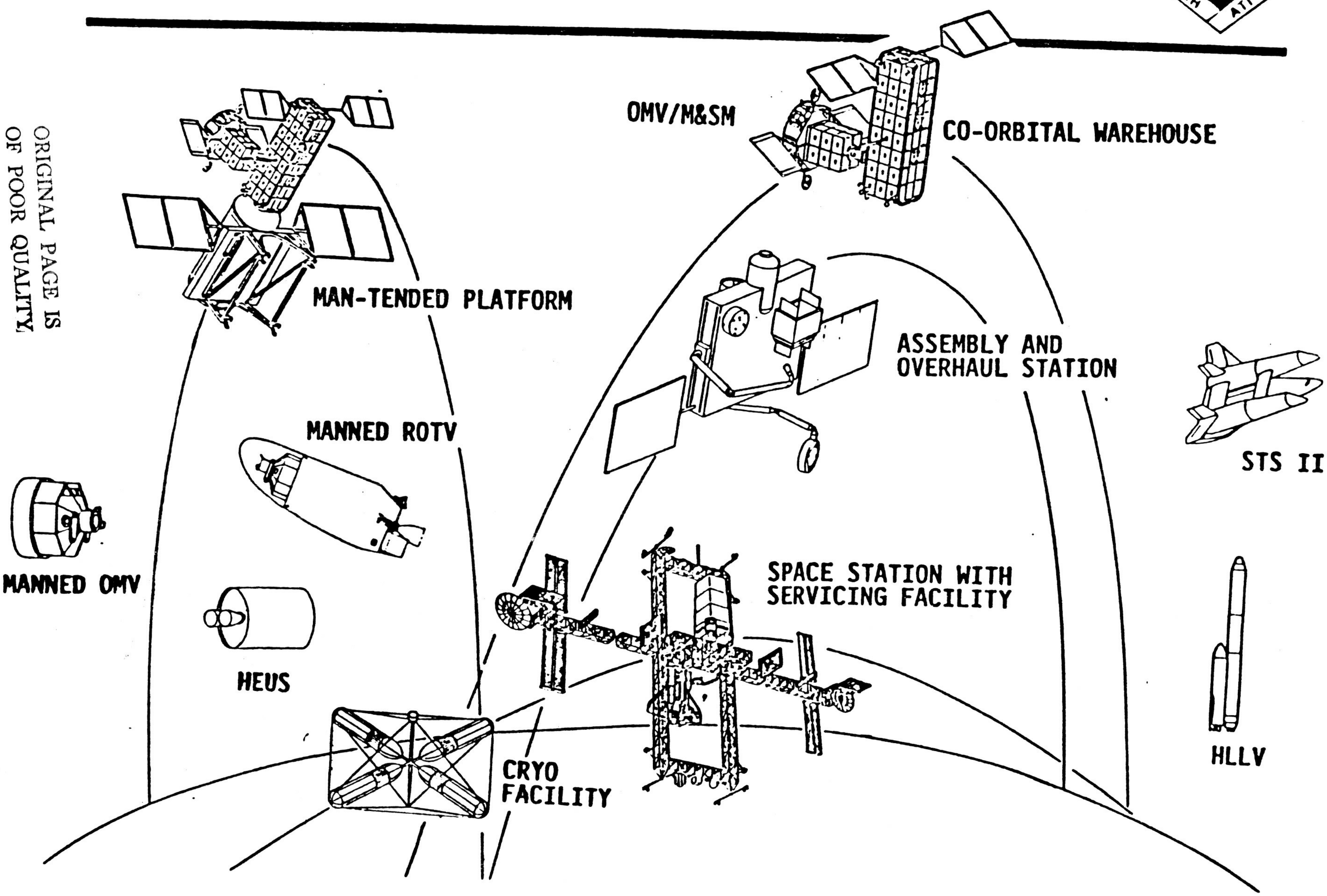
The High Energy Upper Stage (HEUS) will be required to place large mass payloads in orbit at assembly points, or to directly launch SDI-type payloads to their operational orbits. It has the capacity for 150,000 lb of cryogenic propellants.

The Martin Marietta fully reusable STS II concept was listed as being adaptable to a range of payloads which included the 40,000 - 45,000 lb SAMS derived requirement. Scenario 8 requires the capability to lift a servicing/overhaul crew and about 35,000 lb of spares and equipment to the Assembly and Overhaul Station at 290 NM and 55 degree inclination.

The General Dynamics heavy lift concept employs a Fly-back booster and expendable core and was shown to have LEO lift capabilities of up to 207,000 lb. SAMS derived requirements show a need for 200,000 lb or more to LEO in support of SDI assembly operations and to launch such items as the propellant carrier.

A Cryogenic Propellant Storage Facility is shown in trail of the station, in the same orbit. It will be required to store and refrigerate cryogenic propellants for the ROTV, and future manned lunar and planetary stages. It is separated from the station for safety reasons.

SAMS INFRASTRUCTURE (CIRCA 2010)



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CONCEPTUAL ORBITAL "WAREHOUSE"

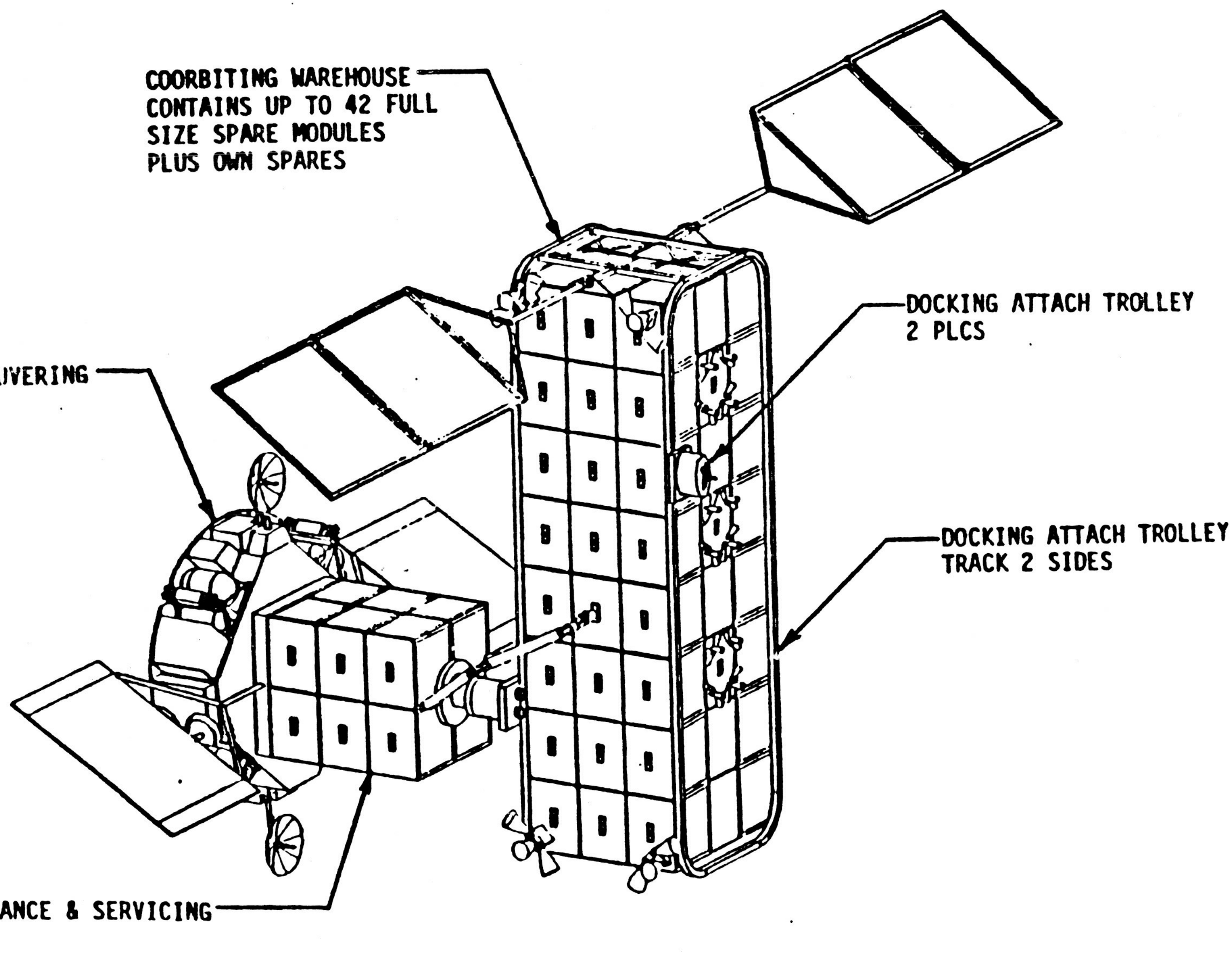
The TRW concept for an orbiting warehouse is shown here with the OMV/M&SM combination docked. The warehouse concept shown was sized such that it could be transported by no more that two ROTV flights. Whether this sizing is "right" would be determined by the specifics of the mission under analysis/consideration. In any case, the warehouse concept can be tailored in discrete "ROTV-sized" increments to meet the need.

The warehouse would carry spare ORUs for the constellation being serviced, as well as replacement ORUs for itself and the OMV/M&SM combination. The precise mix and number of ORUs would be determined by the planned servicing life, the expected ORU life and considerations of shelf-life for the stored ORUs.

The warehouse and its attending OMV/M&SM would be coorbital with the satellite or constellation to be serviced, with the OMV making circuits at intervals to replenish satellite consumables and perform whatever servicing/ORU replacement was needed.

Built in Test Equipment (BITE) would maintain a continual check on the health and status of the warehouse and servicer so that appropriate servicing/repairs could be carried out. It is not yet clear whether it would be more cost effective to replenish the warehouse and OMV/M&SM at intervals, or to simply launch replacements. The specifics of that tradeoff may vary greatly with orbit location and the composition of the serviced constellation.

CONCEPTUAL ORBITAL WAREHOUSE

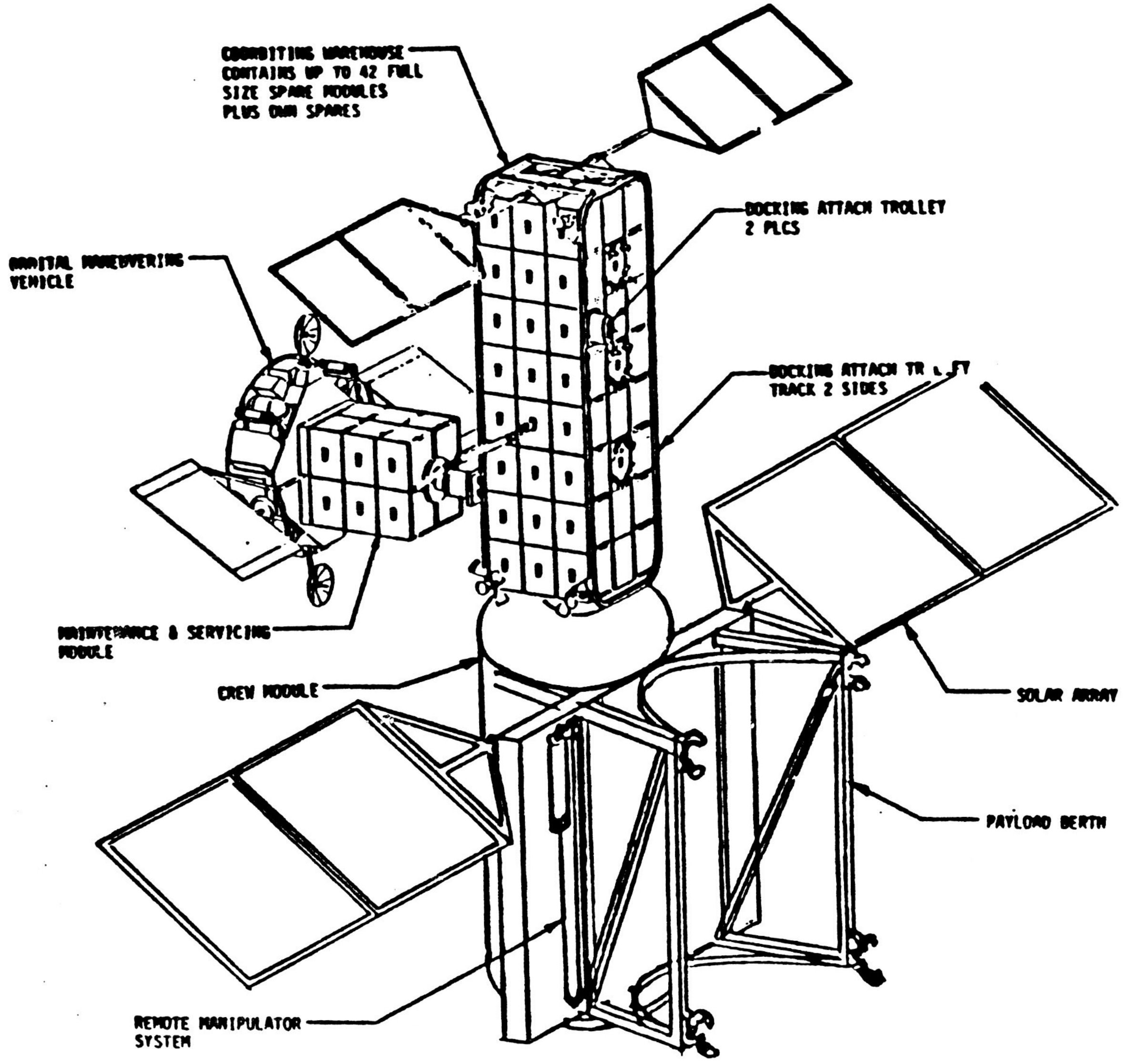


MAN TENDED ASSEMBLY, MAINTENANCE, AND SERVICING STATION

The concept for the warehouse with OMV/M&SM servicer could be extended to encompass a man-tended platform. This platform could be placed in less populous orbits (such as polar or GEO) to serve as a temporary base of operations for assembly or overhaul operations which are unsuitable for remote execution.

The concept illustrated has a Space-Station-Like habitation module, one or (more probably) two manipulator arms and a cradle for docking large Shuttle-type payloads/pallets. Between manned visits, the warehouse and OMV/M&SM servicer would operate much as in the concept discussed previously.

Man Tended Assembly, Maintenance, and Servicing Station



STANDARDIZED ORU MOUNTS IN STANDARDIZED ORU RECEPTACLE

This chart is an overview of the standard ORU concept. The receptacle and ORU containers would come in one basic size and would have several "standard" attributes.

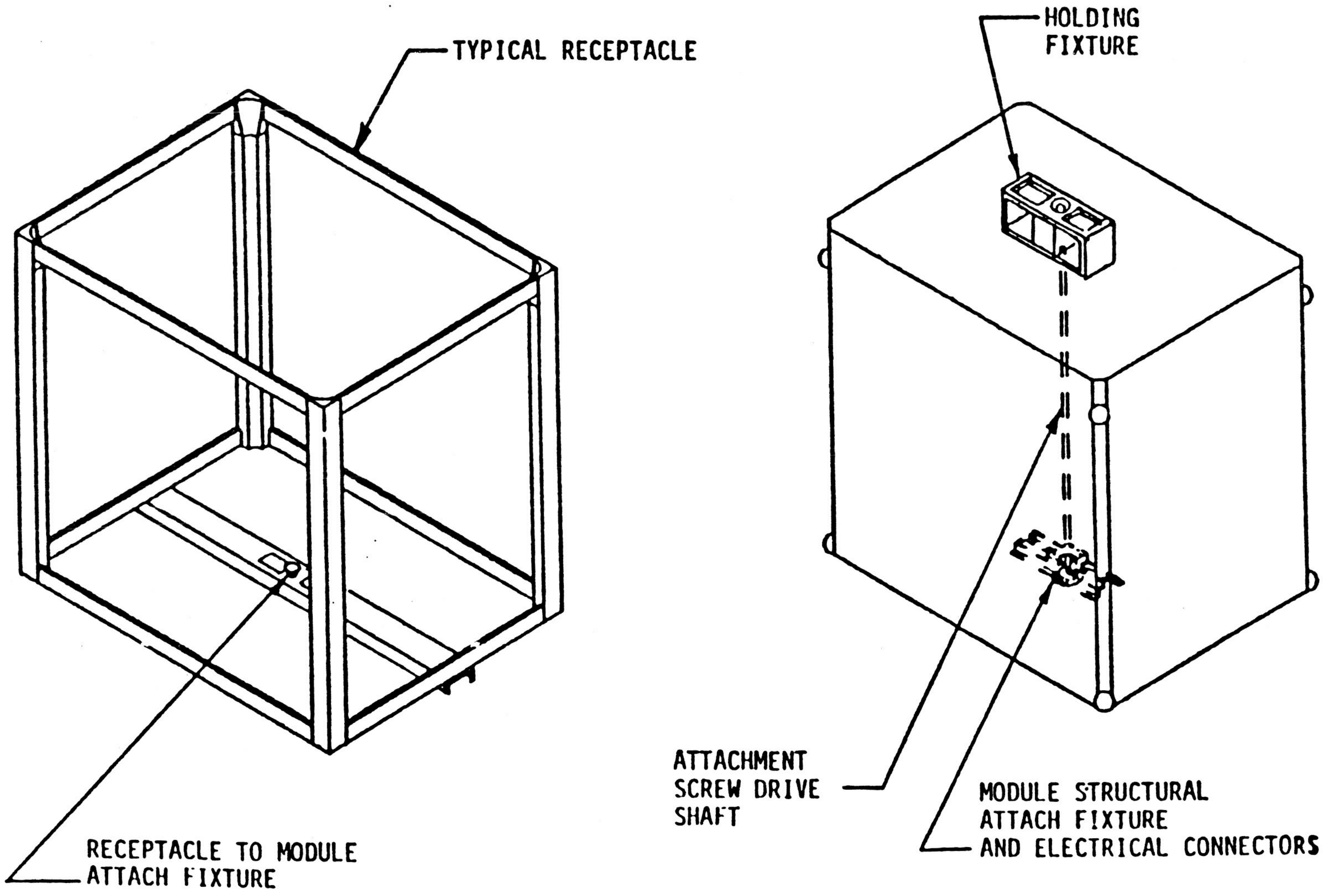
The receptacle would contain standardized mechanical and electrical interface provisions as shown in the "bottom" center. The receptacle would house the floating retention nut and the act of mechanical mating would also make electrical connections. The connection would be standard and sized to accomodate all anticipated ORU requirements.
Pin assignments would vary from application to application, but the connectors would remain the same.

The ORU "box" would be a standardized structure with a common interface for the Universal Servicing Tool (UST) and matching electrical connectors.

In order to avoid binding while inserting or removing ORUs, casters are provided. These are roughly two inch diameter balls, which mate to machined tracks in the ORU receptacles.

If laser hardening of the satellite is required, the ORU outer walls might be fabricated using Controlled Emission and Re-radiation (C.E.R.R.) material.

Standardized ORU Mounts in Standardized ORU Receptacle



Typical Cryo Fluid Servicing Elements

Common fluids

LN_2, LO_2, LH_2, SFHe, SCH_2, SCO_2, SCHe

Special purpose fluids

LD_2, LF_2, LNF_3, LHe

SAMS elements

Launch vehicles, autonomous and manned transfer vehicles, Space Station, coorbital warehouses, cryo-depots

Cryo subsystem elements

Storage tanks, refrigerator plants, radiator farms, transportation, transfers, servicing enclosures, and telerobotic operations

Cryo element serviceable components

Pumps, valves, pressurants, manifolds, fluid disconnects, instrumentation and gauging, cryo-coolers, heat exchangers, vent controls, insulations, catalytic converters, and transfer lines

SAMSS Cryo Servicing Examples

Solid cryogen exchange

Liquid cryogen telescope resupply

Cold-sensor exchange/upgrade

MLI, radiator maintenance

Cryo refrigerator maintenance

Cold-optics cleaning/exchange

SDI reactant maintenance

SDI burst-power platform maintenance

Storage depot maintenance

Servicing bay contamination control

ROTV propellant resupply

EXPENDED S.T.S. TANKS CAN BE ADAPTED TO

ORBITAL CRYOGENICS PROPELLANT STORAGE

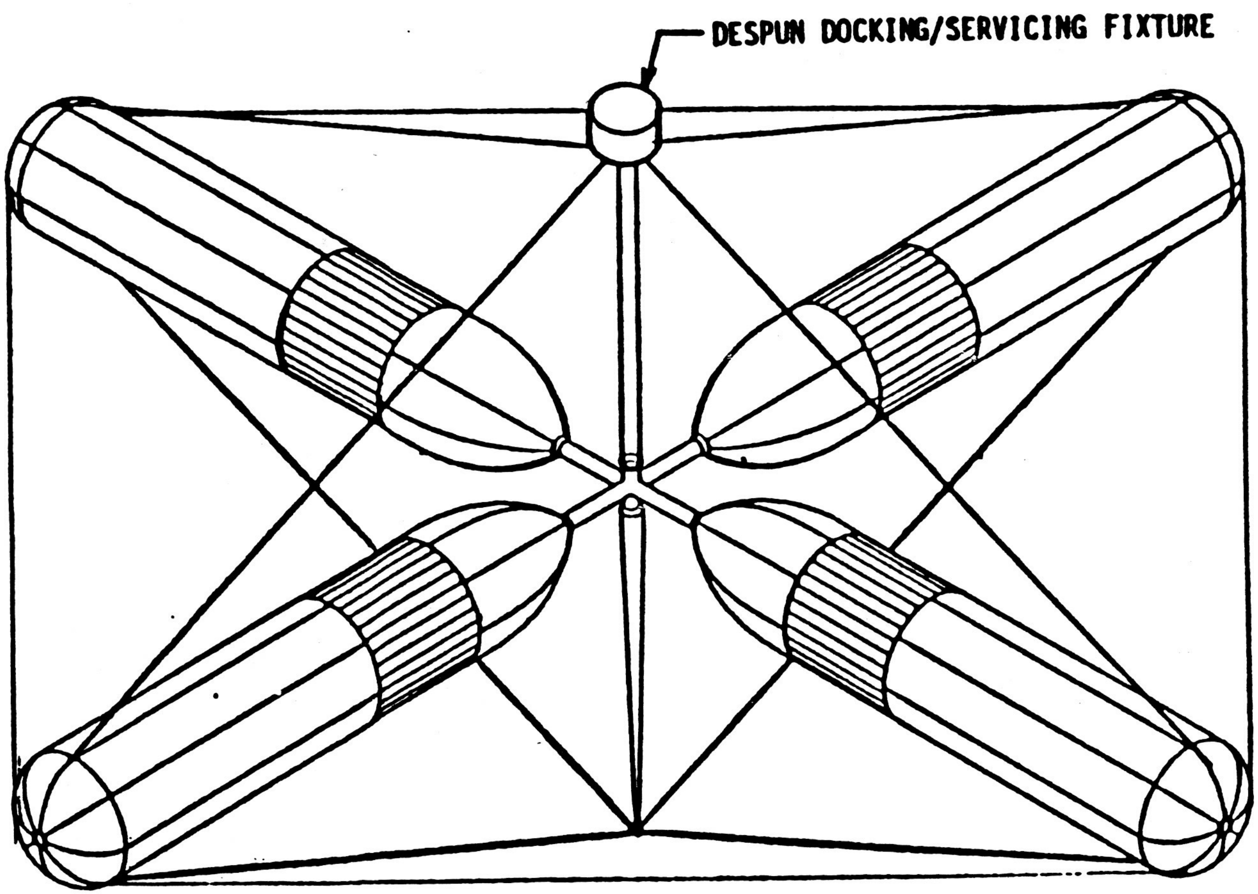
A Cryogenic Propellant Storage Facility will be required to support ROTV operations.

A concept for a CRYO Facility using expended STS External Tanks is illustrated here. The propellant would be symmetrically distributed for dynamic balancing of the facility, which is spun to facilitate propellant and vapor handling. The liquid oxygen is stored in the LOX tanks of one opposing pair of tanks, while hydrogen vent vapors are stored in the LH_2 tanks of that same pair. The opposite procedure is followed with the other pair of tanks.

The Central Docking Facility would be despun for docking of the ROTV or upper stage, then spun again to provide ease in handling the propellant and vent vapors. The spin would settle the liquids to the outside of the tanks and the central mast, while vent vapors would be returned through the center of the same conduits.

Not shown in this illustration, but required, is a cryogenic refrigerator plant and radiator farm. Conceptually, it would be attached at the opposite end of the mast from the Docking/Servicing Facility.

Expended S.T.S. Tanks Can Be Adapted to Orbital Cryogenics Propellant Storage



TANK ASSEMBLY SPUN TO FACILITATE VENTING AND PROPELLANT PUMPING

CRYO FACILITY CHARGES

An item of infrastructure not called out in any pre-study groundrules/assumptions is a Cryogenic Propellant Facility at Station orbit. It will be needed to store and refrigerate propellants for the ROTV, and other high energy stages for manned lunar and planetary missions in the future. A fairly minimal sizing for 5 ROTV missions per year was assumed for initial development, the propellant mass fraction used to generate weight of tankage required assumes a moderate advance over current practice in tank insulation.

Two new technology items will be required, the refrigeration plant to keep the propellants cold and the zero g propellant handling and venting system. The weight estimates are highly preliminary.

CRYO FACILITY CHARGES

- O AT ~37,000 LB/ROTV MISSION, ~5 MISSIONS/YR
  - o NEED CAPACITY FOR ~170,000 LB
    - \- SIZE FOR ~250,000 LB

- O 0.85 PROPELLANT MASS FRACTION YIELDS ~44,000 LB "DRY" WEIGHT FOR TANKAGE

o AT $15,000/LB (LOW TECH), DEVELOPMENT IS	~ $ 660 M
o CRYO REFRIGERATION (5,000 LB @ $120,000/LB)	600 M
o ZERO G PROP HANDLING/VENTING (~2,500 LB @ $60,000/LB)	150 M
o 20 YRS O&M @ $5 M/YR	100 M
TOTAL	$1,510 M
AMORTIZE OVER 100 USES	$15.1 M/USE

Space Cryogen Demonstration

Flight-demonstrated cryogen storage (1965 to 1985)

- Solid methane—HEAO B.C., Nimbus F, G
- Solid ammonia—HEAO B.C., Nimbus, F, G
- Solid carbon dioxide—SESP-72-2
- Superfluid helium—IRAS, IRT, SFHE
- Supercritical hydrogen, oxygen—Gemini, Apollo, Shuttle
- Supercritical helium—Cirrus, et. al.

Pending flight cryogen storage demonstrations (1985 to 1995)

- Solid hydrogen—CLAES
- Solid neon—TEAL RUBY
- Liquid hydrogen—CFMFE

Pending flight resupply demonstrations (1990 to 2000)

- Superfluid liquid helium—Shoot, SFHT
- Liquid hydrogen—CFMFE
- Liquid oxygen—none
- Liquid nitrogen—none
- Supercritical fluids—none

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SPEAKER: WILLIAM W. BURT/TRW SPACE AND TECHNOLOGY GROUP

E. Patrick Symons/Lewis Research Center:

I had a question on your chart that had to do with resupply and maintenance. When you talk about maintenance of SDI reactants are they talking about resupply of those systems with fluids or are they talking about change out of reactant tanks or can't you say?

Burt:

I can say that the fifteen year interval is primarily for propellant resupply for station keeping and in the event of cryogen blow-off, for resupply of cryogen. For the systems that would have nuclear power, you would perhaps have a resupply of the nuclear power source and one of the issues is providing a kick stage or some other means of getting rid of the old nuclear power source.