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REFERENCE DATA, PART 1 Final Report

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**SKYLAB REUSE STUDY
FINAL REPORT AND REFERENCE DATA**

Part 1

DECEMBER 1978

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PREFACE

The Skylab Reuse Study was an 11-month effort (November 1977 to October 1978) which contributed to the Skylab Reactivation Mission and defined Skylab reuse objectives, benefits, and concepts. The study was organized into the two noted activities with emphasis on subsystems interrogation occurring during the initial two months.

The final report was prepared as both a Skylab reuse study report and a summary reference document for the Orbital Workshop and Airlock Module Mission performance. This approach was employed as a means of providing a single source of the basic information necessary for understanding the chronological flow of events and the related hardware status. As a point of departure in implementing this technical record the following information is presented in the final report: end-of-mission conditions, reactivation status, refurbishment requirements, additional mission hardware definitions, Skylab reuse concepts, and candidate payloads. An addendum volume is also provided to address special emphasis tasks and describe the original flight configuration of the Airlock Module and Orbital Workshop. Thus, should further activities be of interest at a future date, the necessary background information has been assembled in one set of documents.

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Section 1.0 INTRODUCTION AND SUMMARY

This report discloses the results of the tasks performed by McDonnell Douglas Astronautics Company on the Skylab Reuse Study. Particular emphasis was placed on the Airlock Module (AM) and the Orbital Workshop (OWS), the principal habitation areas of Skylab. The accommodations provided by these modules have been completely examined with the thought of total reactivation as an enhancement to the STS long duration missions. A brief description of each subsystem is provided and a summary of subsystem performance during the Skylab missions is presented. End-of-mission status and the status of today for each subsystem is shown together with refurbishment/resupply requirements and refurb kit descriptions to restore Skylab to full operational capability.

Section 2.4 of this report provides an inspection/refurbishment and operations plan for Skylab. It includes program schedules and funding for three program cases developed for planning purposes. These cases are (1) Case I - MSFC Baseline Reference, (2) Case II - Lower Risk Study Option, and (3) Case III - Higher Risk Study Option.

1.1 INTRODUCTION

The advent of the Space Shuttle Transportation System in the early 1980s will create the second "giant step for mankind" in the progress of manned space. Coincidental with this milestone development, high-potential, long-duration manned space facility candidate--the Skylab--is being subjected to detail scrutiny with regard to its future space operations usefulness. This coincidence may provide a singular opportunity over the next decade for the United States to develop and empirically evaluate the universal importance and productive benefits of continuously manned long-duration missions. Many missions which require these support characteristics are defined in current mission models. Parallel Phase A studies were conducted by the McDonnell Douglas Astronautics Company and Martin Marietta Corporation. The two studies operated under the same study groundrules, addressing different key technical areas or assessing a salient point from different viewpoints as appropriate.

The benefits of longer missions and continuous operations must be thoroughly addressed as a prerequisite to the program planning for the latter decades

of this century as this can be the threshold of the next great age of mankind-- the true space age.

As the Skylab concept can be implemented at a relatively modest funding level, the pursuit of this route to the future is supported by cost-effectiveness logic based not only upon available flight-proven hardware, but assembled hardware already on orbital station.

The Skylab Reuse Program objectives listed in Table 1.0-1 are generally in chronological order. The hardware buildup sequence and information supporting all of these objectives follows in the body of the briefing.

The initial Shuttle-tended operational activity would provide a safe, effective phase of Skylab rehabilitation while simultaneously benefitting the Orbiter crew through the addition of private accommodations, off-duty recreation area, and physical conditioning equipment. This period would also permit exercising selected onboard experiments.

Implementation of secondary objectives becomes a function of real-time decision-making processes with sufficient lead-time planning to support a reasonable accomplishment schedule. The support of advanced payloads in this phase would be shared with the STS; only those requiring a particular Skylab support characteristic would be considered for Skylab assignment (e.g., longer duration).

In order to appropriately address the noted reuse program objectives, study objectives, groundrules, and assumptions were developed by Marshall Space Flight Center. These are shown in full in Table 1.0-2. For the specific study schedule and tasks definition, please refer to Appendix A.

During the first decade of Space Shuttle operations, a continuing growth in manned space operational and payload support capabilities will occur, although the particular path that will be followed is still to be determined. The scenario introduced in Figure 1.0-1 portrays a Skylab reuse plan which is both compatible with the STS/Power Module and the Skylab Reuse concepts. This is not intended to indicate that Skylab supplants the Shuttle Sortie missions in the latter years, but rather augments them by supporting payloads/missions which demand greater resources in mission duration and number of crew.

Table 1.0-1
SKYLAB REUSE PROGRAM OBJECTIVES

Primary

- o Engineering evaluation of long-duration effects
- o Augment Orbiter habitability provisions
- o Utilize selected onboard experiment equipment

Secondary

- o Support and evaluate long-duration missions
 - o Supply berthing/support accommodations for Spacelabs
 - o Provide growth path to "hotel" concept for increased crew size
 - o Support advanced payloads in:
 - Astronomy --- Life Sciences
 - Astrophysics --- Materials Processing
 - Earth Viewing --- Space Construction
-

Table 1.0-2
TECHNICAL AND PROGRAMMATIC GROUNDRULES
FOR THE SKYLAB REUSE STUDY

SKYLAB REUSE STUDY OBJECTIVES

Conduct Mission/Payload Analyses

- o Define payloads and requirements
- o Provide mission scenarios
- o Determine benefits of Skylab utilization

Conduct Mission Accommodations and Configuration Analyses

- o Analyze compatibility of mission/payloads with Skylab, Shuttle, Spacelab, etc.
- o Define capabilities that enhance Shuttle/Spacelab operations
- o Evaluate Power Module extended capabilities
- o Provide augmented capabilities concepts

Assess Skylab Subsystems and Experiments

- o Develop ground interrogation plan
- o Develop refurbishment/resupply requirements
- o Provide Power Module docking mission definition

Develop Early Inspection/Revisit Plan & Implementation Programmatic

- o Provide preliminary plans and resource requirements
- o Develop costs, schedule and funding requirements

GROUNDRULES AND ASSUMPTIONS

Design/Operations

1. All basic Skylab subsystems shall be considered operational, repairable, or replaceable.
 2. Operations that require Orbiter hardware modifications will be avoided.
-

Table 1.0-2 (Continued)
TECHNICAL AND PROGRAMMATIC GROUND RULES
FOR THE SKYLAB REUSE STUDY

GROUND RULES AND ASSUMPTIONS (Continued)

Design/Operations (Continued)

3. Orbiter/Skylab communications subsystems shall be compatible with TDRSS.
 4. Current Skylab capability, mission hardware, and scenarios which have potential early benefits will be emphasized; however, future potential for significant mission accomplishments should be evaluated to define growth requirements upon initial Skylab configuration and performance.
 5. Operational design life goal of Skylab is 10 years from reactivation.
 6. Crew transfer during nominal and rescue operations will be achieved by an Orbiter equipped with a docking module. Docking mechanism and hatch clear opening envelope are described in JSC 07700, Vol. XIV.
 7. Skylab operating pressure nominally 5 psia; Orbiter nominal operating pressure is 14.7 psia. Trade studies shall be performed to determine the impact of different pressure ratios (Orbiter-to-Skylab).
 8. Existing, minimally modified, and anticipated hardware and components will be (in that order of preference) as much as possible. Examples of hardware are as follows:
 - 25 kW Power Module (MSFC baseline as updated)
 - Teleoperator (MSFC baseline as updated)
 - Manned maneuvering unit
 - Instrument pointing system
 9. Ground interrogation of Skylab will be possible during unmanned periods.
 10. Interface module shall be designed such that Power Module can be detached from Skylab cluster without module shuffling.
-

Table 1.0-2 (Continued)
TECHNICAL AND PROGRAMMATIC GROUND RULES
FOR THE SKYLAB REUSE STUDY

GROUND RULES AND ASSUMPTIONS (Continued)

Design/Operations (Continued)

11. Untended (no Orbiter docked to Skylab) manned/unmanned operations shall be investigated as a Phase IV operational mode.
12. Reference altitude for PM/Skylab operations is 230 n.mi. study will determine desired altitude for initial reuse operations.

Schedule

1. Skylab will have been reboosted to a higher orbit in October 1979. Requirements for additional reboost missions will be determined by MSFC.
2. 25 kW Power Module orbital operations will begin in early 1983. 25 kW Power Module will be available in January 1984 to support Skylab reuse operations.
3. Skylab reuse utilization begins with PM docking in January 1984. Trade studies should assess feasibility of earlier utilization of Skylab prior to PM docking.
4. Skylab Reuse Program shall consist of the following phases:
 - Phase I - Initial ground interrogations
 - Phase II - Reboost/inspection/habitability refurbishment
 - Phase III - PM/Skylab dock and initial reuse operations
 - Phase IV - Growth and continuously manned operationsStudy emphasis shall be on the first three phases.

Cost

1. Costing activity will concentrate on reactivation and refurbishment of Skylab systems and experiments (Phases I and II); however, estimates should be made for all elements of the reuse program through Phase III and the cost impact of Shuttle untended operations if determined to be an attractive mode.
-

Table 1.0-2 (Continued)
TECHNICAL AND PROGRAMMATIC GROUNDRULES
FOR THE SKYLAB REUSE STUDY

GROUNDRULES AND ASSUMPTIONS (Continued)

Cost (Continued)

2. Shuttle flights for Skylab reactivation and operation may be shared with other programs to reduce costs. STS cost per flight will be in accordance with the NASA space transportation system reimbursement guide.
 3. Costs will be in 1978 dollars. Cost inflation factors will be per NASA/MSFC provided table, dated December 1977.
 4. Costs will be prepared for categories defined in the NASA approved work breakdown structure.
 5. Estimates will exclude NASA institutional costs.
 6. Costing will assume a protoflight approach to hardware development.
 7. Parametrically derived estimates based on weight will include a weight contingency of 25%.
 8. Basic cost of GFE hardware (25 kW Power Module, teleoperator, Spacelab, etc.) will be excluded. Cost of any modifications will be included.
-

SKYLAB REUSE MISSION PHASES

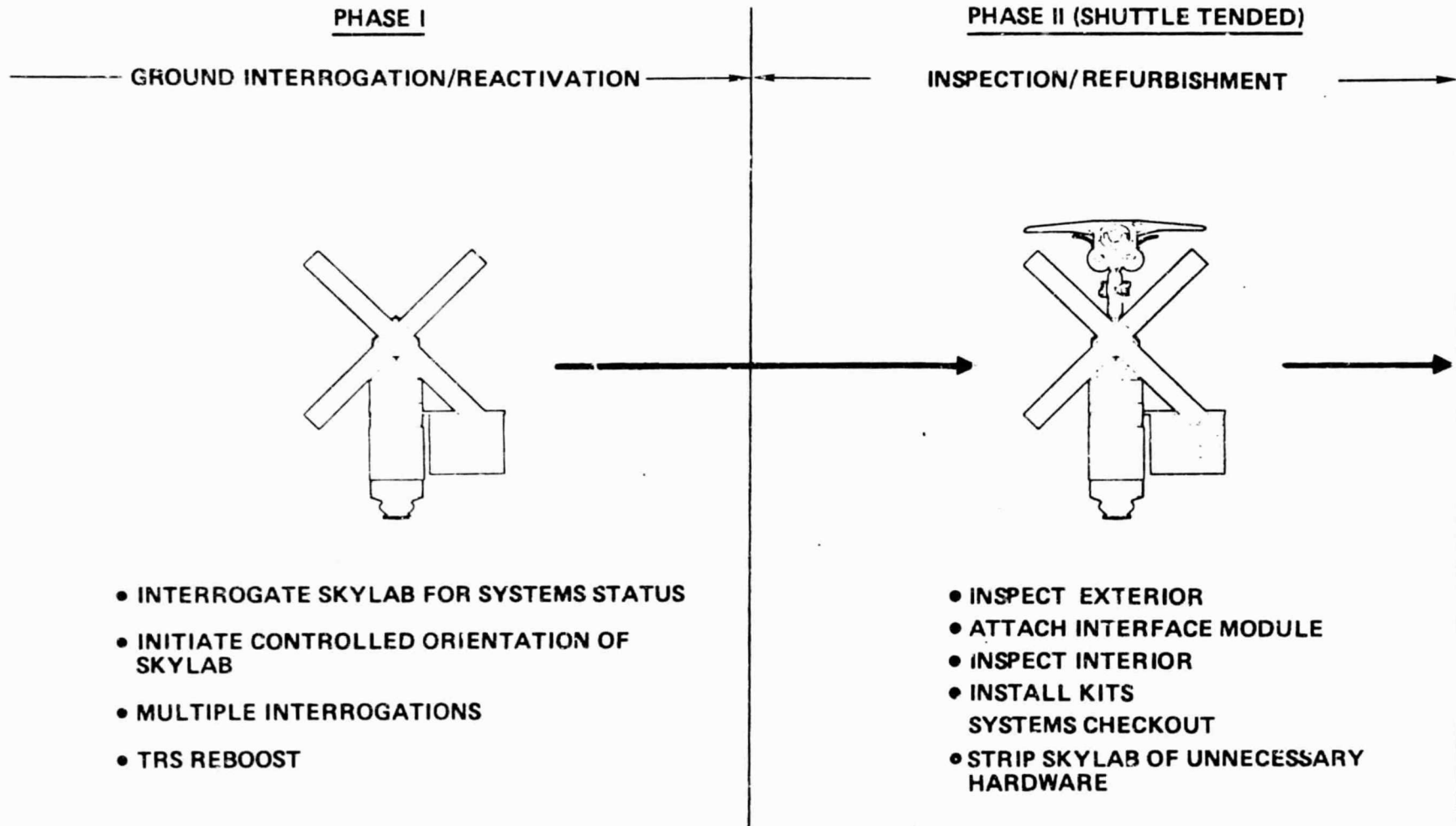
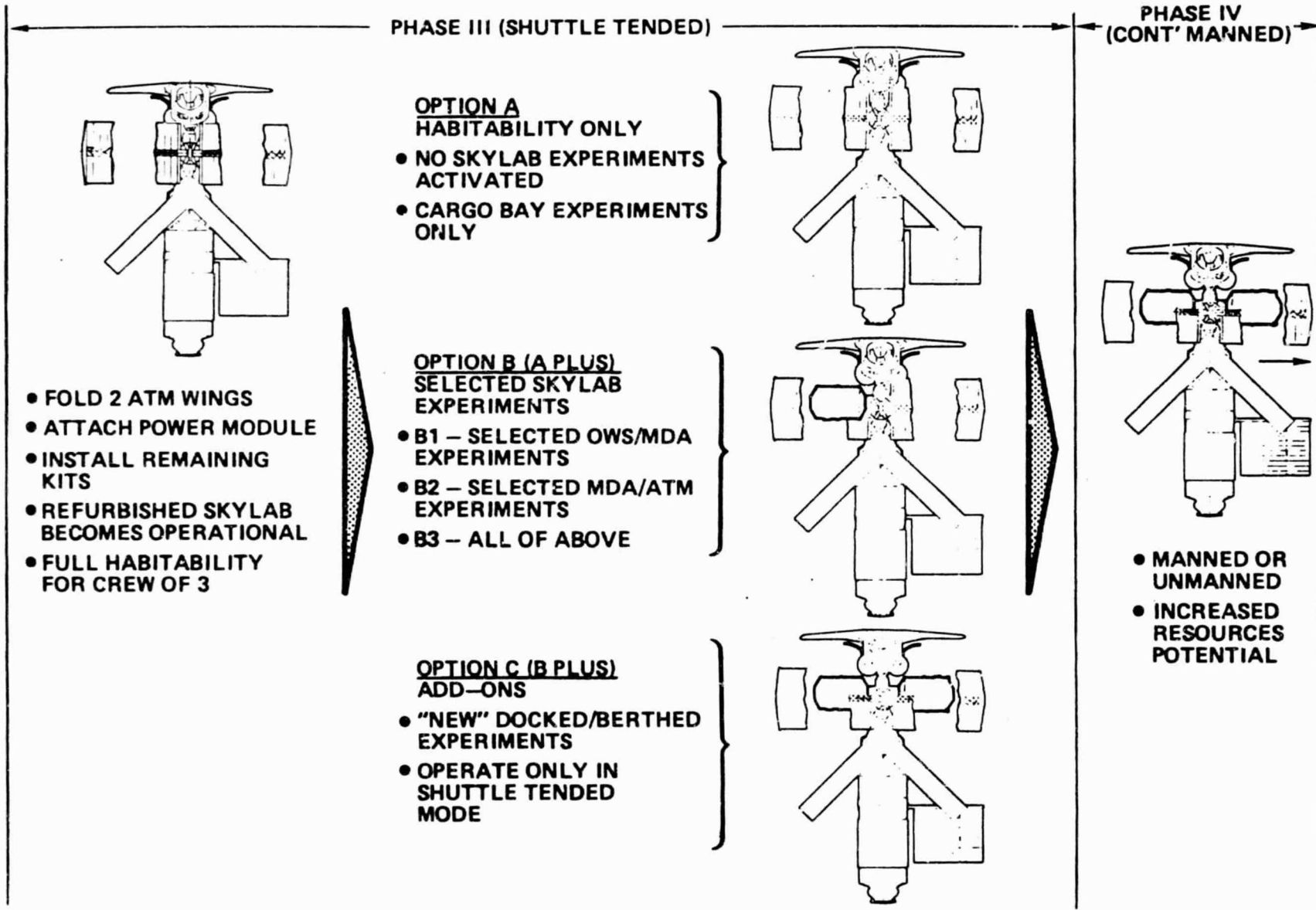


Figure 1.0-1

SKYLAB REUSE MISSION PHASES

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In the Shuttle-tended mode, it was assumed that the Orbiter would require approximately 14 kW for standby operations. During that period and in the subsequent continuously-manned mode, it would be possible for the Skylab to provide additional power should the advanced payloads require it. As the mission man-day demands increase, the Skylab could be modified to accommodate additional crew members. Ample volume is available on the second deck to install six or seven crews quarters without creating unacceptable conditions. As the Skylab crews were satisfied with the original Skylab crew quarters, similar units would be used for this modification. Several candidate installation concepts are shown later in this section of the briefing.

The logistics resupply system would be implemented at that point when the crew size and mission duration exceeded the 30-day Orbiter's capability.

1.2 SUMMARY

The Skylab Reuse Study had ATP mid-December 1977. The study plan was negotiated, updated, and finalized in February 1978, reference Appendix A. In addition to orientation briefings and periodic study meetings four milestone reviews were conducted by the COR. These were as follows:

- o Payload/Mission Analysis, Preliminary Requirements Review, March 1978 at MSFC.
- o Reuse Study Midterm Review, April 1978 at MSFC.
- o Executive Summary, Reuse Study Midterm Review, June 1978 at NASA Hqts.
- o Reuse Study Final Briefing, August 1978 at MSFC.

The following sections summarize the conclusions of the Skylab Reuse Study and the results of Skylab Reactivation and Interrogation during the study period.

1.2.1 Reuse Study Conclusions

The most significant conclusion to be drawn from the reuse study is that Skylab is in remarkably good condition and can be returned to operational capability in conjunction with the STS program for an investment of about 50 million dollars. Thus, Skylab offers the most economical and cost-effective means for NASA to activate an operational space station in the near future.

Following are highlights of our study conclusions:

- o Skylab system/subsystems are currently functioning
 - Early resupply (i.e., TACS) or refurbishment (e.g., power) may be necessary

- o Skylab reuse will enhance STS operations--especially long-duration missions.
- o Crew safety can be established to meet requirements of long-duration flight and Orbiter rescue mission concept.
 - Skylab can be divided into two habitable volumes.
 - Required safety equipment can be installed.
 - Additional airlocks and exit hatches can be added.
- o Reuse can benefit life sciences, material processing, and engineering studies (material exposure, space construction).
- o Skylab can provide habitability accommodations for crews of five to seven with minimum modifications.
- o Skylab's IOC (circa 1983) is appropriately timed to support payload development scenarios.
- o Long-duration missions greater than or equal to 30 days or greater than or equal to three to four crewmen will require a dedicated logistics system.
- o Skylab can effectively support both crew and capability growth in concert with a controlled (i.e., rapid or slow) evolutionary plan.

Skylab offers extensive potential for the enhancement of STS missions. A Skylab utilization plan denoting mission class and hardware buildup during the 1980s is projected in Figure 1.2-1. Figures 1.2-2 and 1.2-3 suggest the early role for Skylab in Life Sciences Research Materials Processing activities.

Following is a tabulation of recommended Phase B tasks developed at the conclusion of the reuse study.

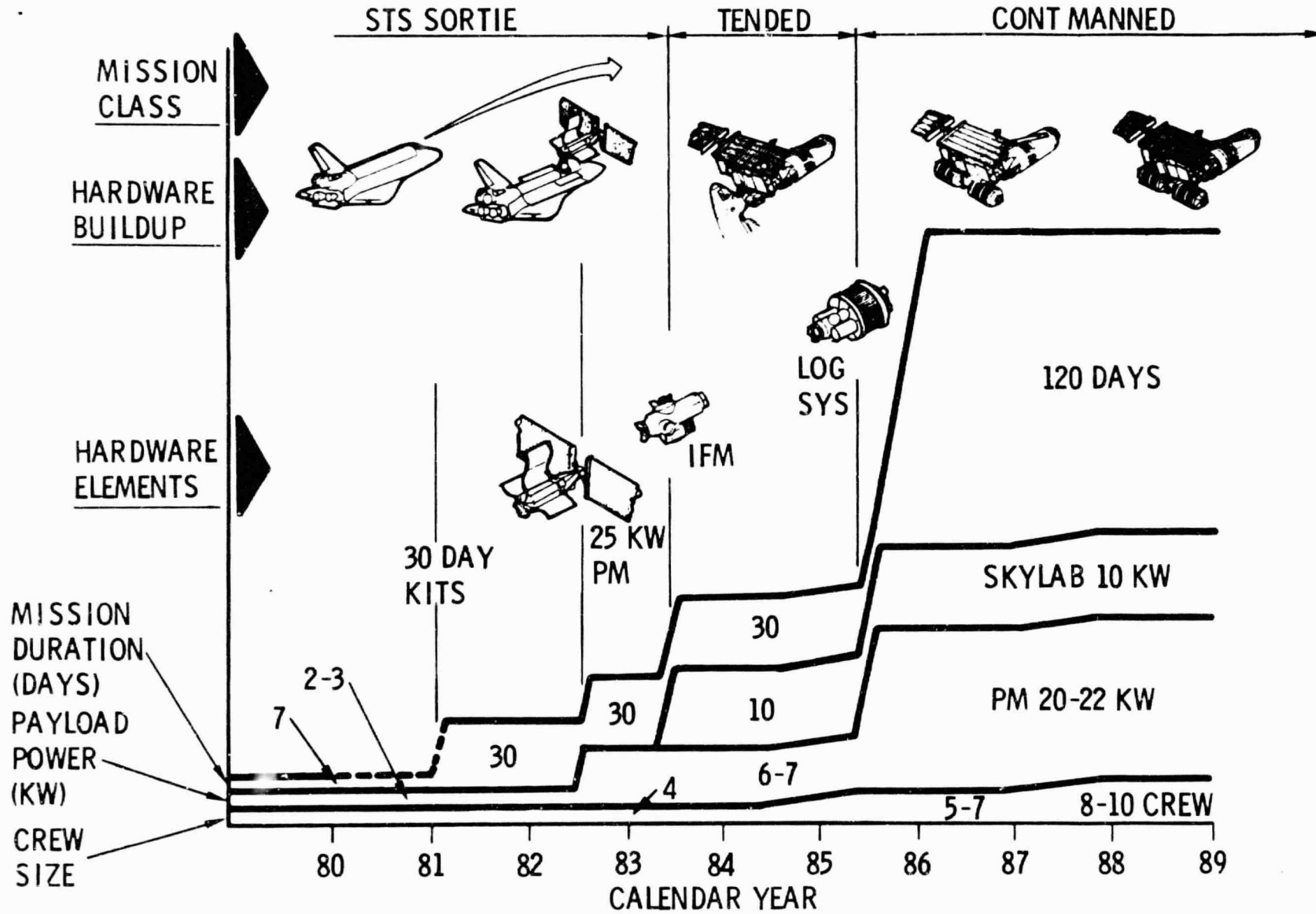
- o Develop baseline reference mission plan.
 - Define Phases II, III, and IV operations.
 - Establish operational/design requirements.
- o Prepare preliminary design criteria and guidelines specifications.
 - Integrate Skylab-A criteria, lessons learned, and STS requirements.
 - Set up specifications documents tree.
- o Prepare crew safety plan.
 - Establish operational design criteria and requirements consistent with STS.
 - Define critical timelines and event sequence.

Figure 1.2-1

MANNED SPACE GROWTH POTENTIAL

SKYLAB UTILIZATION

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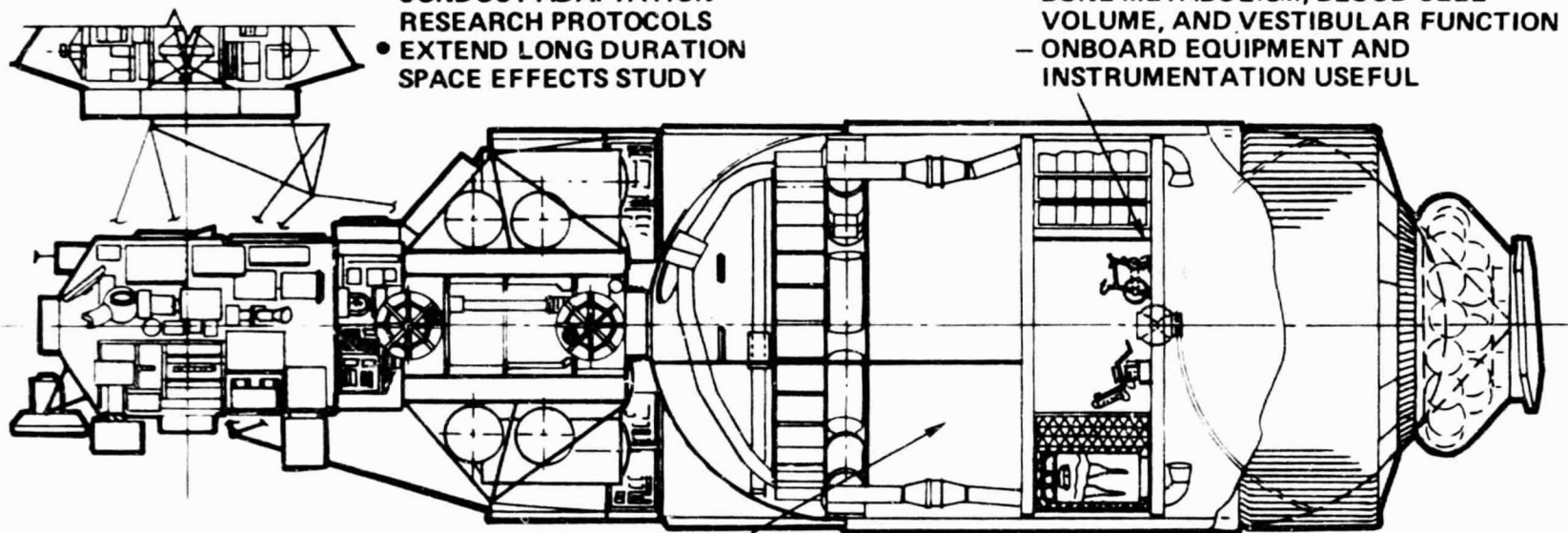
SKYLAB EARLY ROLE - LIFE SCIENCES

POTENTIAL BENEFITS

- ENSURE WELLBEING OF CREW DURING EXTENDED MISSIONS
- CONDUCT ADAPTATION RESEARCH PROTOCOLS
- EXTEND LONG DURATION SPACE EFFECTS STUDY

OBJECTIVE

- REUSE OF BIOMEDICAL FACILITY
 - RESEARCH REQUIREMENTS INCLUDE BONE METABOLISM, BLOOD CELL VOLUME, AND VESTIBULAR FUNCTION
 - ONBOARD EQUIPMENT AND INSTRUMENTATION USEFUL



- UTILIZATION OF SKYLAB EXERCISE AREA
 - DAILY VIGOROUS EXERCISE REQUIRED ON FLIGHTS LONGER THAN 14 DAYS
 - USE BICYCLE ERGOMETER TREADMILL, AND RUNNING TRACK

EQUIPMENT

- BICYCLE ERGOMETER
- ROTATING LITTER CHAIR
- LOWER BODY NEGATIVE PRESSURE DEVICE
- EXPERIMENT SUPPORT EQUIPMENT
- STORAGE LOCKERS AND SUPPLIES

SKYLAB EARLY ROLE — MATERIALS PROCESSING

POTENTIAL BENEFITS

- EARLY AVAILABILITY — 1985-86
- LOWER PRESSURE
- COLD ROOM
- LOW COST HABITATION

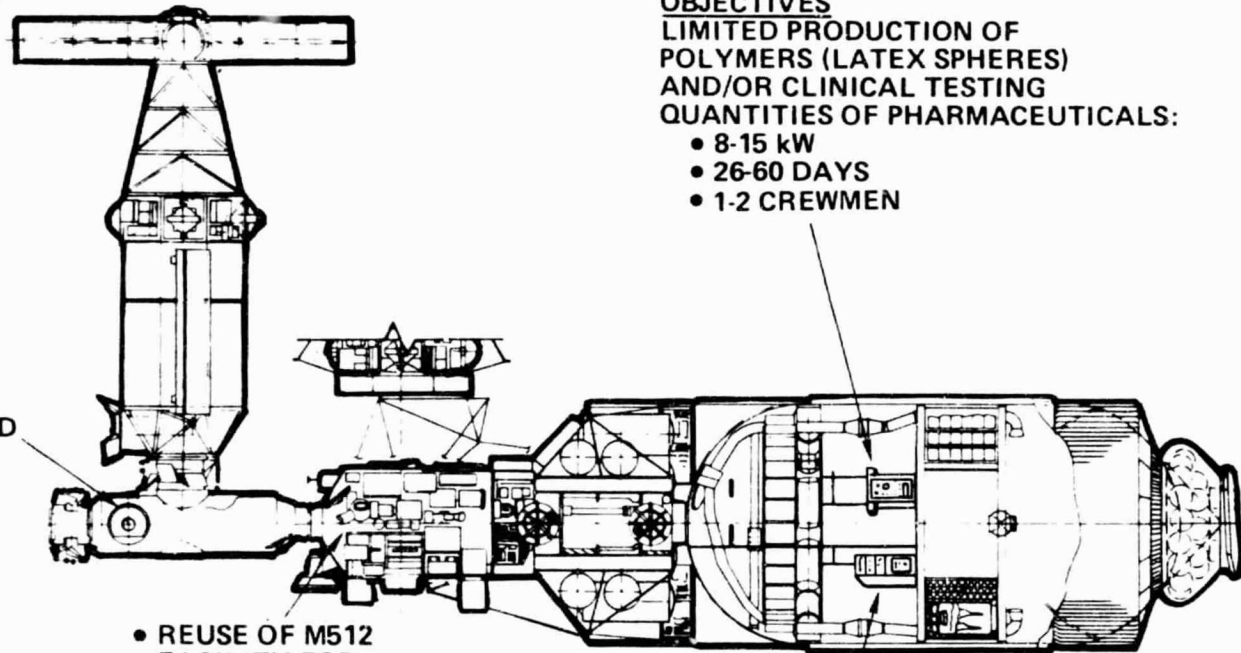
OBJECTIVES

LIMITED PRODUCTION OF
POLYMERS (LATEX SPHERES)
AND/OR CLINICAL TESTING
QUANTITIES OF PHARMACEUTICALS:

- 8-15 kW
- 26-60 DAYS
- 1-2 CREWMEN

BERTHED MODULES

- MEM/MEM II
- FOREIGN AND/OR PRIVATELY OWNED



- REUSE OF M512 FACILITY FOR ADDITIONAL FLAMMABILITY TESTING
- UTILIZE WORKSHOP FREEZERS

TYPICAL EQUIPMENT (WALL OR FLOOR MOUNTED)

- POLYMERIZATION CHAMBER
- MIXING/CONDITIONING EQUIPMENT
- ELECTROPHORESIS SYSTEM
- ANALYTICAL ASSAY SYSTEM
- MATERIAL PRESERVATION SYSTEM

*MEM — MATERIALS EXPERIMENT MODULE

- o Lay out Skylab reuse baseline configurations--inboard/outboard profiles.
 - Accommodate the Phase B baseline reference mission hardware elements, e.g.,
 - o Skylab
 - o Orbiter
 - o Thermal Shield
 - o Docking adapter
 - o Interface Module
 - o 25 kW Power Module
 - o Logistics system
 - o Spacelab(s)
 - o Long-duration Materials Exposure Facility
 - o Initial Space Construction Facility
- o Define mission support hardware.
 - Conduct configuration trades and select optimum.
 - Establish general specifications.
 - Prepare inboard/outboard profiles for those items required for Phases C/D.
 - o Docking adapter
 - o Interface Module
 - o Thermal shield
 - o Logistics system
 - o Long-duration Materials Evaluation Facility
 - o Initial Space Construction Facility

1.2.2 Reactivation and Interrogation

A major task in the reuse study was to develop a Ground Interrogation Plan for Skylab. At the outset the intention was to interrogate Skylab as a post study activity; however, the decision to reactivate Skylab during the study period was made and our efforts were supplemented and redirected to assist MSFC in the interrogation.

Skylab ground interrogation and system verifications were accomplished in three phases; Phase I, initial contact and preliminary system data, March 6 through April 20; Phase II, power system evaluation; battery activation and computer programming, April 21 through May 31; Phase III, orienting Skylab to and End-On-Velocity-Vector (EOVV) and monitoring of orbital data, June 1, 1978 through early 1980.

Initial operational activities were concerned primarily with establishing contact with Skylab and determining the operational status of the communications/ Digital Command System (DCS), Power and Telemetry (Data) systems.

Second phase activity was directed to the activation of the total cluster power system for continuous operations. Additionally, the ATM computer was

programmed for Phase III operations and the cluster pressurized to provide cooling for the rate gyros.

Phase III operations was the positioning of the Skylab in a low-drag orbital profile, End-On-Velocity-Vector (EOVV), extending its orbital life into early 1980.

Data evaluations of cluster status were made using End-Of-Mission (EOM) data, February 9, 1974, as the baseline for comparative analysis against data acquired during the Skylab reactivation period, March 6 through June 1, 1978. These telemetry data were downlinked to several GSFC ground stations where a portion of the data was processed in real-time to support NASA operations. All telemetry data was recorded at the ground stations and selected magnetic tapes were shipped to MDAC Huntington Beach for data processing. At MDAC the magnetic tapes were processed and several Interrogation Data Books of data plotted in engineering units were printed. The Data Books were provided to NASA operation support engineers and included plots of all AM and ATM telemetered measurements from multiple station passes. In addition, selected telemetry parameters were periodically processed at MDAC Huntington Beach in support of specific operational problems. This data support was provided to NASA using the data processing software and hardware facilities developed for the original Skylab missions.

PHASE I - INITIAL INTERROGATION

The initial contact period was originally scheduled for the week of March 6, 1978. Subsequently, the period was extended to take advantage of the excellent operational condition of the Skylab and prepare the Cluster for position orientation operations in June 1978. This section summarizes the results of the interrogation/operations period of March 6 through April 20, 1978.

Vital Systems

Critical system evaluations consider only those systems necessary to the survival operational capability of the Cluster; i.e., Structure, Power, Communications and Attitude Pointing and Control.

Structure - Initial structure integrity evaluations were made based on telemetry data received from all sections of the Cluster. It was determined that no major

structural damage had occurred as received data verified all operational systems functional. Although internal OWS temperatures ranged between 75° and an estimated 250°F, these temperature excursions were cyclic. It was calculated that the Cluster was spinning around the X-axis at a rate of 1.2°/sec. Using the newly acquired temperature data and correlating data from the initial two weeks of Skylab in 1973 when the heat shield was lost, it is considered that neither insulation debonding nor hazardous material degradation has occurred.

Power Systems - The Electrical Power System (EPS) consists of two major categories: (1) the solar array systems, AM and ATM and (2) the power conditioning groups; batteries, battery chargers and voltage regulators. Power generated by both systems, AM and ATM, is delivered to the Cluster subsystems at a nominal 28 VDC.

The AM power system consists of eight Power Conditioning Groups (PCGs) tied through command relays to the OWS Solar Array Panel. Telemetry data verified power generation from each of the eight solar array power groups. Analysis of power data, voltage and currents, determined that power being derived from the SAS had degraded approximately 9% from EOM in February of 1974. Voltage and current profiles for the eight PCGs can be found in the Data Books provided NASA during the reactivation and interrogation.

The ATM power system is similar to the AM EPS in that it uses solar array groups for primary power sources and batteries for periods when the solar array is not illuminated. The ATM power conditioning system is referred to as CBRMs; Charger-Battery-Regulator Modules. Operations during this period verified the functional status of the ATM CBRM system.

Communications/Data Acquisition - Initial operation of the Skylab Communications and Data Acquisition systems was highly successful. The AM and ATM Command Systems (DCS) responded to initial contact commands and evidenced no degradation after thousands of thermal cycles, and in the case of the AM DCS, on-off cycles each time the SAS was illuminated.

Excellent telemetry data was received from both AM and ATM systems. Initial analyses of this data has determined that there has been no significant loss of

any of the TM systems components; i.e., multiplexer, signal conditioners, sensors. As an added plus, the AM low level "B" multiplexer, which had failed during the Skylab program, came on and is functional on all channels. TM data for both AM and ATM systems are located in the Interrogation Data Books provided to NASA.

Attitude Pointing and Control System - The APCS was not enabled in Phase I as an operational system, however, all major component operations have been verified with the exception of the OWS Thruster Attitude Control System (TACS) firing solenoids. The operational status of the APCS was as follows:

- o ATM/APCS and OWS/TACS control electronics configured for ground command
- o ATM Computer: Operational
- o CMGs (2): TBD; CMG 1 failed during Skylab mission
- o Sun Sensor: Activated
- o Star Tracker: Non-operational (failed during Skylab mission)
- o TACS propellant (N_2): 22,000 lb-sec

The APCS is operational in either a TACS only or CMG/TACS mode. Possible constraints are the limited quantity of propellant gas and the questionable status of CMG #2, which was indicating some heating and speed changes at the end of the Skylab program. The total system was operationally activated during Phase III.

Crew Systems and Accommodations - The two support systems capable of ground control, refrigeration, and external lighting, were not operationally checked. Monitored data, however, indicated that these systems should function normally when activated.

Lighting - It was not planned during this interrogation to exercise the exterior lighting systems, tracking and docking, of the Cluster through use of the DCS. Internal lighting cannot be activated or monitored, therefore, will not be evaluated until the first revisit.

Water System - The water supply system functioned without any known discrepancies during the entire Skylab mission. There is currently a water supply on board that can be utilized after treatment with iodine and filtered. The onboard system shows no degradation with respect to either leakage or damaged containers.

Refrigeration System - The OWS refrigeration system consists of two independent coolant loops, each capable of maintaining food freezers and storage units and water chillers as pre-selected temperatures. Both coolant loops were functional at EOM.

The loops were not activated during any of the three phases of ground interrogation, however, when power was applied to the OWS power busses, TM data indicated both loop pump inverters came on in the standby mode, 0.47 VDC. There are no indications that the systems will not function normally.

The current status of the system indicates a potential problem in the Primary Loop. Measurement D7002, Pump Inlet Pressure, reads zero pressure, which would indicate a loss of coolant. The Accumulator Low indicator switches, however, do not verify D7002. This problem will be evaluated when the loop is activated.

Ancillary Systems - Cluster pressurization, atmospheric composition and thermal control systems were not functionally verified during this period. Telemetry data, however, indicates sufficient onboard supplies of gaseous oxygen, 2505 lbs, and nitrogen, 605 lbs, to provide the required cluster pressurization, 5.0 \pm .2 psia, and a habitable atmosphere. The onboard gas supplies represent 41 and 37 percent respectively of the O₂ and N₂ fill quantities. Data also indicates that the AM coolant loops, which provide the cooling for the thermal control system, has retained pressure sufficient for initial revisit operations.

PHASE II - OPERATIONAL PHASE

The second phase of the Skylab reactivation operations occurred during the period April 21 through May 31, 1978. The objectives were primarily concerned with bringing the ATM and AM batteries to full charge, pressurizing the Cluster to provide cooling for the rate gyros and programming the ATM computer for the Skylab positioning maneuvers scheduled for Phase III of the interrogation program. The results of this operational phase are summarized in the following paragraphs.

AM Power - Phase I data verified the operational status of the Skylab SAS and one of the AM batteries, No. 7. Subsequent activities during Phase II verified the operational status of all AM Power Conditioning Groups (PCGs). The AM

power system status at the completion of Phase II operations was:

- o AM batteries (8) charged
- o Solar Array Power Groups (8) operational
- o OWS and AM power busses functional
- o AM/ATM power transfer busses functional
- o Average battery power: 35 + amp/hours

There is no discernable degradation in the AM batteries or their charging systems. The solar array groups have degraded approximately 9% since EOM in February 1974. Reference Interrogation Data Books for AM power data.

ATM Power Subsystem - Data received during the Phase II interrogation indicated that 14 of the 18 ATM CBRMs were functional. Two CBRMs, #3 and #15, failed during the original Skylab mission and two, #4 and #16, did not respond to charge commands. The loss of four batteries did not affect the normal operation of the ATM power system.

ATM power system status at the conclusion of the Phase II interrogation period was:

- o ATM batteries charged - 14, failed - 4
- o CBRMs operational - 14
- o ATM power busses functional
- o Average battery power: 10 + amp/hours

Degradation of the ATM solar array power groups appeared to be similar to that of the OWS (i.e., approximately 9%). Reference Interrogation Data Books for ATM power data.

Cluster Pressurization - Cluster pressurization was required to provide a cooling medium for the operation of the APCS rate gyros. The rate gyros and their cooling fans operate automatically when power is applied to the ATM power busses. Without cooling, an overheat condition might have developed resulting in rate gyro failure.

The Cluster was pressurized using nitrogen gas to 0.7 psia. Leakage rates were comparable to actual EOM data, thereby, verifying the initial evaluations of structural integrity. Appendix A contains data for typical habitable area pressure measurements; i.e., D0207, D0256, D7111, D7112.

ATM Computer Programming - Operational capability of the ATM computer was verified during Phase I operations. New software was generated by IBM to reprogram the computer to control cluster positioning maneuvers during Phase III operations. The new software was successfully loaded into the ATM computer and verified by May 31, 1978.

SKYLAB PHASE III - POSITIONING OPERATIONS

Phase III of the Skylab interrogation was successfully completed in June 1978, with the positioning of the Cluster, through use of the APCS and the two remaining CMGs, in a low-drag mode called an End-On-Velocity-Vector. This position has the X-axis of the vehicle positioned parallel to the velocity plane with the MDA end leading. Orbital life of the Cluster should be extended from six to 12 months from mid-1979 until early 1980.

The TACS was used to perform several maneuvers during the early portion of this phase. These maneuvers depleted the TACS nitrogen gas propellant supply to 7500 \pm 2500 lb-sec.

Support during this phase was primarily limited to reducing AM and ATM data tapes for NASA. Direct support was not requested for either on-site or MDC locations.

Future operational support, between June 1978 and reboost or deboost activity in the first half of 1980, will be limited to data reduction, on an as-selected basis by NASA, from the daily monitoring of Cluster data.

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Section 2.0

TECHNICAL SUMMARY

The Skylab Reuse study was unique in that it involved the orbital integration of existing orbital hardware with new hardware launched by the Orbiter. Thus, it is both appropriate and useful to develop the technical data base by means of technical descriptions, and related chronological events in conjunction with time-slices of system performance status. The subject is primarily divided into three major items of MDAC concern: (1) Skylab cluster, including key experiments, (2) Airlock Module, and (3) Orbital Workshop. The AM and OWS data is chronologically arranged to scope the end-of-mission (EOM) status, reactivation status as of mid-October 1978, and the gross definition of refurbishment kits.

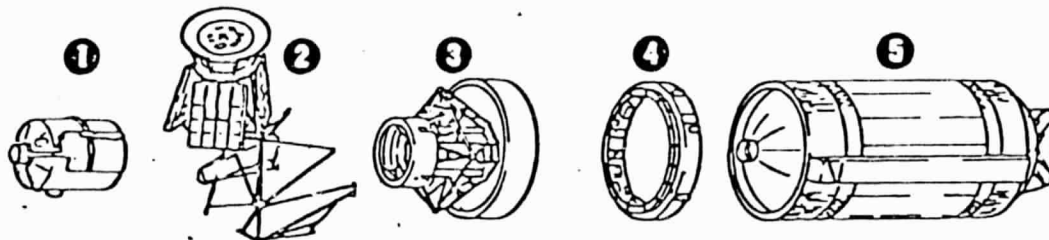
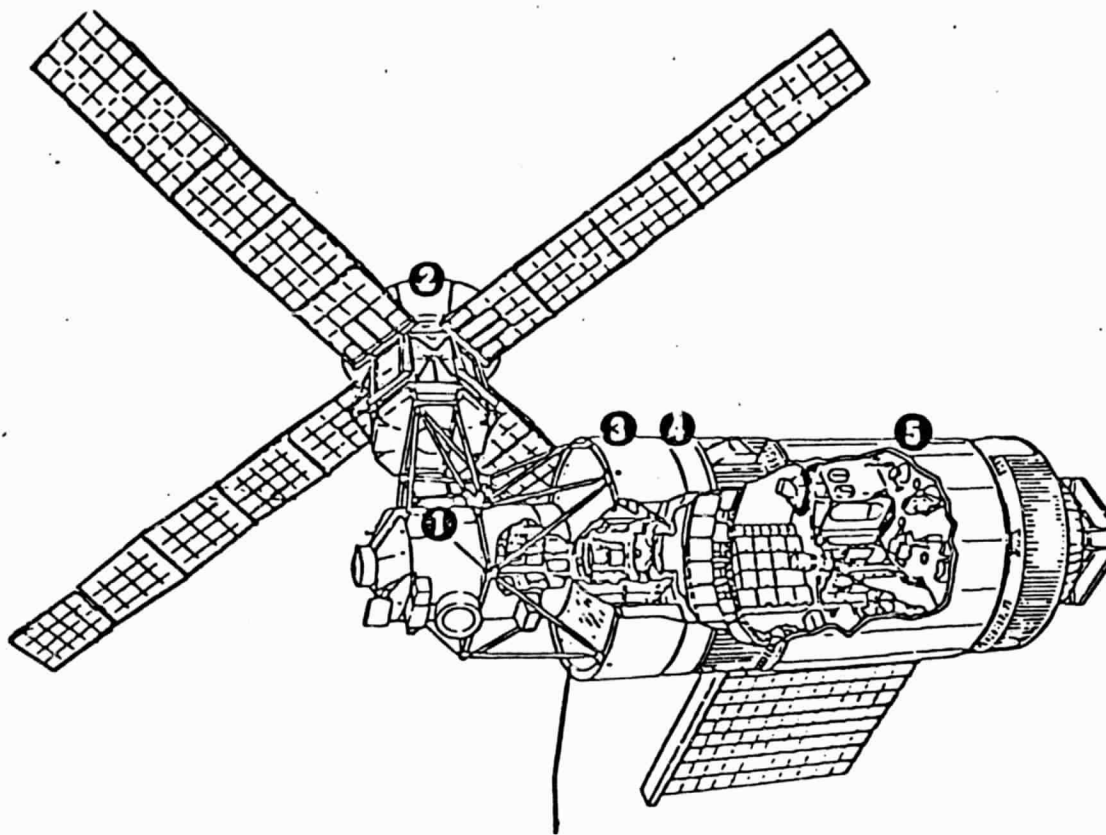
2.1 ASSESSMENT OF SKYLAB SYSTEM AND EXPERIMENTS

Skylab, the United States' first manned spacestation, is a well-equipped research facility in which unique experimental and operational tasks were performed in near-earth orbit. It was fully outfitted and provisioned, including the installation of experimental apparatus while still on the ground and was launched as an unmanned payload (SL-1) from Launch Complex 39A at KSC on 14 May 1973.

Though designed for an orbital life of 240 days during which three different crews visited her, Skylab is in operable condition today as revealed by the 1978 reactivation and ground interrogation. The Skylab space station was initially inserted into a virtually circular orbit 433.8 by 431.5 kilometers (approximately 270 miles); however, as of October 1978, the orbit had decayed to 360 kilometers (approximately 225 miles nm).

2.1.1 System Description and Mission Performance

The Skylab orbital configuration consists of five major elements as shown in Figure 2.1.1-1. These elements are (1) Multiple Docking Adapter (MDA) which provides the docking interface for visiting manned modules; (2) Apollo



Element	Multiple Docking Adapter	Apollo Telescope Mount	Airlock Module/Fixed Airlock Shroud	Instrument Unit	Orbital Workshop
Function	Docking Interface Controls & Displays	Solar Observation	Power Control & Distribution Environmental Control Utility Center Data System Extravehicular Activity Port	Launch Vehicle Control	Primary Living & Working Area Experiment Laboratory Stowage
Length (ft)	17.5	13.5	17.5	3.0	48.0
Diameter (ft)	10.0	-	10.0	21.5	21.5
Working Volume (cu ft)	1,140	-	613	-	9,550

Figure 2.1.1-1. Skylab Orbital Configuration

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Telescope Mount (ATM), containing the United States first manned telescope in space; (3) Airlock Module (AM) which provides an airlock to space and controls for operational systems; (4) Instrument Unit (IU) used only during launch and initial deployment; and (5) Orbital Workshop, containing crew quarters and accommodations and extensive experiment facilities.

Skylab was first visited by Astronauts Conrad, Kerwin, and Weitz during the SL-2 mission from 25 May to 22 June 1973. Fifty-five experiments and nine subsystem/operational detailed test objectives had been planned for SL-2. Of these, data were obtained on 46 experiments and nine subsystem/operational detailed test objectives. The experiments cancelled or having low performance were generally those of low priority.

The second visit, SL-3, was made by Astronauts Bean, Garriot, and Lausma from 28 July to 25 September 1973. Forty-four experiments, 14 science demonstrations, 11 student investigations, and eight subsystem/operational detailed test objectives were planned for the mission. The science demonstrations were included as candidates to be performed at crew option. Although all planned objectives were not completed, data were obtained on all but two. Only six of the original 14 science demonstrations were worked into the schedule by the crew. Further, data were obtained on 12 experiments, two science demonstrations, and eight special tests which had not been planned.

SL-4 was the third and final visit to Skylab. It was accomplished by Astronauts Carr, Gibson, and Pogue between 16 November 1973 and 8 February 1974. For SL-4, 56 experiments (including hydrogen alpha telescope and earth visual observations), 26 science demonstrations, 13 student investigations, and 15 subsystem/operational detailed test objectives were planned. In addition, plans were made to observe the comet "Kohautek" using hardware from six of the onboard corollary experiments and six Apollo Telescope Mount experiments. The science demonstrations were candidates to be performed at crew option. All planned objectives were not completed, but data were obtained on all except three. The crew scheduled only 11 of the 26 science demonstrations. In addition, data were obtained on five additional subsystem/operational detailed test objectives.

Figures 2.1.1-2 and 2.1.1-3 show a comparison between Mission Design Profile and the Mission Actual Profile for SL-1/2, SL-1/3 and SL-1/4. The overall

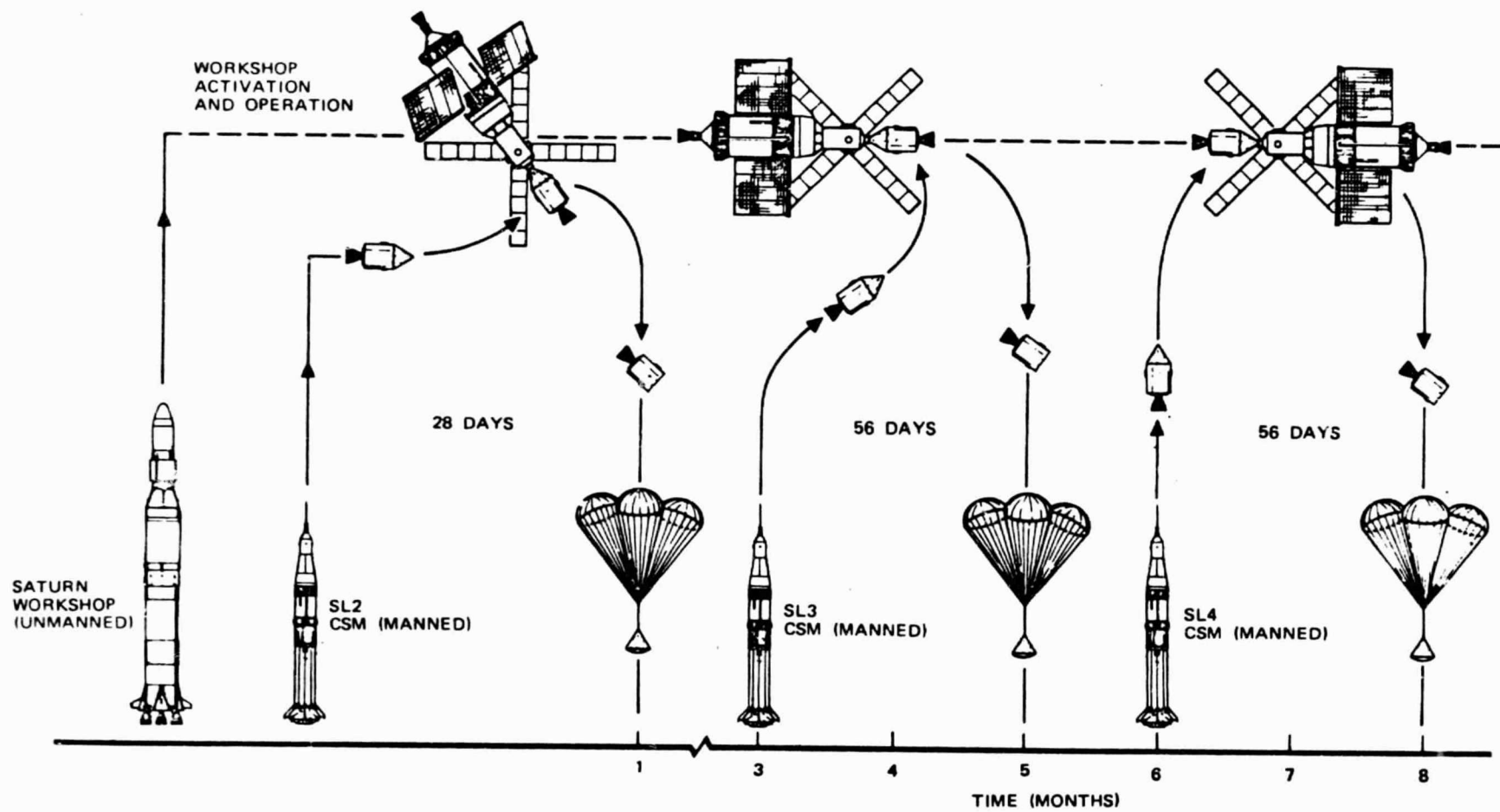


Figure 2.1.1-2. Mission Design Profile

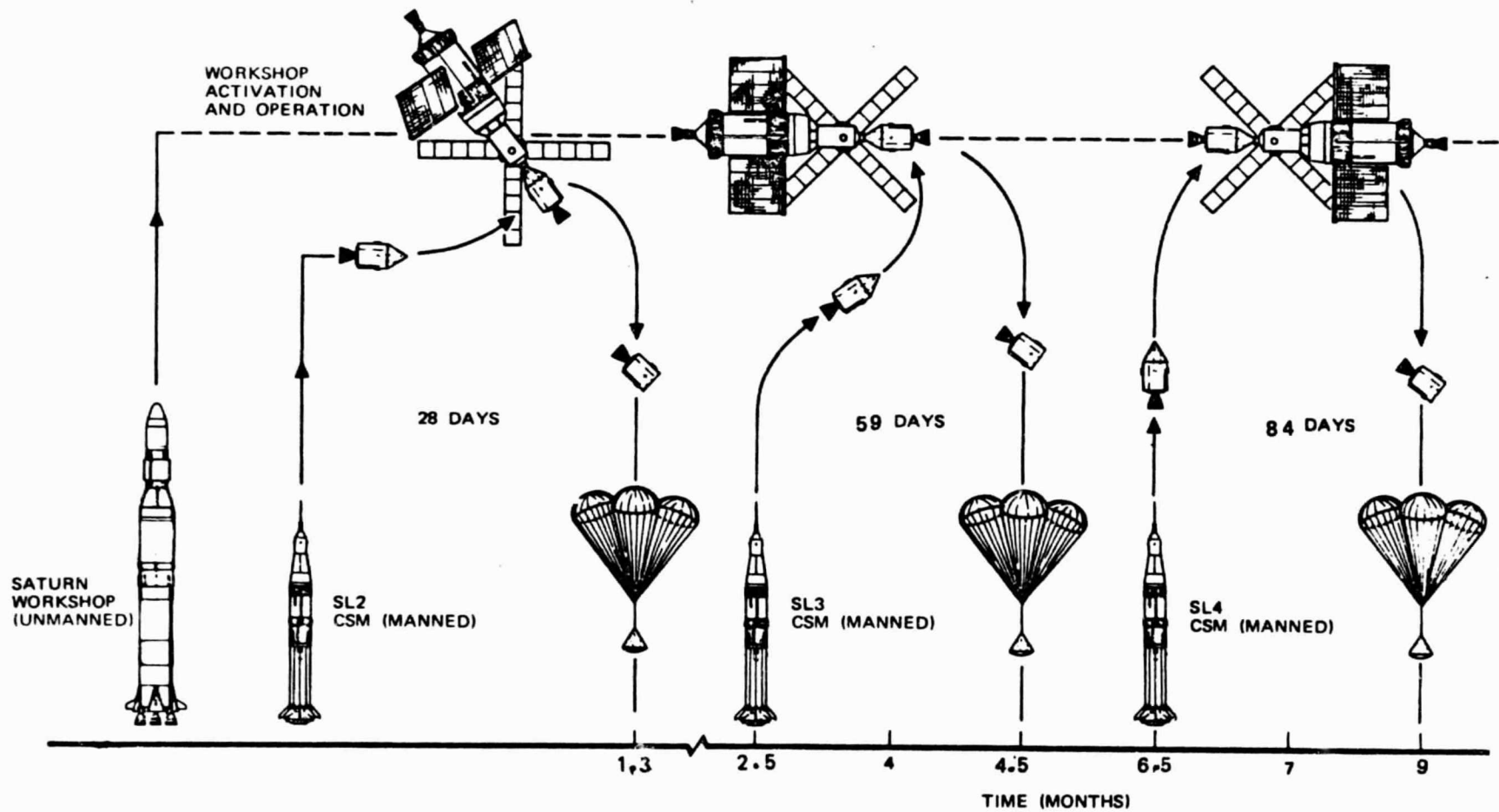


Figure 2.1.1-3. Mission Actual Profile

2.1.2 Airlock Module

The vital Skylab support systems are primarily located in the AM. The following information summarizes the end-of-mission (EOM) status and the current status as determined by the Skylab reactivation activities. From this data, the refurbishment requirements are outlined.

2.1.2.1 Airlock Module Subsystem Status

All airlock systems were fully operational at the end-of-mission. The system discrepancies that remained were relatively insignificant and had no effect on the capability to adequately support all mission objectives.

In summary, Airlock end-of-mission systems status was:

- o Structural/Mechanical System was fully operational with no reported discrepancies.
- o Thermal Control System was fully operational with ATM C&D Panel/EREP cooling loop flow fluctuation the only discrepancy. Loop cooling was adequate and periodic system deaeration with liquid/gas separator would restore full flow.
- o Environmental Control System was also operating normally with an occasional QD leakage on gas side of Condensate System being the only discrepancy. Problem was correctable by QD reconnection of capping.
- o EVA/IVA System was working perfectly with no problems. Leakage of SPTs LSU/PCU composite quick disconnect during last EVA depleted SUS 1 reservoir; system would have required reserVICING prior to next usage.
- o Electrical Power System was fully operational--total mission performance was exceptional with no anomalies reported.
- o Sequential System functioned successfully during SL-1/2 and was deactivated as planned.
- o Instrumentation System was operating normally with existing discrepancies having no effect on the capability to fully support the mission.
- o Communication System was also operating adequately--system redundancies and work-arounds effectively recovered full capability of the system.
- o C&W System was fully operational except for one parameter which was not critical to mission continuation.
- o Crew Systems were fully operational and capable of providing required crew support.

Following, by subsystem, is a tabulation of the end-of-mission, EOM status for the AM subsystems. Also included is a summary of today's status as determined during the reuse study and verified by the reactivation and interrogation of Skylab.

Structural/Mechanical Systems

All AM structural/mechanical systems were fully operational at EOM.

Table 2.1.2.1-1 presents a summary of the EOM status. The status today is as follows.

Pressure integrity was checked by pressurizing the cabin to 0.6 psia and monitoring pressure decay and temperature with time. Conversion of the decay data to leakage rate indicates the rate is still within the 10.46 lb/day specification allowable leakage and somewhat higher than the 2.68 lb/day leakage measured four years ago.

Citings have indicated the general configuration is as expected. These data together with the low orbital loads indicate the structural/mechanical system is in good condition.

Thermal Control System

The TCS performed so effectively that original mission objectives were expanded and all mission objectives were accomplished. Designed-in redundancies and real-time work-around procedures were used to alleviate the effect of system discrepancies that did occur. The EOM status is summarized in Table 2.1.2.1-2.

Following is today's status. The active system is shut down due to insufficient coolant in the primary and secondary loops. Adequate equipment to service both loops and 34.3 lb of coolant were left onboard. The primary loop was serviced with 7.7 lb of coolant on DOY 323 of 1973. During the interrogation (March to June 1978) pressure in the primary loop was 21.8 psia. Both the primary and secondary coolant systems were operated during the interrogation and performed normally. This indicates that the equipment in both loops is in good condition and that little leakage from either loop occurred during the dormant period. The loops were shut down after going to the colder EOVV vehicle attitude in early June 1978.

The passive system is in good condition as indicated by the nominal temperatures recorded during the interrogation. The electrical power and communication systems are being operated cyclically to permit operation with passive temperature control.

Table 2.1.2.1-1
 END-OF-MISSION STATUS
 AIRLOCK STRUCTURAL/MECHANICAL SYSTEM

<u>SYSTEM/OPERATIONAL FUNCTION</u>	<u>SUBSYSTEM/COMPONENT</u>	<u>EOM STATUS</u>
o MAINTAIN PRESSURE INTEGRITY.	AIRLOCK MODULE (STS, TUNNEL AND FLEX TUNNEL EXTENSION) HATCH SEALS	LEAKAGE RATE WELL WITHIN SYSTEM ALLOWABLE; NO INCREASE IN LEAKAGE RATE NOTED DURING MISSION. SEALS IN EXCELLENT CONDITION; NO DEGRADATION IN SEALING CAPABILITY
o PROVIDE RIGIDITY AND DAMPING CHARACTERISTICS REQUIRED TO MAINTAIN EXPERIMENTS AND ATM POINTING ACCURACIES.	DEPLOYMENT ASSEMBLY (RIGIDIZING AND LATCHING MECHANISM)	BOTH MECHANISMS FULLY LATCHED; NO EFFECT ON EXPERIMENT OR ATM OPERATION.
o PROVIDE AN EVA CAPABILITY.	EVA AND INTERNAL HATCH MECHANISMS	OPERATION OF ALL HATCH MECHANISMS WAS SMOOTH WITH NO REPORTED OPENING OR CLOSING PROBLEMS.
o PROVIDE A MOVABLE PROTECTIVE COVER FOR STS WINDOWS.	EXTERNAL MOVABLE COVER ASSEMBLY	WINDOW COVER MECHANISM OPERATING AS EXPECTED WITH NO SIGNIFICANT CHANGE IN CRANK LOADS.

Table 2.1.2.1-2
 END-OF-MISSION STATUS
 AIRLOCK THERMAL CONTROL SYSTEM

<u>SYSTEM/OPERATIONAL FUNCTION</u>	<u>SUBSYSTEM/COMPONENT</u>	<u>EOM STATUS</u>
o PROVIDE CLUSTER ATMOSPHERIC COOLING, AM EQUIPMENT COOLING, EVA SUIT COOLING AND ATM C&D/ EREP COOLING BY CIRCULATING COOLANT FLUID.	ACTIVE COOLANT SYSTEM - PRIMARY AND SECONDARY LOOPS	BOTH COOLANT SYSTEMS WORKING NORMALLY o PRIMARY SYSTEM SUCCESSFULLY RESERVICED DURING SL-4. o SECONDARY SYSTEM RESERVOIR LOW LIGHT ACTIVATED ON LAST DAY OF SL-4 - RE-SERVICE KIT AVAILABLE. o ALL SIX PUMPS OPERATING NORMALLY - ONE OF SIX INVERTERS INOPERATIVE.
o PROVIDE A HEAT SINK FOR EXCESS HEAT DISPOSAL.	ACTIVE COOLANT SYSTEM - RADIATOR AND THERMAL CAPACITOR	RADIATOR/THERMAL CAPACITOR WORKING NORMALLY. HEAT REJECTION CAPABILITY EXCEEDED REQUIREMENT. DATA INDICATED SLIGHT INCREASE IN ABSORPTIVITY.
o PROVIDE CONTROLLED COOLANT TEMPERATURES FOR SELECTED COMPONENT GROUPS.	ACTIVE COOLANT SYSTEM - THERMAL CONTROL VALVES (TCV)	ALL TCV'S OPERATING NORMALLY.
o MAINTAIN THE TEMPERATURE OF ELECTRICAL POWER CONDITIONING.	ACTIVE COOLING SYSTEM - SUIT/BATTERY MODULE, BATTERY HEAT EXCHANGER	SYSTEM WORKING NORMALLY; TEMPERATURE OF COOLANT ENTERING THE BATTERY MODULE HAD BEEN MAINTAINED AT APPROXIMATELY 40°F EXCEPT DURING HIGH BETA ANGLES.
o PROVIDE ACTIVE COOLANT SYSTEM ACROSS MDA/STS I/F TO COOL ATM C&D/EREP EQUIPMENT.	ATM C&D/EREP COOLING SYSTEM	SYSTEM PERFORMANCE ADEQUATE o FLUCTUATION OF FLOW APPARENTLY CAUSED BY GAS IN SYSTEM - FULL FLOW RESTORED BY PERIODIC USE OF SPARE LIQUID/GAS SEPARATOR. o ALL THREE PUMPS FULLY OPERATIONAL.
o REMOVE HEAT FROM ATM C&D/EREP COOLING SYSTEM.	ATM C&D/EREP COOLING SYSTEM - HEAT EXCHANGER	NORMAL PERFORMANCE; OPERATING WITHIN REQUIRED TEMPERATURE RANGE.

Table 2.1.2.1-2 (cont'd)
 END-OF-MISSION STATUS
 AIRLOCK THERMAL CONTROL SYSTEM

<u>SYSTEM/OPERATIONAL FUNCTION</u>	<u>SUBSYSTEM/COMPONENT</u>	<u>EOM STATUS</u>
o PROVIDE THERMAL CONTROL FOR FAS INSTALLED EQUIPMENT.	THERMAL COATINGS - FAS INTERIOR/EXTERIOR COATINGS, TUNNEL WALL AND STS BULKHEAD EXTERIOR COATINGS.	PERFORMANCE NORMAL - ALL TEMPERATURE READINGS AS EXPECTED - NO SIGNIFICANT DEGRADATION DURING THE MISSION.
	THERMAL AND METEOROID CURTAINS.	PERFORMANCE NORMAL - ALL TEMPERATURES AS EXPECTED.
o PROTECT WATER SYSTEMS FROM FREEZING.	MICROFOIL INSULATION (EXTERNAL)	WORKING NORMALLY - COLDER THAN DESIGN CONDITIONS OCCURRED EARLY IN MISSION WITH NO APPARENT PROBLEMS FROM SYSTEM FREEZING.
o PREVENT CONDENSATION ON WATER AND COOLANT LINES.	MOSITE INSULATION (INTERNAL)	WORKING NORMALLY - NO CONDENSATION PROBLEM REPORTED.
o MAINTAIN AM COMPARTMENT WALL TEMPERATURE ABOVE MINIMUM SPECIFIED LIMIT.	AM WALL HEATERS - HEATING ELEMENT, THERMOSTATS.	WORKING NORMALLY - TEMPERATURES WERE MAINTAINED WITHIN SPECIFIED LIMITS THROUGHOUT THE MISSION.
o MAINTAIN MOLECULAR SIEVE EXHAUST DUCT TEMPERATURE ABOVE WATER FREEZING TEMPERATURE.	MOLECULAR SIEVE EXHAUST DUCT HEATERS - HEATING ELEMENT, THERMOSTATS.	WORKING NORMALLY.

Environmental Control System

The ECS performed so effectively that all mission objectives were accomplished in spite of the off-nominal conditions to which the total vehicle was exposed during the first few days of the SL-1/SL-2 mission. System discrepancies during the mission were corrected by designed-in system redundancies or by real-time work-around procedures. The end-of-mission status is summarized on Table 2.1.2.1-3. The interrogation showed 2505 lb O₂ or 41% of the initial fill quantity still remains onboard. In addition, 605 lb of N₂ or 37% of the initial fill quantity still remains onboard. Consequently both the O₂ and N₂ storage systems are in good condition.

Valves in the pressurization subsystem were opened and closed by DCS command to pressurize the cabin. Consequently, at least portions of this subsystem were proven to be functional. All of this system could be checked, using a procedure presented in Appendix Q if desired.

The ability of the O₂/N₂ pressurization subsystem to provide thrust for attitude control was investigated for the interrogation. It was concluded that the pressurization system O₂/N₂ cannot be used for Skylab Attitude Control or Spin-up by forcing it through the cabin pressure relief valves as the crew compartment cannot be overpressurized by DCS command. Pressure switches automatically cut off gas flow to the cabin when the cabin pressure reaches 5.0 ±0.2 psia in this mode of operation. Relief valves cracking pressures are shown below.

<u>Valve Location</u>	<u>Specification</u>	<u>Crack Verification - PSID</u>		<u>Leakage at 5.35 PSID</u>
		<u>Factory</u>	<u>KSC</u>	
FWD	Crack and reseal between	5.65	5.68	15 SCCM
LOCK	5.5 and 6 PSID	5.72	5.72	10 SCCM
AFT		5.70	5.78	0 SCCM

Verification of the atmospheric control, condensate, and in-flight water Servicing/Deservicing systems requires an onboard crew. However, the favorable thermal environment and the good condition of other equipment provides some assurance that this equipment probably is still functional.

Table 2.1.2.1-3

END-OF-MISSION STATUS

AIRLOCK ENVIRONMENTAL CONTROL SYSTEM

<u>SYSTEM/OPERATIONAL FUNCTION</u>	<u>SUBSYSTEM/COMPONENT</u>	<u>EOM STATUS</u>
o PROVIDE GAS STORAGE SYSTEM TO SUPPORT PRESSURIZATION REQUIREMENTS.	GAS STORAGE SYSTEM - O ₂ /N ₂ TANKS	NORMAL PERFORMANCE - NO DETECTABLE LEAKAGE; O ₂ REMAINING 2609 LBS; N ₂ REMAINING 609 LBS.
o AUTOMATICALLY MAINTAIN ATMOSPHERIC PRESSURE TO 5 + 0.2 PSIA WITH PPO ₂ OF 3.6 ± 0.3 PSIA.	ATMOSPHERE CONTROL SYSTEM - TWO GAS CONTROL SYSTEM	ALL REGULATORS PERFORMING NORMALLY - PROBLEM WITH 150 PSI N ₂ REGULATOR CLEARED SELF DURING SL-4. PPO ₂ SENSOR WORKING CORRECTLY.
o LIMIT THE MAXIMUM ATMOSPHERIC PRESSURE TO 6.0 PSIG AFTER ACTIVATION.	CABIN PRESSURE RELIEF VALVES.	FUNCTIONING NORMALLY.
o PROVIDE CAPABILITY TO PRESSURIZE/DEPRESSURIZE CLUSTER, INCLUDING LOCK COMPARTMENT.	GAS SYSTEM - VENTS	FUNCTIONING NORMALLY - REMOVABLE SCREEN FOR AIRLOCK DEPRESS VALVE FLOWN ON SL-3; ALLOWS QUICK REMOVAL OF ICE BUILDUP.
o PROVIDE CAPABILITY TO MAINTAIN ATMOSPHERIC PRESSURE BETWEEN 0.5 PSI AND 1.5 PSI DURING ORBITAL STORAGE.	GAS SYSTEM - REGULATORS, CONTROL VALVES	FUNCTIONING NORMALLY.
o CONTROL HUMIDITY LEVEL IN CLUSTER.	ATMOSPHERIC CONTROL SYSTEM - COOLANT SYSTEM, CONDENSING HEAT EXCHANGER, WATER SEPARATOR ASSEMBLY.	FUNCTIONING NORMALLY - ALL CONDENSING HEAT EXCHANGERS FULLY OPERATIONAL. SPARE WATER SEPARATOR ASSEMBLIES AVAILABLE.
o DISPOSE OF CONDENSATE BY TRANSFER TO OWS HOLDING TANK OR VENTING OVERBOARD.	CONDENSATE SYSTEM - LINES, VALVES, TANKS, QUICK DISCONNECTS	PERFORMANCE ADEQUATE - OCCASIONALLY FAILED TO HOLD VACUUM - CORRECTED BY OD RECONNECTION OR CAPPING. O-RING LUBRICANT PROCEDURE ON-BOARD.

Table 2.1.2.1-3 (cont'd)
 END-OF-MISSION STATUS
 AIRLOCK ENVIRONMENTAL CONTROL SYSTEM

<u>SYSTEM/OPERATIONAL FUNCTION</u>	<u>SUBSYSTEM/COMPONENT</u>	<u>EOM STATUS</u>
o REMOVE CARBON DIOXIDE AND ODORS FROM CLUSTER ATMOSPHERE.	ATMOSPHERIC CONTROL SYSTEM - MOLECULAR SIEVE SYSTEM, PPCO ₂ DETECTORS.	BOTH MOLECULAR SIEVE SYSTEMS ARE FULLY OPERATIONAL. JUMPER CABLE FLOWN ON SL-4 TO ALLOW POWERING OF SIEVE B FAN FROM SIEVE A INVERTER. PPCO ₂ DETECTOR PERFORMANCE IS ADEQUATE - ALL SENSORS RESPOND TO CO ₂ LEVEL CHANGE AND MOLE SIEVE A SENSOR WAS PERFORMING NORMALLY - PERIODIC CHECKS MADE WITH M171.
o PROVIDE ATMOSPHERIC TEMPERATURE CONTROL (60° TO 90°F).	ATMOSPHERIC CONTROL SYSTEM - COOLANT SYSTEM, HEAT EXCHANGERS, FANS, DUCTS.	SYSTEM WORKING NORMALLY.
o PROVIDE ATMOSPHERIC CIRCULATION THROUGHOUT CLUSTER.	ATMOSPHERIC CONTROL SYSTEM - COOLANT SYSTEM, HEAT EXCHANGERS, FANS, DUCTS.	SYSTEM PERFORMANCE SATISFACTORY - PERIODIC VACUUMING OF OWS HEAT EXCHANGERS RESTORED FULL FLOW.
o PROVIDE INFLIGHT SERVICING OF WATER SEPARATOR PLATES.	INFLIGHT WATERING SYSTEM - TANKS, HOSES, VALVES, QUICK DISCONNECTS.	WORKING NORMALLY.

EVA/IVA Suit System

The EVA/IVA system performed well enough to include some lengthy and strenuous workshop repair tasks, resulting in expansion of original mission objectives. All mission objectives were accomplished and at no time was crew safety compromised. Airlock Module systems provided support for 12 EVA/IVA operations of up to seven hours duration. Oxygen flow was normal on each occasion. Satisfactory water cooling was supplied for all other EVA operations. Operation of the lock compartment was accomplished normally. A summary is presented in Table 2.1.2.1-4. The status of the suit system today is as follows.

Liquid-cooled garment water inlet temperatures were monitored during the interrogation and found to be normal which is near freezing. Further checking of this system is not feasible until a crew is onboard.

Table 2.1.2.1-4
 END-OF-MISSION STATUS
 AIRLOCK EVA/IVA SUIT SYSTEM

<u>SYSTEM/OPERATIONAL FUNCTION</u>	<u>SUBSYSTEM/COMPONENT</u>	<u>EOM STATUS</u>
o SUPPLY O ₂ TO THREE UMBILICALS TO PROVIDE EVA/IVA SUIT ATMOSPHERE CONTROL TEMPERATURE AND PRESSURE.	EVA/IVA O ₂ SUPPLY - REGULATORS, LINES VALVES, QUICK DISCONNECTS, HEAT EXCHANGER	SYSTEM WORKING NORMALLY. ADEQUATE COOLING PROVIDED ON ONE EVA BY O ₂ FLOW ONLY.
o SUPPLY WATER COOLING SYSTEM FOR EVA/IVA TEMPERATURE - PROVIDE HEATING OR COOLING AS REQUIRED.	SUS COOLING LOOPS - PUMPS, LINES, VALVES, HEAT EXCHANGER.	BOTH SUS LOOPS FULLY OPERATIONAL - ALL FOUR PUMPS OPERATIONAL. SUS #1 RESERVOIR DEPLETED DURING FINAL EVA.
o PROVIDE CAPABILITY TO CONNECT UMBILICALS IN STS OR LOCK COMPARTMENT.	EVA CONTROL PANELS, IVA CONTROL PANEL, DISCONNECT	ALL EVA/IVA CONTROL PANELS FULLY OPERATIONAL.
o PROVIDE LIQUID/GAS SEPARATOR TO CONTROL GAS IN WATER LOOP.	SUS COOLING LOOPS	LIQUID/GAS SEPARATOR FUNCTIONING NORMALLY. o ONE SPARE GAS SEPARATOR ASSEMBLY AVAILABLE. o ONE SPARE GAS SEPARATOR ASSEMBLY EFFECTIVELY USED TO REMOVE GAS FROM ATM C&D LOOP.
o PROVIDE CAPABILITY TO STOW TWO UMBILICALS.	UMBILICAL STORAGE CONTAINERS.	FUNCTIONING AS PLANNED.
o PROVIDE FOR SUS LOOP RESERVICING.	INFLIGHT SERVICING SYSTEM - HOSES, VALVES, QUICK DISCONNECTS, DEIONIZER.	SYSTEM FULLY OPERABLE o SUS LOOP SATISFACTORILY SERVICED DURING MISSION. o SUS LOOP #1 REQUIRES RESERVICING.

Electrical Power System

Upon completion of Skylab missions the EPS was configured into a "dormant" mode with the batteries and all switchable buses off. The non-switchable EPS control bus is powered during periods of sufficient solar array illumination. All eight PCGs were operating properly at ground monitoring termination, and could have continued to supply baseline performance indefinitely. A status summary is shown in Table 2.1.2.1-5.

The EPS status today is as follows. Three power conditioning groups were successfully activated in early March 1978. Skylab orientation was determined to be a coning-roll making one revolution every four minutes. AM and ATM batteries were charged in late April/early May. The Skylab was placed into solar inertial attitude in early June and into End-on Velocity Vector (EOVV) attitude on June 11, 1978. On June 9, orientation was lost due to ATM electrical power loss. Batteries were recharged and Skylab reoriented to a solar inertial attitude on July 19. It was placed in EOVV on July 25, 1978 and has been maintained in this attitude ever since then.

OWS solar arrays have degraded less than 10%. Seven of the eight power conditioning groups and nine of 18 charger, battery, regulator modules are operative. Consequently, the electrical power systems are in very good condition.

Instrumentation System (IS)

The IS was operational during all phases of the Skylab mission and successfully acquired, multiplexed and encoded selected vehicle systems, experiment and biomedical data. Data handling included telemetry downlink, crew displays and PCM hardline for prelaunch utilization.

During the mission, the system sampled and encoded over 1200 input parameters and transmitted in real-time approximately 4×10^{11} bits of data. An additional 10^{11} bits of data, excluding voice comments, were recorded on the AM tape recorders and transmitted during delayed time data dumps. Over 3650 delayed time data dumps were successfully initiated. Following the resolution of early mission STDN station(s) PCM bit synchronization problems, ground recovery of all data was consistently good.

Table 2.1.2.1-5
 END-OF-MISSION STATUS
 AIRLOCK ELECTRICAL POWER SYSTEM

<u>SYSTEM/OPERATIONAL FUNCTION</u>	<u>SUBSYSTEM/COMPONENT</u>	<u>EOM STATUS</u>
<ul style="list-style-type: none"> o RECEIVE AND CONDITION SOLAR ARRAY POWER FROM THE OWS ARRAY. 	BATTERY CHARGERS, BATTERIES, VOLTAGE REGULATORS, RELAYS, CIRCUIT BREAKERS,	ELECTRICAL POWER SYSTEM FULLY OPERATIONAL <ul style="list-style-type: none"> o NO REPORTED ANOMALIES OR SUSPECTED MALFUNCTIONS.
<ul style="list-style-type: none"> o PROVIDE FOR DISTRIBUTION OF POWER TO SYSTEM LOADS AND TO BATTERY CHARGING. 	SWITCHES, POTENTIOMETERS, INSTRUMENTATION, DCS CONTROL AND WIRING SYSTEM.	<ul style="list-style-type: none"> o ALL BATTERIES FULLY OPERATIONAL <ul style="list-style-type: none"> 1) APPROXIMATELY 3800 BATTERY CYCLES THROUGH SL-4. 2) DEGRADATION RATE LOWER THAN PREDICTED.
<ul style="list-style-type: none"> o PROVIDE FOR CONTROL OF POWER TRANSFER BETWEEN THE AM, ATM, AND CSM. 		

Although some discrepancies occurred during the mission with certain sensors, low level multiplexers and tape recorders, the system concept and design proved more than adequate for meeting the unique mission requirements and for handling the large quantity of data involved. The end-of-mission status of the IS is summarized on Table 2.1.2.1-6.

Today's status of the instrumentation system is that it worked perfectly during the early interrogation. Following the first power loss communications were lost. The anomaly was diagnosed by NASA as a DC-DC converter failure. Data system operation was restored by switching to the backup system.

Later in the mission about 150 measurements on subframe 2 were lost. This anomaly was diagnosed by NASA as failure of card F2 in the signal conditioner box within electronics module 3. Adequate data still is available and the mission is being continued.

Communication System

The end-of-mission status of the communication system is shown in Table 2.1.2.1-7. Today's status is that the data transmission, antenna, and digital command systems were successfully activated in early March 1978. They have been performing well and are still in use.

Caution and Warning System

The system was operational during all manned phases of the mission and successfully monitored all 76 preselected parameters relieving the crew to perform other assigned activities. The crew reported that the C&W system performed in an outstanding manner and that they were well pleased with all C&W System/crew interfaces; i.e., system control/inhibit switches, audio alarms, indicator lights, parameter categories, memory recall, and system reset capabilities. A summary of the end-of-mission status is presented on Table 2.1.2.1-8.

Since the caution and warning system is a crew alert system it was designed to be activated by the crew and has not been operated during the interrogation. The environment has been monitored during the interrogation and found to be quite nominal. Consequently the systems condition is not expected to have changed since the end of the mission.

Table 2.1.2.1-6
 END-OF-MISSION STATUS
 AIRLOCK INSTRUMENTATION SYSTEM

<u>SYSTEM/OPERATIONAL FUNCTION</u>	<u>SUBSYSTEM/COMPONENT</u>	<u>EOM STATUS</u>
<ul style="list-style-type: none"> o ACQUIRE, MULTIPLEX AND DATA FROM THE AM, OWS AND MDA AND PROVIDE IT: <ul style="list-style-type: none"> 1) VIA TELEMETRY, FOR REAL-TIME COVERAGE 2) VIA TAPE RECORDING, FOR CONTINUOUS COVERAGE 3) VIA PANEL DISPLAYS, FOR CREWMEN 	INSTRUMENTATION SYSTEM INCLUDING: <ul style="list-style-type: none"> o PROGRAMMERS (2) o MULTIPLEXERS (13 in AM; 12 IN OWS) o INTERFACE BOX o DC-DC CONVERTERS (5) o TAPE RECORDERS <ul style="list-style-type: none"> 3 ACTIVE 4 SPARE 2 LAUNCHED ON SL-3 o SENSORS AND SIGNAL CONDITIONERS o PORTABLE TIMERS (4) 	SYSTEM OPERATING NORMALLY EXCEPT: <ul style="list-style-type: none"> o 79 PARAMETERS OUT OF APPROXIMATELY 1400 WERE KNOWN TO BE PARTIALLY OR TOTALLY DEGRADED: <ul style="list-style-type: none"> 1) 8 CHANNELS IN EACH AM LOW LEVEL MULTIPLEXER WERE NOISY 2) 3 FLOWMETER SENSORS FAILED 3) ONE SIGNAL CONDITIONER DEGRADED SYSTEM FULLY CAPABLE OF SUPPORTING ALL MISSION OBJECTIVES. ALL REDUNDANT COMPONENTS FULLY OPERATIONAL. <ul style="list-style-type: none"> o TAPE RECORDER STATUS: <ul style="list-style-type: none"> 3 INSTALLED AND OPERATIONAL 3 AVAILABLE AS SPARES 2 REPAIRABLE USING REPAIR KIT AND PROCEDURES LAUNCHED ON SL-4 1 FAILED

Table 2.1.2.1-7
 END-OF-MISSION STATUS
 AIRLOCK COMMUNICATION SYSTEM

<u>SYSTEM/OPERATIONAL FUNCTION</u>	<u>SUBSYSTEM/COMPONENT</u>	<u>EOM STATUS</u>
<ul style="list-style-type: none"> o PROVIDE ELAPSED TIME TO TELEMETRY AND TO CREW DISPLAY PANEL; PROVIDE TIMED RESET OF COMMAND FUNCTIONS; PROVIDE TIMED AUTOMATIC SWITCHOVER 	TIME REFERENCE SYSTEM: <ul style="list-style-type: none"> o ELECTRONIC TIMERS (3) o TIME CORRELATION BUFFERS (2) o DIGITAL DISPLAY UNIT (2 ACTIVE, 1 SPARE) o DIGITAL CLOCK 	ENTIRE SYSTEM FUNCTIONING NORMALLY: <ul style="list-style-type: none"> o ALL REDUNDANT UNITS FUNCTIONING. o DDU SPARE UNIT NOT USED.
<ul style="list-style-type: none"> o DETERMINE RANGE AND RANGE RATE DURING RENDEZVOUS; PROVIDE MEANS FOR VISUAL LOCATION OF SWS DURING RENDEZVOUS; PROVIDE ORIENTATION INFORMATION DURING DOCKING. 	RENDEZVOUS AND DOCKING SUBSYSTEM: <ul style="list-style-type: none"> o VHF TRANSCEIVER o RANGING TONE TRANSFER ASSEMBLY o TRACKING LIGHTS (4) o DOCKING LIGHTS (8) 	ENTIRE SYSTEM FUNCTIONING NORMALLY: <ul style="list-style-type: none"> o REDUNDANT TRACKING LIGHTS WERE NEVER OPERATED.
<ul style="list-style-type: none"> o PROVIDE TRANSMISSION OF REAL-TIME AND DELAYED-TIME TELEMETRY AND DELAYED-TIME VOICE; PROVIDE FOR RECEPTION OF COMMAND DATA; PROVIDE SELECTION BETWEEN ANTENNAS TO OPTIMIZE TRANSMISSION AND RECEPTION 	DATA TRANSMISSION AND ANTENNA SUBSYSTEM: <ul style="list-style-type: none"> o 2-WATT TRANSMITTER o 10-WATT TRANSMITTERS (3) o DISCONE ANTENNAS (2) o STUB ANTENNAS (2) o QUADRIPLXER 	ENTIRE SUBSYSTEM FUNCTIONING NORMALLY EXCEPT EXCEPT FOR FAILED 10-WATT TRANSMITTER: <ul style="list-style-type: none"> o 3 TRANSMITTER CONFIGURATION MAINTAINED WITH 2-WATT TRANSMITTER. o PCM S-BAND CABLE LAUNCHED ON SL-4 WOULD PROVIDE DAPABILITY TO DOWNLINK AM RECORDED DATA VIA CSM S-BAND SYSTEM--NOT INSTALLED.

Table 2.1.2.1-7 (continued)
 END-OF-MISSION STATUS
 AIRLOCK COMMUNICATION SYSTEM

<u>SYSTEM/OPERATIONAL FUNCTION</u>	<u>SUBSYSTEM/COMPONENT</u>	<u>EOM STATUS</u>
o PROVIDE COMMAND CAPABILITY TO: 1) PROVIDE GROUND CONTROL OF ONBOARD SWITCHING FUNCTIONS. 2) UPDATE THE TIME REFERENCE SUBSYSTEM. 3) SEND UPDATE MESSAGES TO THE TELEPRINTER.	DIGITAL COMMAND SUBSYSTEM: o RECEIVER/DECODERS (2) o RELAY MODULES (4) o COMMAND RELAY DRIVER UNIT.	ENTIRE SUBSYSTEM FUNCTIONING NORMALLY EXCEPT COMMAND NO. 19.3 (EXP 2/DATA 2 TAPE RECORDER FAST FORWARD) WHICH WAS DETERMINED UNUSABLE BECAUSE OF A RESET PROBLEM. o BOTH PRIMARY AND SECONDARY SYSTEMS FUNCTIONAL AT EOM.
43 o PROVIDE HARD COPY UPLINK MESSAGES TO CREW.	TELEPRINTER SUBSYSTEM o TELEPRINTERS (1 ACTIVE, 1 SPARE) o INTERFACE ELECTRONICS UNIT o SPARE CARTIDGE AND SPOOL o PAPER (156 ROLLS)	SUBSYSTEM FUNCTIONING NORMALLY o REPAIR KIT LAUNCHED ON SL-4 TO REPAIR FAILED DRIVE ROLLER ON SPARE TELEPRINTER. o OVER 100 ROLLS OF PAPER AVAILABLE.
o PROVIDE REAL-TIME VOICE COMMUNICATION BETWEEN CREW MEMBERS AND BETWEEN CREW AND THE GROUND; PROVIDE RECORDING OF CREW VOICE; PROVIDE TWO CHANNEL OPERATION.	AUDIO SUBSYSTEM o SPEAKER INTERCOM ASSEMBLIES (13 ACTIVE, 2 SPARE) o AUDIO LOAD COMPENSATORS (2) o CREWMAN COMMUNICATION UMBILICALS (3) o LIGHTWEIGHT CCUs (8) o LCCU CONTROL HEADS (4)	ENTIRE SYSTEM FUNCTIONING NORMALLY EXCEPT: o VOICE RECORD CAPABILITY AVAILABLE FROM CHANNEL A ONLY. o EARPHONE LINE DEGRADED ON CHANNEL B. o EMERGENCY/TAPE RECORDER VOICE CABLE PROVIDED MICROPHONE LINE AUDIO FOR TAPE RECORDING OR EMERGENCY DOWNLINK, BYPASSING FAILED ALC; LAUNCHED ON SL-4; INSTALLED, THEN REMOVED. o BOTH SPARE SIAs USED

Table 2.1.2.1-8
 END-OF-MISSION STATUS
 AIRLOCK CAUTION AND WARNING SYSTEM

<u>SYSTEM/OPERATIONAL FUNCTION</u>	<u>SUBSYSTEM/COMPONENT</u>	<u>EOM STATUS</u>
CAUTION AND WARNING	C&W SUBSYSTEM, EMERGENCY SUBSYSTEM: o C&W UNIT o HLAA o KLAXON ASSYS (2) o C&W SIGNAL CONDITIONING PACKAGES (2) o C&W DISPLAY CONVERTERS (2) o CONTROL PANELS o FSCP'S (12 ACTIVE, 2 SPARE) o FSA'S (22 ACTIVE, 6 SPARE)	SYSTEM FULLY OPERATIONAL EXCEPT FOR ONE EVA PARAMETER - EVA LCG-1 PUMP DELTA P (K931): o REDUNDANT COMPONENTS ALL OPERATIONAL. o ONE SPARE FIRE SENSOR CONTROL PANEL AVAILABLE, REPLACED UNIT AVAILABLE AS SPARE FOR LOCATIONS REQUIRING ONLY SIDE 1.

Experiments and M509 Nitrogen Recharge Station

Table 2.1.2.1-9 provides a summary on end-of-mission status for the AM experiments and recharge station. The status today is presumed to be EOM status. Since the experiments are man-dependent they could not be checked out during the interrogation. They have been stored in a favorable environment which would tend to preserve this end-of-mission condition.

No resupply requirements have been identified.

Table 2.1.2.1-9
 END-OF-MISSION STATUS
 AIRLOCK EXPERIMENTS AND NITROGEN RECHARGE STATION

<u>SYSTEM/OPERATIONAL FUNCTION</u>	<u>SUBSYSTEM/COMPONENT</u>	<u>EOM STATUS</u>
o PROVIDE HIGH PRESSURE N ₂ to M509/T020 PROPELLANT SUPPLY SUBSYSTEM (PSS)	M509 RECHARGE STATION	RECHARGE STATION IS FULLY OPERATIONAL-- N ₂ SUPPLY PRESSURE IS APPROXIMATELY: o 670 PSI IN TANKS 3, 4, 5 AND 6. o 1850 PSI IN TANKS 1 AND 2.
o PROVIDE SUPPORT FOR D024 THERMAL CONTROL MATERIALS	D024 MODULE AND SUPPORT STRUCTURE	D024 MODULE IN PLACE; ALL SNAPS AND RELEASE PINS FULLY OPERATIONAL: ALL SAMPLES AND CONTAINERS REMOVED.
o PROVIDE MOUNTING SUPPORT FOR S230 FOIL SAMPLES	S230 MAGNETOSPHERE PARTICLE COLLECTOR MOUNTING	HOLDER SPOOLS REMAIN MOUNTED ON DA TRUSS. ALL FOIL SAMPLES REMOVED.
o PROVIDE ELECTRICAL POWER AND MOUNTING SUPPORT FOR S193.	S193 SUPPORT BRACKETS, ELECTRICAL WIRING.	S193 FULLY OPERATIONAL - MOUNTED ON DA.
o PROVIDE MOUNTING SUPPORT FOR RADIO NOISE BURST MONITOR (RNBA) ANTENNA	RNBA SUPPORT STRUCTURE, COAX CABLE	RNBA FULLY OPERATIONAL - ANTENNA IN PLACE ON AM TRUSS #4.

2.1.2.2 Airlock Module Refurbishment/Resupply Requirements and Kit Descriptions

The following subsections collect the refurbishment/resupply requirements for the AM subsystems. Included are the refurb kit descriptions. Later in the report these kits are collected together with OWS kits and integrated into the Inspection/Refurbishment Plan and Operations discussed in Section 2.4.

Structure/Mechanical Systems

No refurbishment/resupply requirements have been identified for these AM systems.

Thermal Control System

The coolant reservicing equipment provides the ability to top off both coolant loops with Coolanol 15 to replenish coolant lost through leakage. The hardware used for reservicing is shown on Figure 2.1.2.2-1. The basic method involved pressurizing the coolant supply tank with 35 psig N₂, and forcing coolant into the loop through a line-piercing saddle valve.

Hardware and procedures were developed during the SL-3 mission for reservicing the coolant loops due to the gradual loss of coolant from both loops. The reservicing hardware (except for the 60-foot hose assembly) and procedures were launched with SL-4, and the primary coolant loop was reserviced during the SL-4 mission. A reservice kit is recommended to assure ability to reservice the coolant loops and provide sufficient equipment for subsequent reservicings.

A liquid gas separator was proposed as a replacement for the filter in the ATM C&D/ERP cooling system. The gas vent would be connected to the water separator service fitting. In addition, a supply of replacement liquid gas separators will be required.

The addition of the Power Module to the Skylab cluster with its associated increase in the power available to the Skylab will ultimately result in higher power consumption within the Skylab cabin. This in turn will place a greater demand upon the existing thermal control system particularly in the OWS which has a limited or marginal heat rejection capability due to the PLV fan/air heat exchangers limited capacity. The highest potential payload candidate which would introduce additional power into the OWS is space processing. An additional consideration at a future date would be a larger crew residing in the OWS with

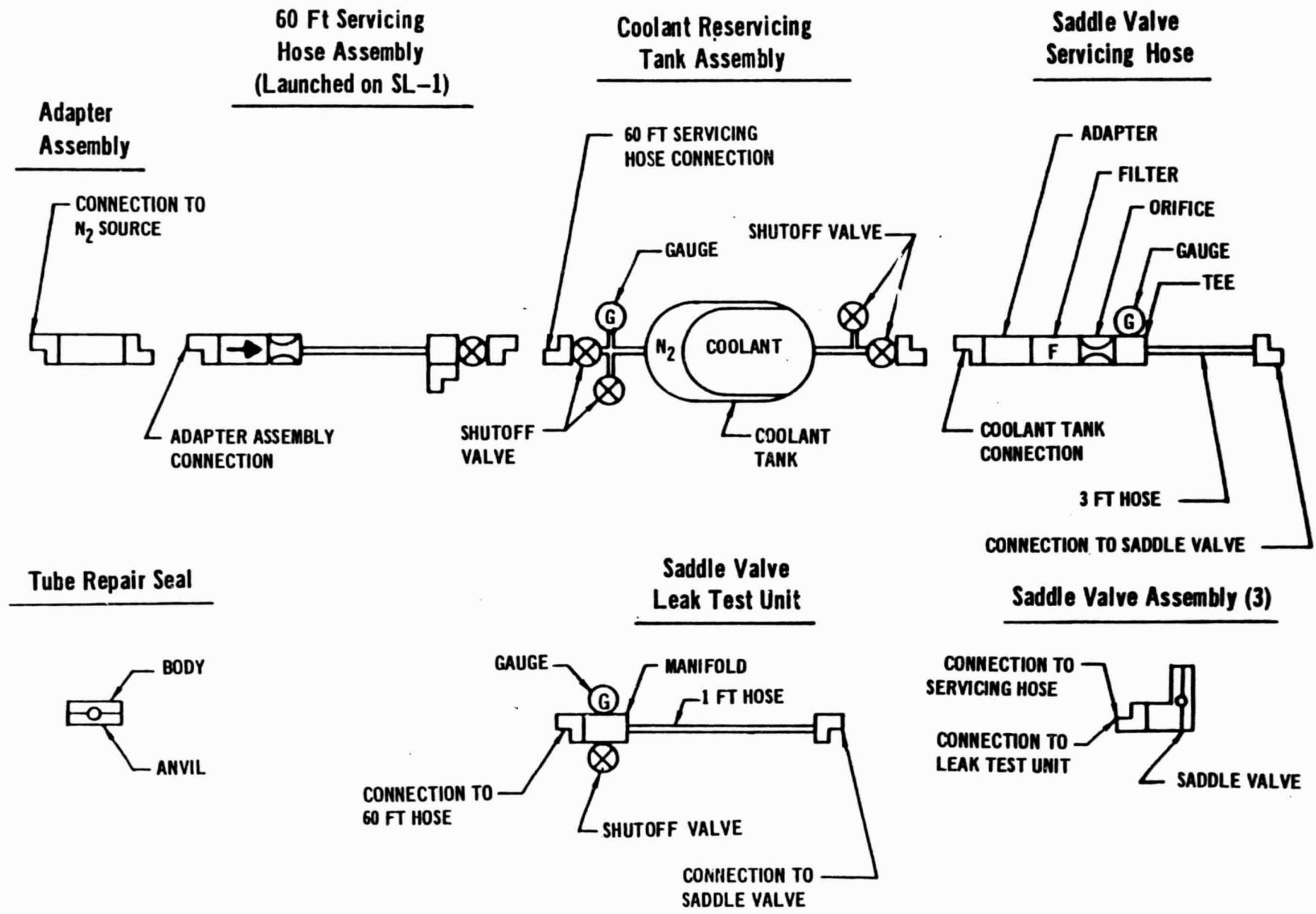


Figure 2.1.2.2-1. Coolant Loop Reservicing

its increased heat rejection. While these considerations are later in a reuse scenario, a second factor concerning Skylab orientation must be considered at an earlier point. During the early Shuttle-tended operations, the solar orientation control requirements of the Skylab Power Module and Orbiter cluster may exceed the Power Module's control capability. This will result in a gravity-gradient resultant orientation which will expose to a greater degree the on-board Skylab radiators to solar energy. As the Skylab AM radiators were designed for a solar inertial baseline, deviation from that baseline will reduce the system performance. Therefore, should consideration of utilizing the Power Module's heat rejection capacity become necessary, the following installation concept would be further defined.

Coolant lines from the 25 kW Power Module to the workshop must pass through the Airlock Module. These lines would be routed external to the airlock from the modular docking adapter to the OWS. They would be shielded from the environment and enter the OWS through an adapter mounted in one of the scientific airlocks. Detail analysis of all contributing factors will be conducted in follow-on investigations to establish a final configuration.

Environmental Control System

The O₂ and N₂ resupply module is used to transport a 90-day supply of O₂ and N₂ for ECS and TACS as a Space Shuttle payload. It stores a total of 1,308 pounds of N₂, including 774 pounds for TACS and 534 pounds for ECS. It stores 2,478 pounds of O₂.

The O₂ and N₂ resupply module is capable of transferring the O₂ and N₂ to tanks on Skylab through a flexible manifold so that it can be returned with Shuttle and prepared for the next Shuttle resupply mission. There are several options to be considered in the selection of the atmospheric gas resupply module. Available high pressure tanks would be a strong candidate; Section 2.1.3.2 - Thruster Attitude Control describes a common supply approach and cryogenic storage. This latter option, which would utilize Orbiter waste heat to gasify the cryogenics, might benefit the Orbiter's heat rejection balance by providing additional capacity. In this system, the O₂ and N₂ are stored cryogenically within concentric spheres. Nitrogen is within the inner sphere and oxygen is within the outer one. The spheres are suspended by a bicycle spoke type

arrangement that fits within a 10-foot diameter envelope. If desirable, the module can provide a heat sink for the Orbiter during transfer. The system is shown on Figure 2.1.2.2-2. Detail tradeoff analysis of both operations and cost must be made prior to selecting the approach.

A space condensate module filled with water separator plate wetting solution is recommended. The module will assure wetting solution is available and provide the extra module necessary for future resupply cycling.

A molecular sieve fan is needed to replace the molecular sieve secondary fan which failed previously. A supply of GFE replacement fans also will be required.

Other resupply items needed for the environmental control system are PPO₂ sensors, charcoal canisters, solids traps, CO₂ detector cartridges, and water separator plates. The quantities of each were addressed in the cost study.

EVA/IVA Suit Systems

No refurbishment was proposed for this module. Liquid gas separators will have to be resupplied.

Electrical Power System

Since the one power conditioning group was lost after the refurbishment equipment was defined, it was not included. No electrical power equipment was defined for refurbishment. However, the addition of power lines to transfer power from the 25 kW Power Module to the OWS was proposed. These lines would be routed external to the AM Module.

Instrumentation System

During the initial Skylab interrogation, a communications failure occurred which was attributed to the converter in the primary circuit. If subsequent tests, which could be conducted during the early refurbishment missions, prove that the converter has failed, the following modification would be implemented.

Since the original converter uses parts which are obsolete now, a replacement converter is needed. The standard Load Center Converter (LCC) catalog No. 5.001 can be used. We would use the currently available four module main frame and three special order modules, namely +24V, -24V, and +5V. Acceptance testing of the converter will be conducted using laboratory equipment.

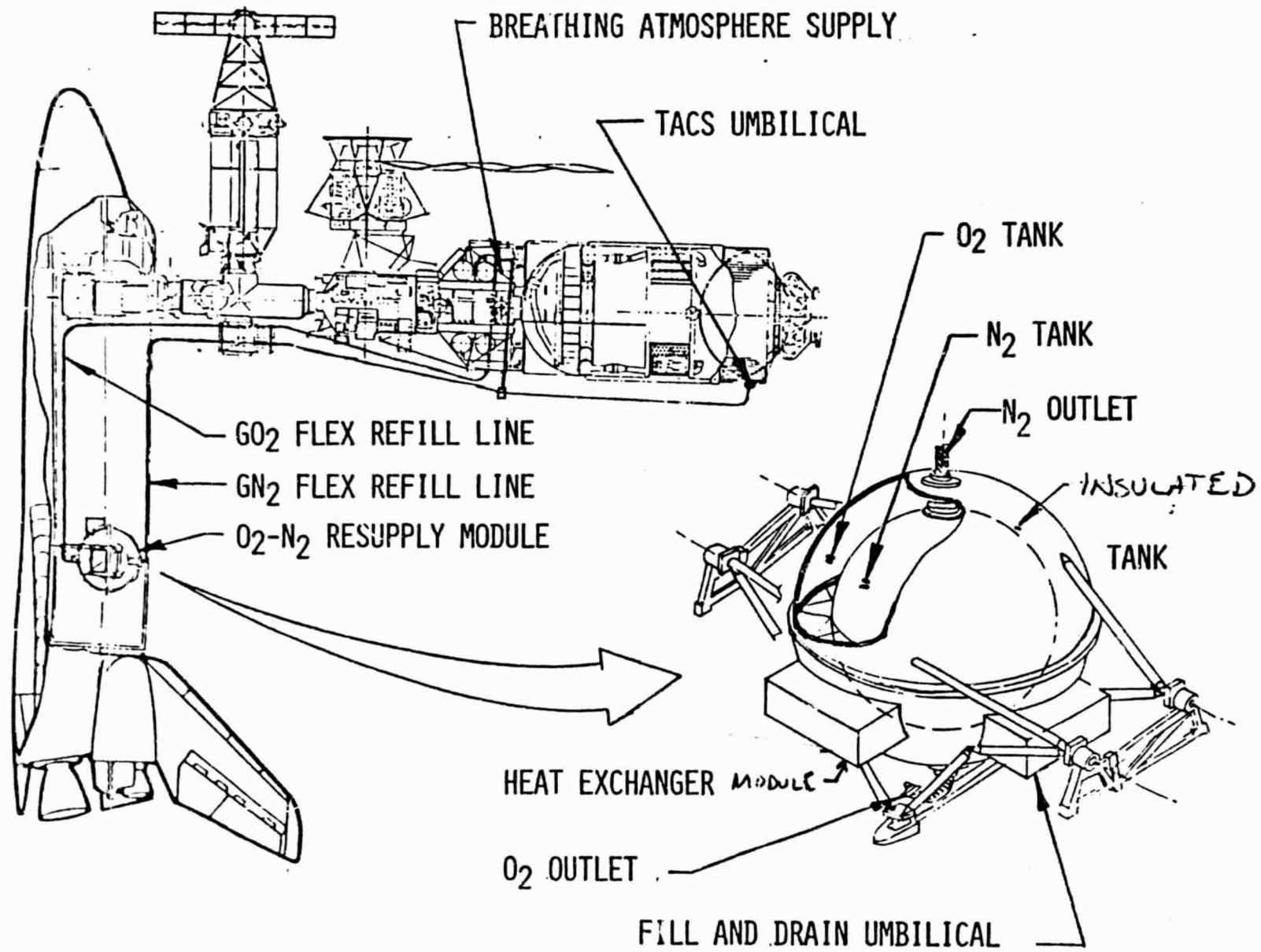


Figure 2.1.2.2-2. O₂-N₂ Resupply Module

To adapt the standard converter to the airlock, a jumper cable, mounting adapter and thermal cover will be required. The jumper cable will interface with spacecraft wiring on one end and the new converter on the other. In addition, it will provide the bundle length required to adapt to the new installation configuration

The mounting adapter will interface with the cold plate where the old 6.3" x 5.5" x 5.3" converter fits and mate with the new 9.6" x 8.4" x 5.5" converter. The adapter will provide adequate conduction to the cold plate to cool the new converter. The new thermal curtain will fit over the larger revised module. The curtain will be of the same materials and general configuration as the present curtain.

Mobility aids will be required to reach the module and to work on implementing the changes. Crew training and real-time mission support will be provided.

Card F2 will be replaced in the signal conditioner on electronic module 3. The plan consists of (1) designing a replacement card, building and testing it, (2) designing and constructing mobility aids for use in replacing the card, and (3) training the astronauts and supporting the in-flight replacement.

The communications system tape recorders were heavily used during the Skylab A missions and even with the extensive on-board maintenance, were subject to frequent malfunction. These units are considered to be unreliable and therefore additional replacement units will be required. Tape recorders will be needed during the TDRSS era to record data during possible communication outages and for selected data on-board processing. These basic requirements can occur during both manned and unmanned operations. The preliminary plan is to refurbish belts on nine existing units and purchase three NASA standard hardware units for the Skylab refurbishment missions. With the new units, adapters will be required to make with cold plates for cooling and stowage locations assigned. Adapter wiring harnesses also will be required.

To comply with Federal Communication Commission regulations banning use of the VHF channels and to eliminate the need for the ground station network used for Skylab, communication via TDRSS is required. In keeping with the desire to delay expenditures on Skylab as long as possible, two systems are proposed.

One system minimizes change to Skylab by using the Space Shuttle KU and S-band communication channels for Skylab transmission. This approach is proposed for early missions (Phases II and III) where Skylab is Shuttle-tended during manned operation. To implement this approach for manned operation, the airlock relay control 61A830126 would be modified to form the input selector box shown on Figure 2.1.2.2-3. In addition, the Spacelab voice system adapter would be added to the Skylab system. To connect these modifications, a cable must be added from the select unit to the Orbiter. Another cable must be added from the CSM plug in the MDA to the Spacelab voice system adapter unit. To modify the Skylab unit and install the other equipment, mobility aids and astronaut training will be required.

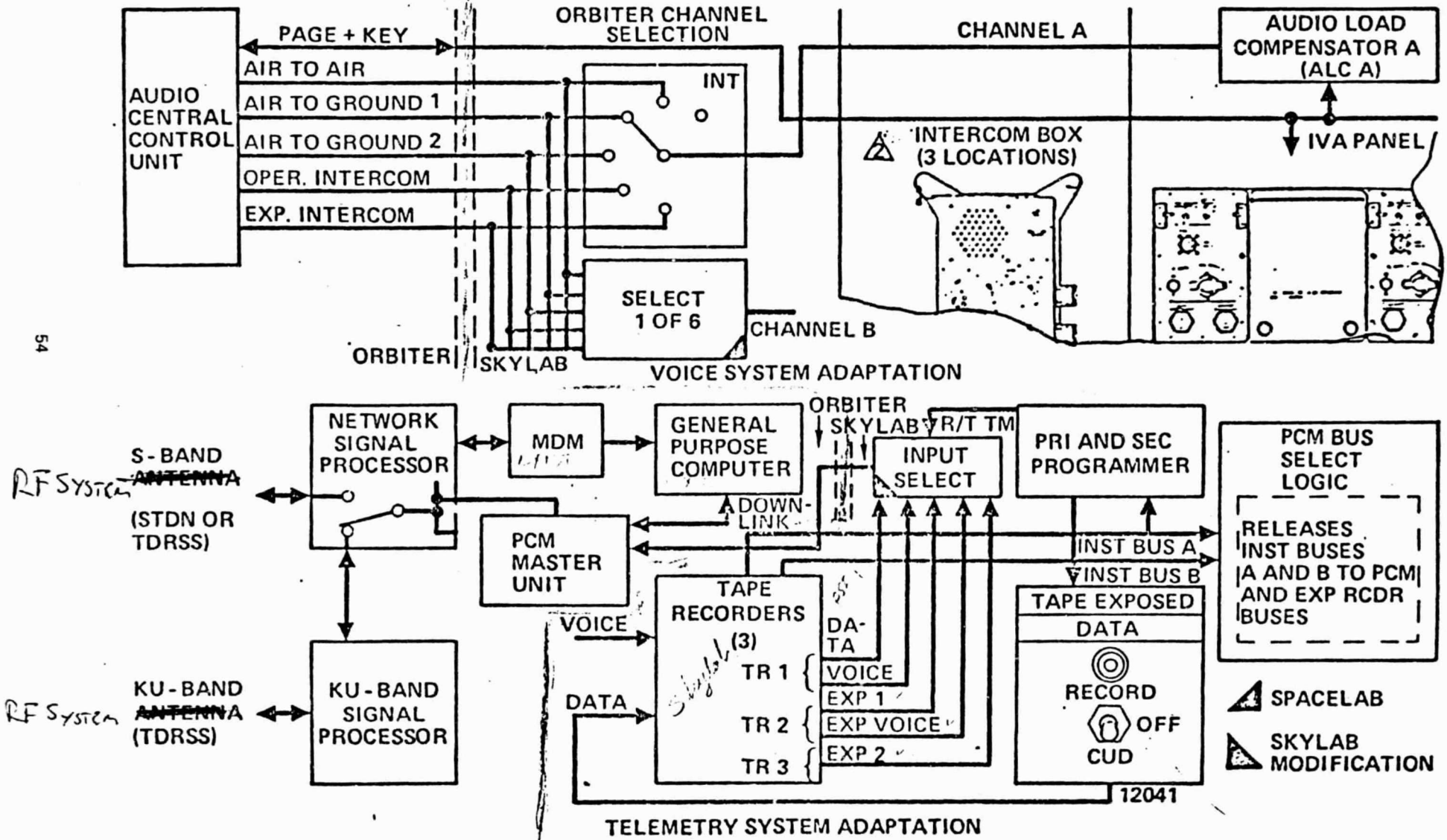
If other than VHF communication is desired for unmanned communication, an Orbiter S-band communication system can be installed on Skylab. This modification was not included in our proposed changes.

The other system provides autonomous Skylab communication. This approach is proposed for later missions (Phase IV) where the Skylab is no longer tended by Shuttle. To implement this approach, the kit shown on Figure 2.1.2.2-4 is needed. This kit uses NASA LCSD standard hardware tape recorders, transponders, and coax switch. It uses existing designs for the omni and hi-gain antennas as shown on Figures 2.1.2.2-5 and 2.1.2.2-6. At this juncture in the reuse, planning candidate antennas have been identified. The ultimate selection depends upon the configuration and data types chosen for the data management system during a subsequent analysis of payloads and operational requirements. The power distribution box, analog to digital computer for voice, and cables and harnesses must be designed. The premod processor and demultiplexer decoder are modified existing designs.

The tape recorders, transponders, power distribution box, premod processor and demultiplexer all require cooling. The kit shown uses the MMS subsystem module structure with radiators, louvers, and insulation for this purpose. This kit would be suitable for mounting on the ATM truss by EVA astronauts. An alternate approach would be to cold plate mount the equipment and install the kit on the interface module prior to launch.

Figure 2.1.2.2-3

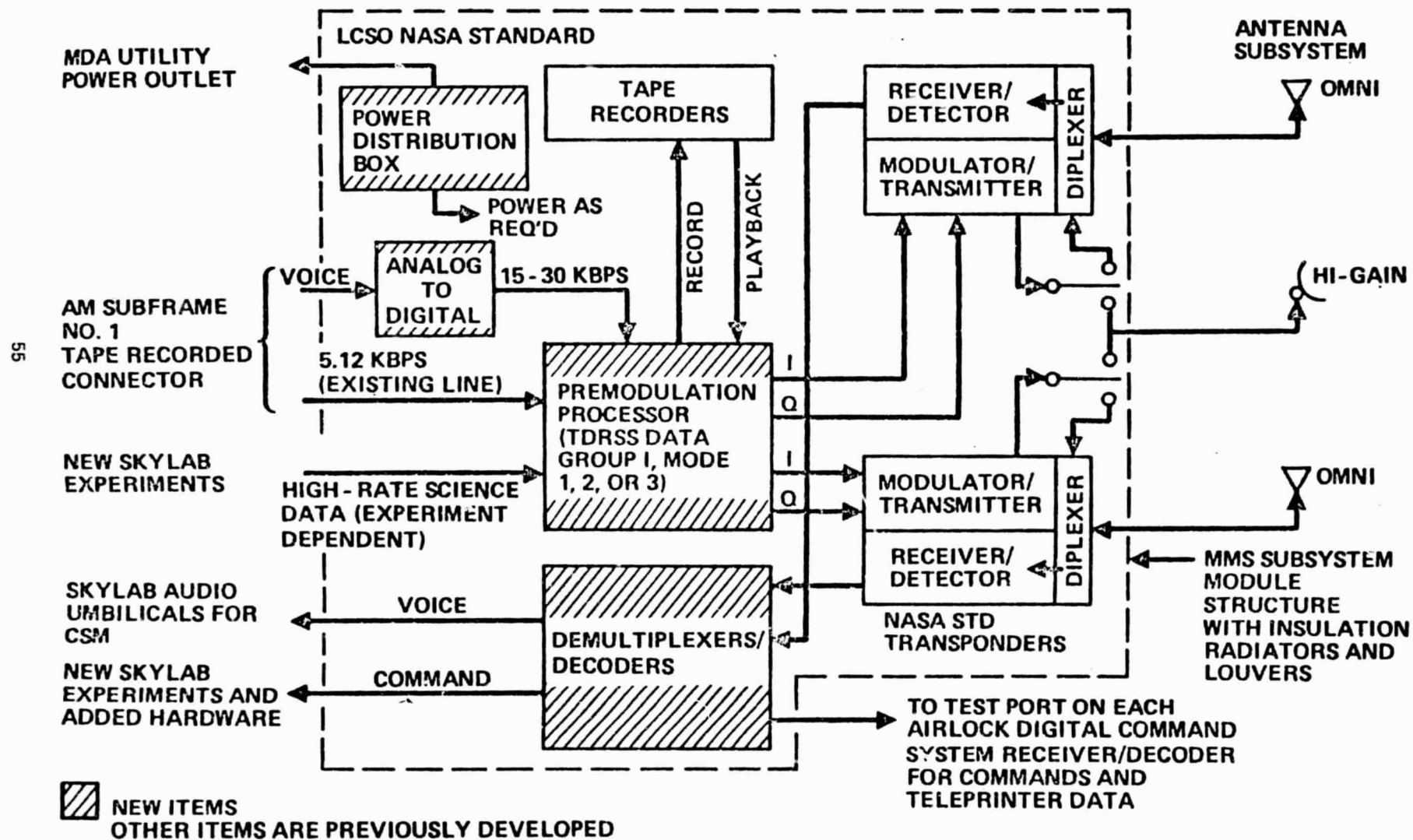
PHASE II COMMUNICATIONS INTERFACE CONFIGURATION-SHUTTLE TENDED



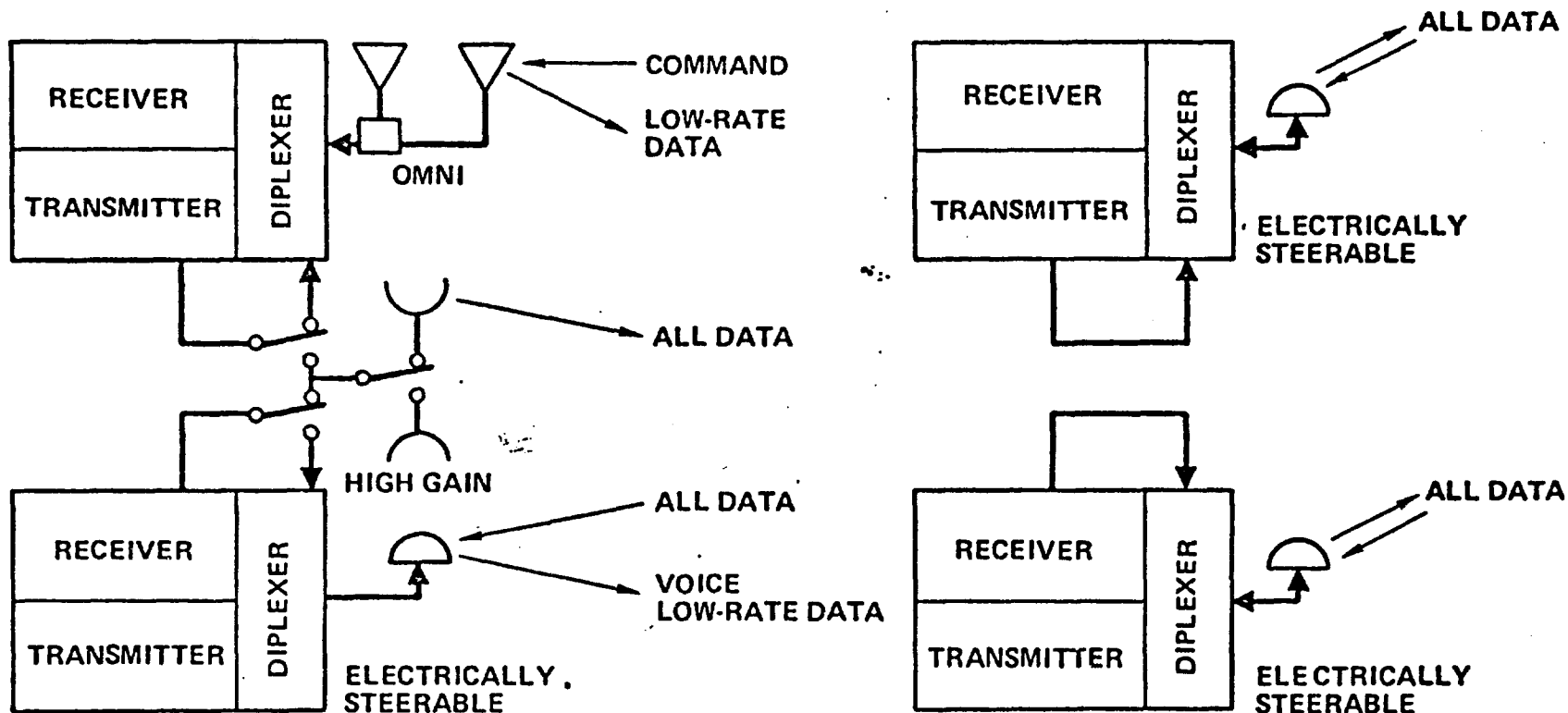
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Figure 2.1.2.2-4

SKYLAB TO TDRSS COMMUNICATION KIT



SKYLAB ANTENNA SUBSYSTEM CANDIDATES



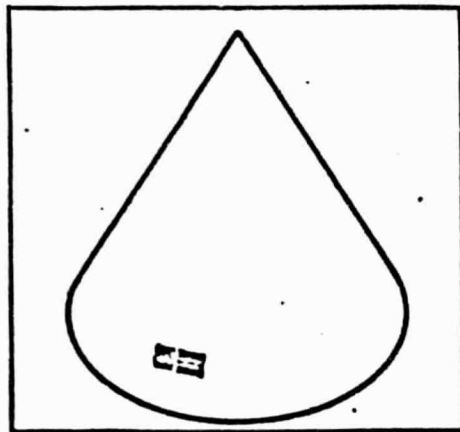
DATA RATE CAPABILITIES (KBPS) (5-W OUTPUT WITH 1-W LOSS, 3-dB MARGIN)

	MODES 1 AND 2 (MULTIPLE ACCESS)			MODE 3 (SINGLE ACCESS)		
	OMNI	STEERABLE	HIGH GAIN*	OMNI	STEERABLE	HIGH GAIN*
FORWARD LINK (COMMAND)	1.0	10	N/A	8.0	80	N/A
RETURN LINK (TELEMETRY)	0.8	8	50/60	12.6	126	750/1500

*ANTENNA SIZE 2.2/3.0 FT

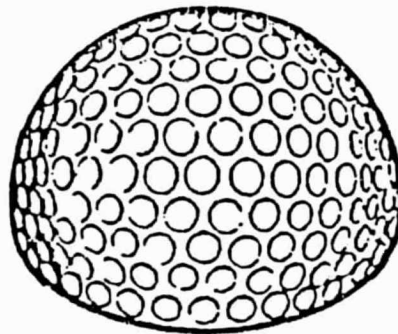
Figure 2.1.2.2-6
ANTENNA AVAILABILITY

OMNI
WATKINS-JOHNSON WJ-8580



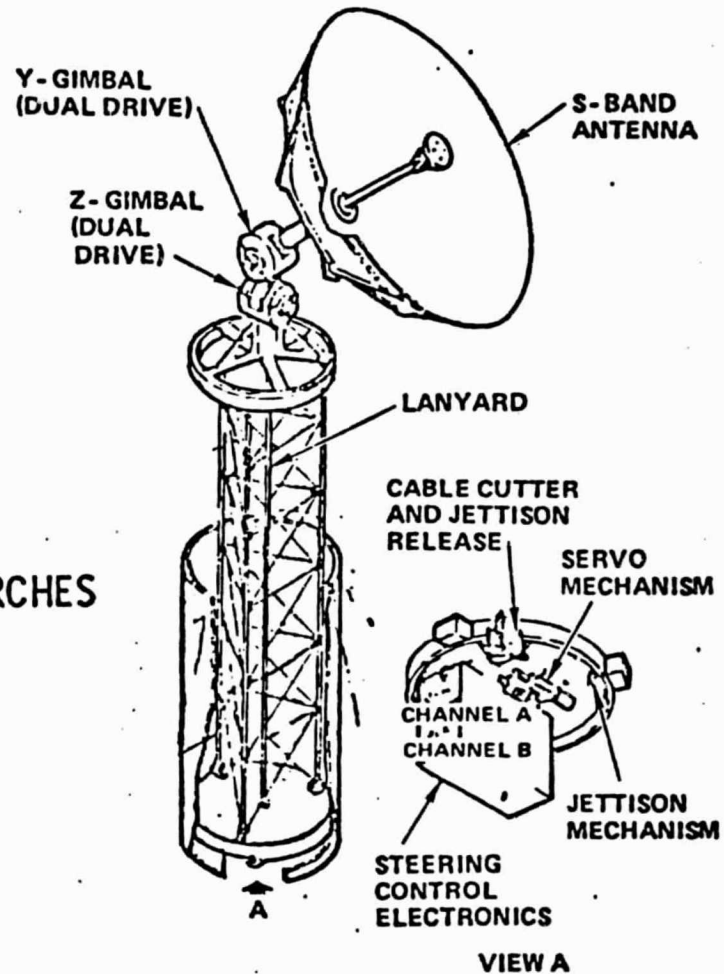
8-IN. DIAMETER
7-IN. HIGH

ELECTRICALLY
STEERABLE
BALL BROS AN 128



13 dBi CURRENT
17 dBi GOAL
AUTOMATICALLY SEARCHES
AND TRACKS TDRS
30-IN. HEMISPHERE

HIGH GAIN
SOLAR MAX MISSION/LAND SAT D



A replacement item required for the communication system is paper for the teleprinter.

Caution and Warning System

No refurbishment or resupply has been proposed for the C&W system.

Experiments and M509 Nitrogen Recharge Station

No refurb/resupply requirements were identified during the reuse study.

Miscellaneous

Resupply items should include 10W lightbulbs, 20W lightbulbs, portable timer batteries and tone generator batteries.

2.1.3 Orbital Workshop

The crew habitability and related support systems are described both at End-of-Mission (EOM) and their current status as derived from the recent Skylab reactivation activities. In conclusions, the currently defined refurbishment requirements are summarized.

2.1.3.1 Orbital Workshop Subsystems Status

Vehicle Structural System: The Orbital Workshop structure is the principal vital system of OWS. It was determined during ground interrogation that structural damage had not occurred to the pressure shell. During ground interrogation, internal OWS temperatures ranged between 75° and an estimated 250°F; however, the temperature excursions were cyclic. Comparing interrogation data collected with correlating data from the initial two weeks of Skylab I orbital flight in 1973 when the heat (meteoroid) shield was lost, leads us to believe that neither insulation debonding nor hazardous material degradation has occurred.

Orbital Workshop Subsystems: The status of the OWS subsystems as determined by the reuse study is End-of-Mission (EOM) status or today's status (as of mid-October 1978) established by the reactivation and ground interrogation.

- A. Environmental/Thermal Control Subsystem (E/TC) status for the active portion of the subsystem should be same as EOM. Active E/TC consists of the active thermal control assembly, radiant heaters, duct heaters, and duct fans which were all functional at EOM. Performance verification tests were not conducted on this system during the initial reactivation activities.

A. (Continued)

- Currently none are planned. The passive portion of E/TC, consisting of the solar shield, goldized Kapton coating on the tank structure, high performance insulation on the tank dome, the painted surfaces, and the internal insulation was functioning normally at EOM. During reactivation thermal interrogation verified an acceptable function of the passive elements. (Reference Vehicle Structural System above.)
- B. Thruster Attitude Control System (TACS), an OWS vital subsystem as a part of Skylab Attitude Pointing and Control, was functioning flawlessly at EOM. The remaining system impulse at EOM was approximately 22,000 lb/sec. During reactivation, interrogation showed that this all brazed plumbing system had zero leakage during the four plus years of orbital storage. The system was exercised during reactivation and again today performs flawlessly. Currently, automatic control of TACS has been disabled to preserve system impulse for use only on discreet ground command. TACS remaining impulse is 7500 ± 2500 lb/sec.
- C. Electrical Power System (EPS) and the OWS Solar Array System (SAS) is the power generator for the AM power system. During reactivation, TM data verified power generation from each of the eight SAS power groups. One of the eight Airlock Module Power Control Groups (PCG's) failed in July 1978, due to extreme cycling of the thermal environment. Analyses of power data, voltage and currents, determined that the power generated by SAS to be degraded by approximately 9% from EOM power output in February 1974.
- D. Power Distribution and Communications and Data system elements integral with the AM system functioned normally during reactivation interrogation.
- E. Illumination, Caution and Warning and other ancillary OWS system elements were not interrogated during activation. Their status is considered to be EOM February 1974, which will be verified on the first revisit to Skylab.
- F. Crew Systems and Accommodations, CS/A. The two support systems capable of ground control, refrigeration and external lighting, were not interrogated during activation. Monitored data, however, indicated that these systems should function normally, as was the case at EOM, when activated. All other CS/A for habitability support are EOM February 1974 status.

2.1.3.2 Orbital Workshop Refurbish/Resupply Requirements and Kit Descriptions
Two OWS vital subsystems and five, possibly six, habitability support subsystems for crew accommodations require refurbishment/resupply to restore Skylab to an Initial Operational Capability (IOC).

There are as follows:

Vital Subsystems

- o Environmental/Thermal Control, E/TCS
- o Thruster Attitude Control, TACS

Crew Systems/Recommendations (Habitability Support)

- o Water Management
- o Food Management
- o Sleep Accommodations
- o Waste/Trash Management
- o Personal Hygiene
- o Refrigeration

During the reuse study, NASA extended direction to identify requirements and kit definitions to accommodate 3 men/30 days and 5 men/60 days in habitability support during reuse missions.

A summary of requirements and descriptions of refurb/resupply kits follow.

Vital Subsystems

- o Environmental/Thermal Control, E/TCS

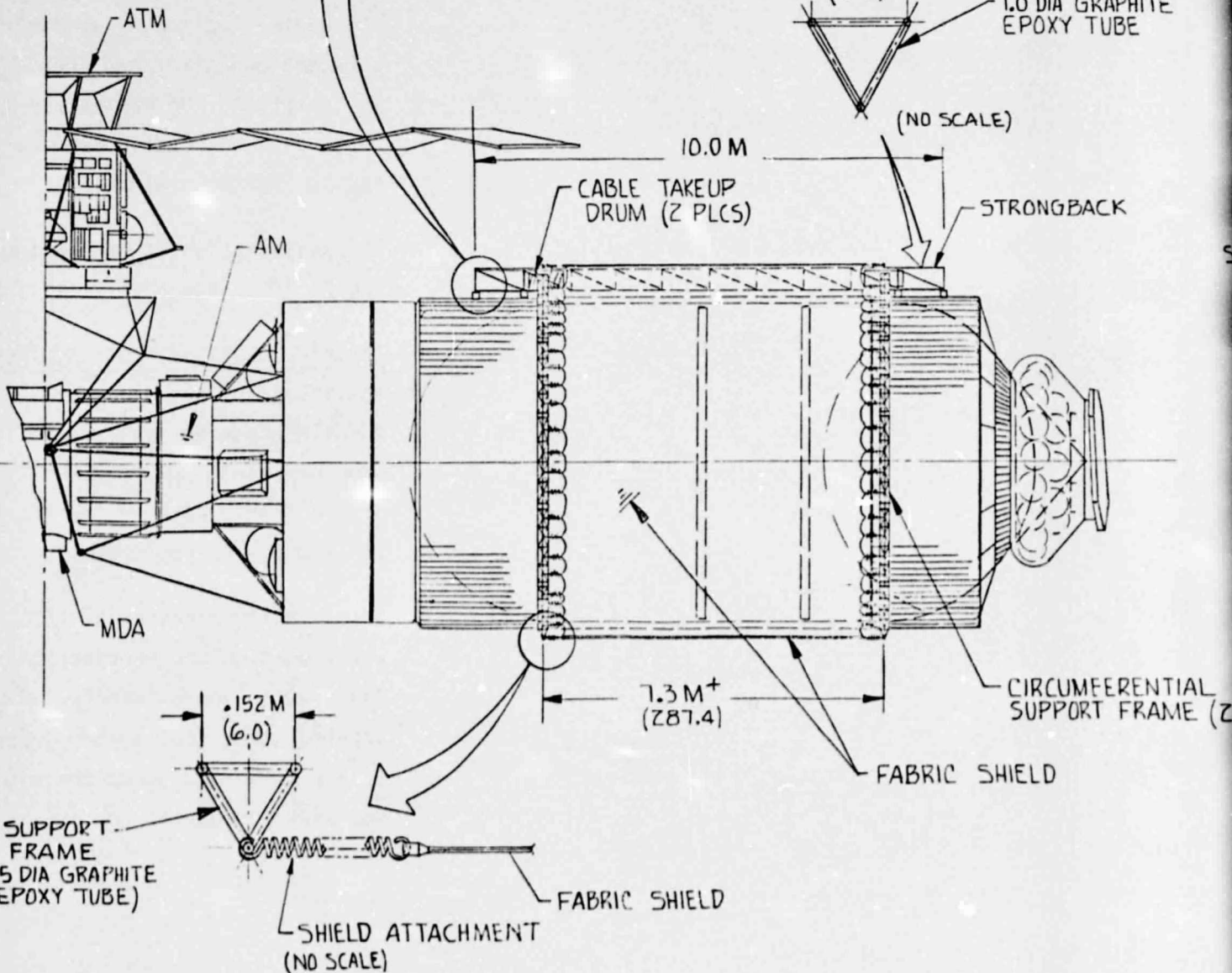
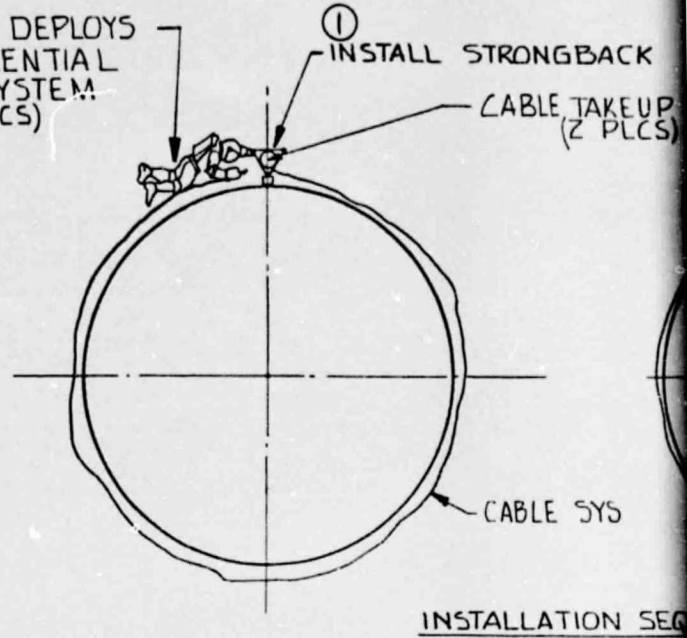
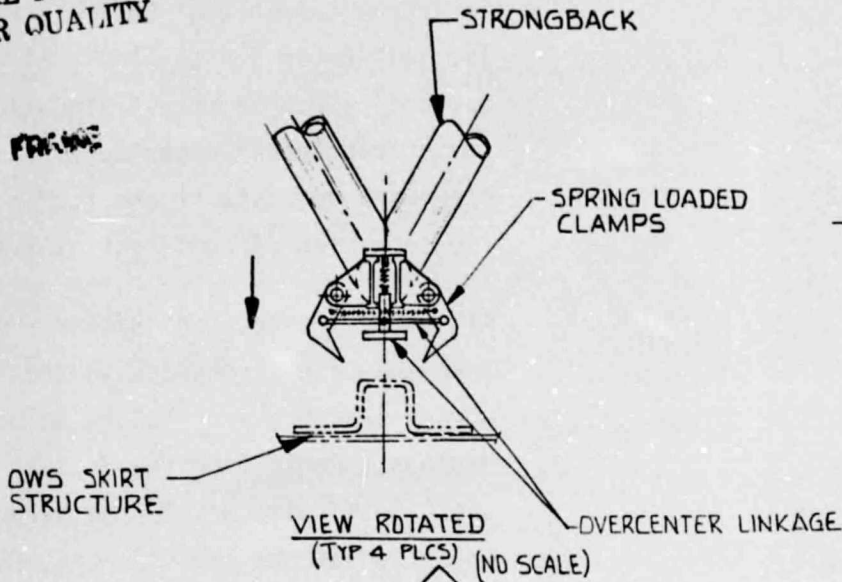
The reuse study reveals that during the operational phases various Skylab cluster attitudes required to operate certain payloads will cause 360° exposure of the Skylab habitation volume. Thus, a 360° solar shield kit has been conceived. The shield can be either hard or soft; the final choice being the result of detailed thermal and meteoroid penetration analyses together with the results of ground interrogation. For early operational missions, a soft cover was selected; see Figure 2.1.3.2-1. Incidentally, following the launch of SL-1, MDAC conducted an exercise for NASA in which the meteoroid shield was deleted from the backup vehicle. This work is documented in MDAC Drawing 1B96371, Meteoroid Shield Removal, OWS Design Specification.

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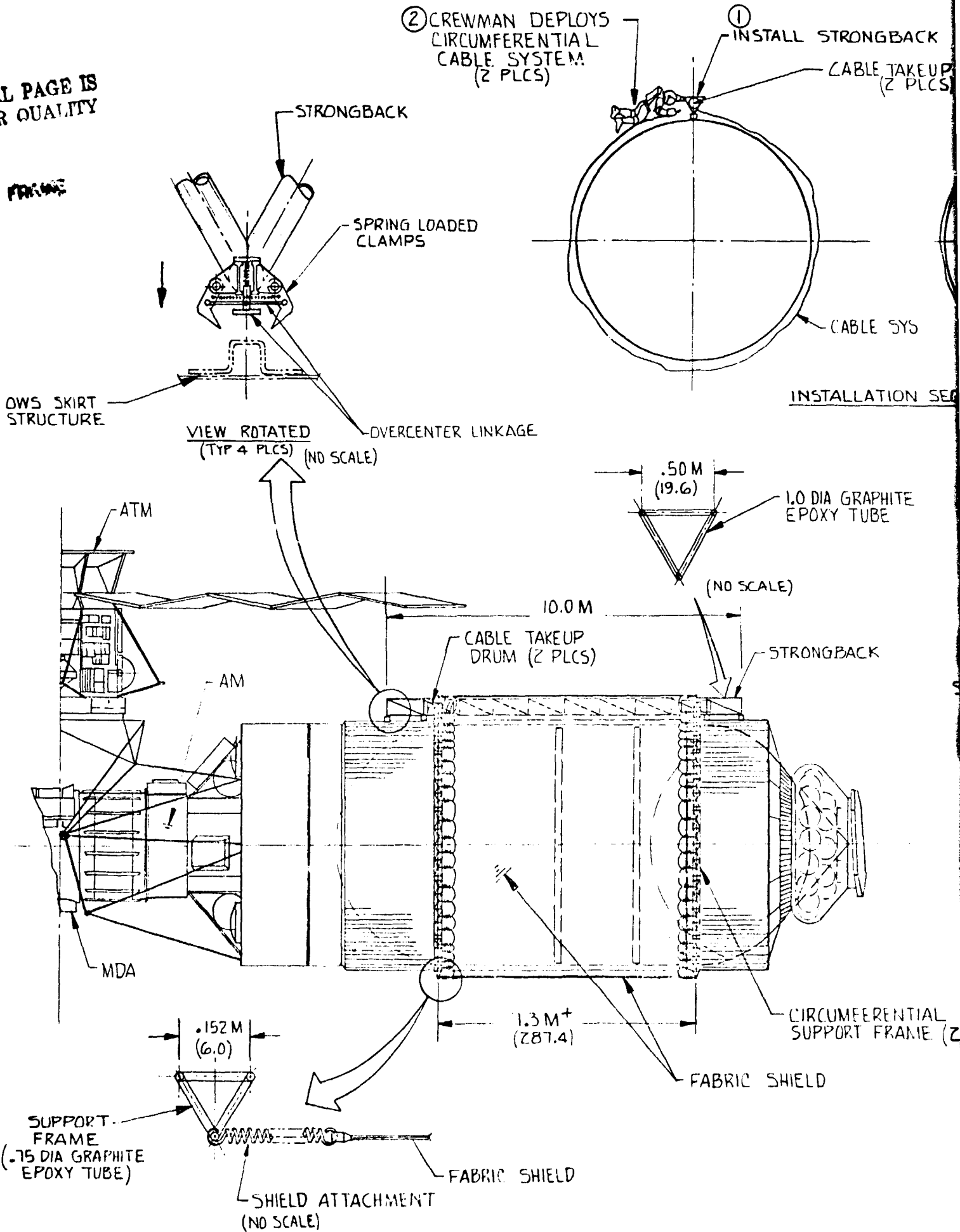
② CREWMAN DEPLOYS
CIRCUMFERENTIAL
CABLE SYSTEM
(2 PLCS)

① INSTALL STRONGBACK
CABLE TAKEUP
(2 PLCS)



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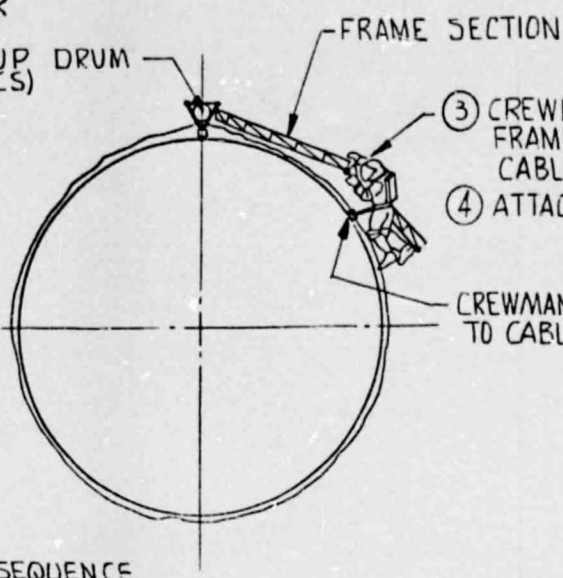


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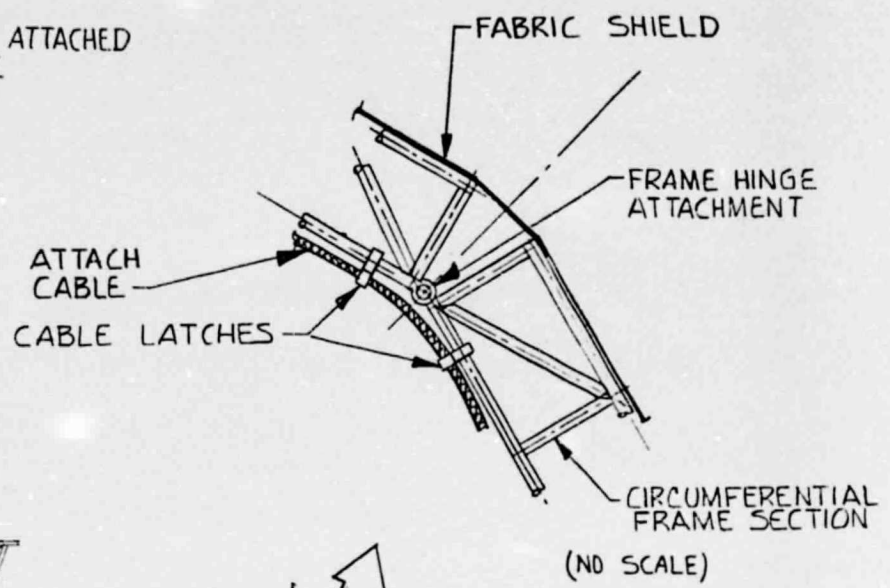
KEEP PLCS)

2 FOLDBOUT FRAME

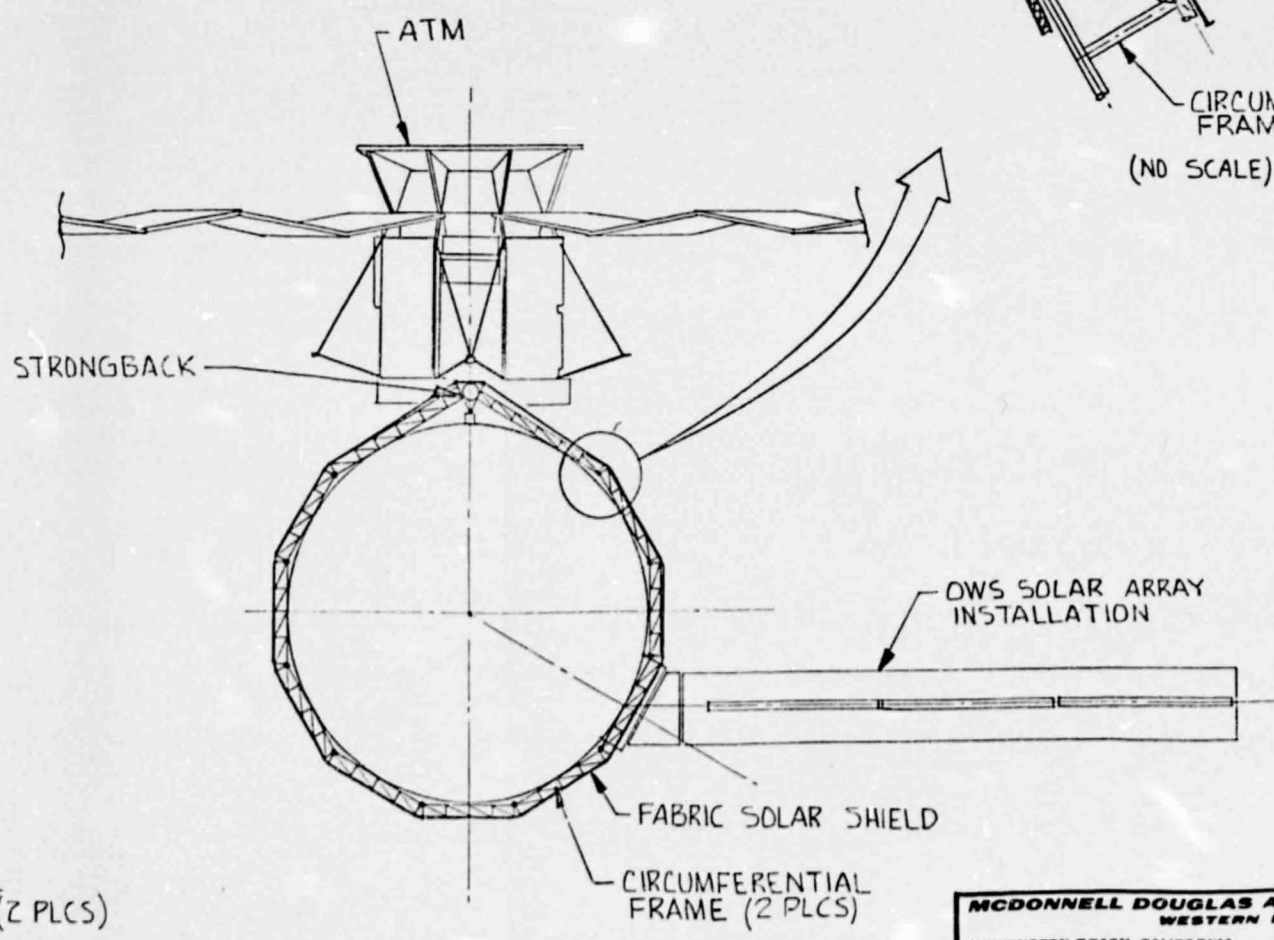
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- ③ CREWMAN ATTACHES FRAME SECTIONS TO CABLE
- ④ ATTACH FABRIC SHIELD TO FRAME



N SEQUENCE



TIAL ME (2 PLCS)

MCDONNELL DOUGLAS ASTRONAUTICS CO.
WESTERN DIVISION
MUNTINGTON BEACH, CALIFORNIA

SKYLAB REUSE
SOLAR SHIELD INSTALLATION

SIZE	CODE IDENT NO.	DRAWING NO.
	18355	GSK 051178

SCALE: 1/4" = 1'-0" 61 SHEET 1 OF 1

Figure 2.1.3.2-1.

BACK

KEEP PLCS)

FRAME SECTION

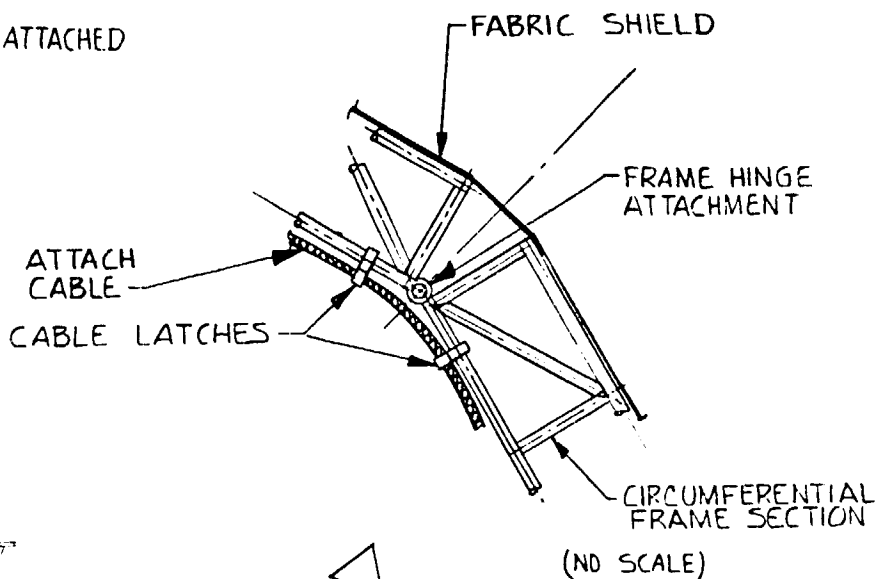
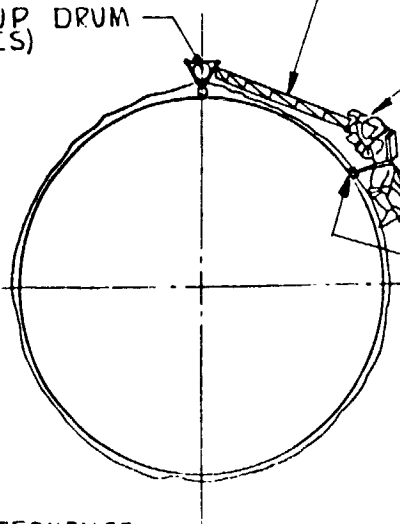
③ CREWMAN ATTACHES FRAME SECTIONS TO CABLE

④ ATTACH FABRIC SHIELD TO FRAME

CREWMAN ATTACHED TO CABLE

2 OUT-OF-FRAME

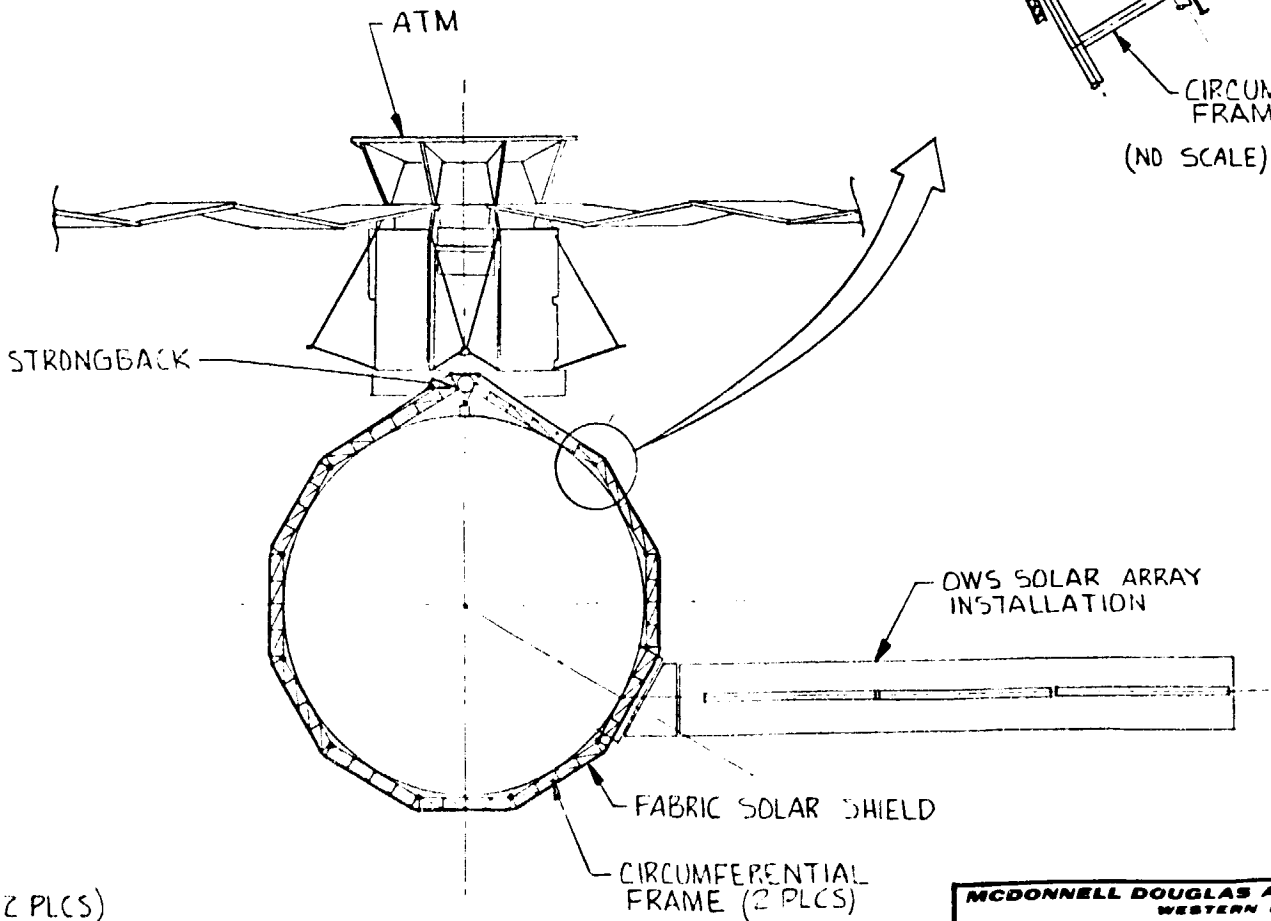
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ON SEQUENCE

E



INITIAL NAME (2 PLCS)

MCDONNELL DOUGLAS ASTRONAUTICS CO.
WESTERN DIVISION
MINTHURST BEACH, CALIFORNIA

SKYLAB REUSE
SOLAR SHIELD INSTALLATION

SIZE	CODE IDENT NO.	DRAWING NO.
	18355	GS-551178

SCALE: 1" = 1'-0" 61 SHEET 1 OF 1

Figure 2.1.3.2-1.

o Environmental/Thermal Control, E/TCS (Continued)

The soft cover sun shield is a coated fabric (similar to the existing parasol) attached to a triangular frame which provides a base for advanced external experiments and construction installations. The framework consists of one 1.0M x 10.0M lg triangular strongback and two segmented circumferential frames on which the soft cover is attached.

After the present sun shields are removed and stowed, two crewmen translate the strongback to the -Z axis of the OWS and attach the four, spring-loaded clamps to the selected hat stringer. One crewman then deploys a cable from the drum on the strongback and translates around the OWS and attaches to the strongback. The second crewman repeats the operation at the opposite end. Sections of the circumferential frames are attached to the cable system by the crewman who is also attached to the cable. Following assembly of the frames, the soft fabric cover is attached and stretched around the OWS. Upon completion of the cover installation, the cables are tightened to add rigidity to the assembly. Cutouts in the fabric provide clear access to the two scientific airlocks and the workroom window.

The installation is made without modification to the Skylab and without use of MMU. Adequate restraints are provided by the assembly.

o Thruster Attitude Control, TACS

At liftoff of Skylab 1, the TACS contained 81,886 lb/sec "usable" impulse. "Usable" meaning impulse available until the 3100 ± 100 psi system has been depleted down to 300 psi; the remaining charge below 300 psi considered unusable because the available thrusts would be below the 10 lb. minimum design requirement.

Based on these criteria, TACS is depleted since during reactivation, interrogation and reorientation of Skylab the system pressure has been depleted to approximately 300 psi. On the basis of total actual usable impulse, some 7500 ± 2500 lb/sec. remains in the system. This amount is available and about the minimum required to accommodate a docking maneuver for Skylab reboost by Teleoperator. Which means, that at the

o Thruster Attitude Control, TACS (Continued)

earliest possible time, first revisit, TACS should be resupplied. One method of resupply is depicted in Figure 2.1.3.2-2. Here we show Orbiter type tanks stowed beneath the payload bay floor. The tanks are charged with the TACS resupply of N_2 . After docking to Skylab, the crew would, by EVA, trail a resupply line from the Orbiter aft over the Skylab cluster to OWS aft skirt where the fill umbilical for TACS is located. The umbilical is a typical quick-disconnect which is readily accessible by the removal of a cover plate.

In due course, the Environmental Control System (ECS) atmosphere supply onboard Skylab will also be depleted. (Today we have approximately 2500 lb. O_2 and 600 lb. N_2 .) It is then that we propose to use a single recharge system to resupply both atmosphere and TACS system. Additional tanks for both GO_2 and GN_2 can be installed in Orbiter and the recharge of both systems can be accomplished by EVA installation of supply lines to the umbilicals for each system. The umbilicals for the atmosphere supply tanks are inside the forward Airlock shroud.

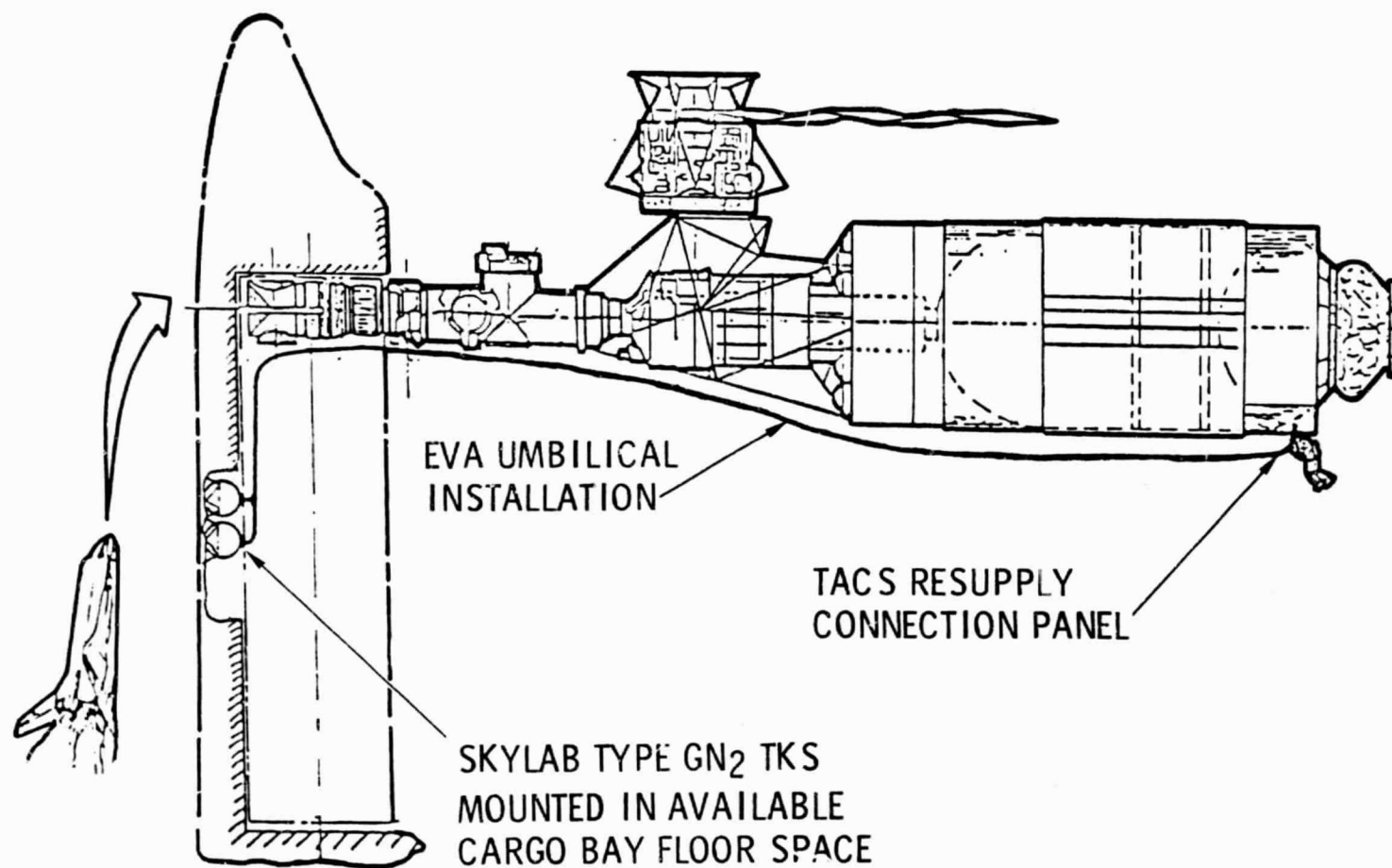
A preferable concept for resupply of the large quantity of gases required is discussed in Section 2.1.2.2. The system is a cryogenic resupply module that would transport a 90-day supply of O_2 and N_2 for the ECS and a 90-day supply of N_2 for TACS. This reduces to 1308 lb. of N_2 (774 lb. for TACS and 534 lb. for ECS) and 2478 of O_2 .

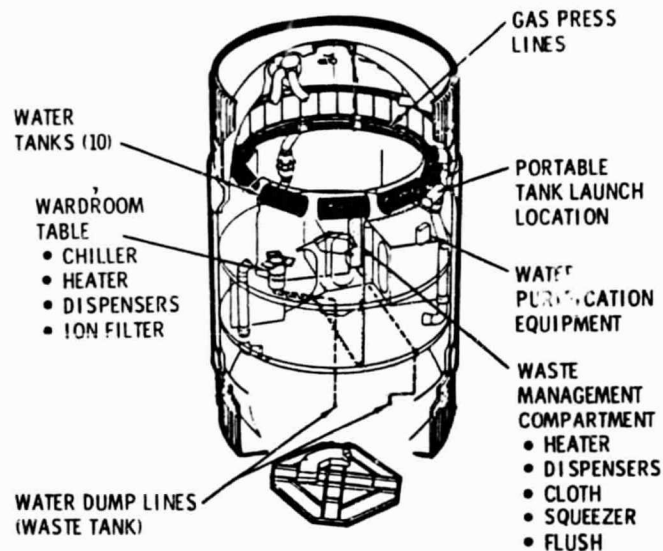
o Crew Systems/Accommodations

Figure 2.1.3.2-3 through Figure 2.1.3.2-9 are copies of briefing charts presented at Midterm and at the Executive Briefing which fully set forth the refurb/resupply requirements for habitability support during Skylab reuse. The charts further provide the refurb/resupply kit descriptions.

Figure 2.1.3.2-2
TACS RESUPPLY

46531





EQUIPMENT	STATUS
WATER STORAGE TANKS	OPERATIONAL - SERVICE REQ
PORTABLE WATER TANK	OPERATIONAL
WATER PRESSURIZATION SYSTEM	OPERATIONAL
(1) WARDROOM WATER NETWORK	REFURBISHMENT REQ
URINE FLUSH NETWORK	OPERATIONAL
(2) WASTE MGT-NETWORK (REF. PERSONAL HYGIENE)	RESUPPLY REQ
VACUUM DUMP/DRAIN	OPERATIONAL
(3) WATER PURIFICATION EQUIPMENT	RESUPPLY REQ

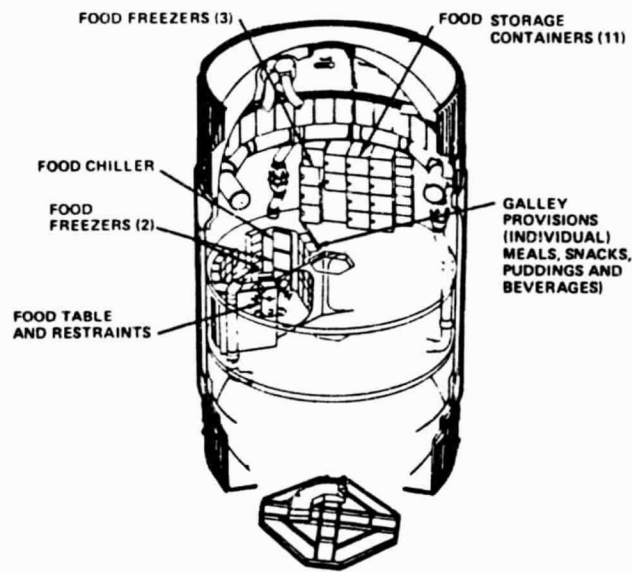
ITEM	ONBOARD	3 MEN/30 DAY		5 MEN/60 DAY	
		REQ	KIT	REQ	KIT
WATER QUANTITY	**1881 LBS	*1080 LBS	*801 LBS	3600 LBS	1719 LBS
GN2 SUPPLY	?	22 LBS MAX AT 35 TO 150 PSI	TBD	22 LBS MAX AT 35-150 PSI	TBD
(1) DEIONIZATION FILTER	0	1	1	1	1
DRINK DISPENSERS	3 + 1 SPARE	3 + 1 SPARE	0	5 + 1 SPARE	2
(2) WASH CLOTH SQUEEZER	0	1	1	1	1
WASH CLOTH BAGS	2	2	0	2	0
(3) PURIFICATION					
• IODINE CONTAINER	SCRAP	2	2	2	2
• WASTE SAMPLE CONTAINER	SCRAP	2	2	2	2
• REAGENT CONTAINER	SCRAP	2	2	2	2
• IODINE INJECTOR	SCRAP	2	2	2	2
• COLOR COMPARATOR	SCRAP	1	1	1	1
WARDROOM WATER HEATER	1	1	SPARE TBD	1	SPARE TBD
WMC WATER HEATER	1	1	SPARE TBD	1	SPARE TBD

*BASED ON SKYLAB "A" AVERAGE USE OF 12 LBS/MAN/DAY

**BASED ON SKYLAB MARCH INTERROGATION

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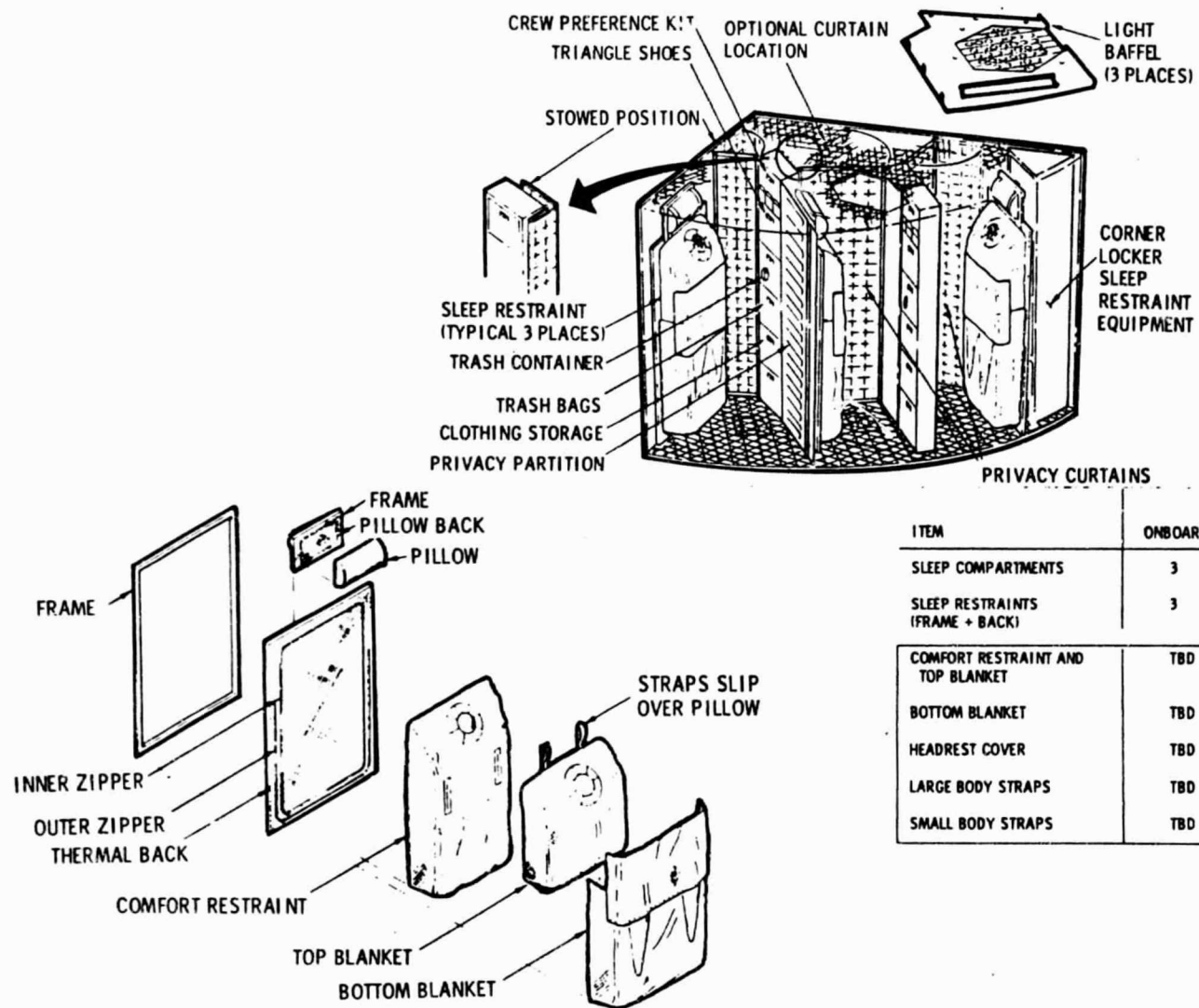
Figure 2.1.3.2-3. Water Management System Status-Refurbishment/Resupply



66

EQUIPMENT	STATUS	DESCRIPTION	ONBOARD	3 MAN/30 DAY		5 MAN/60 DAY	
				REQ	KIT	REQ	KIT
FREEZERS (5)	OPERATIONAL	UTENSILS	3 SETS	3 SETS	0	5 SETS	2 SETS
CHILLER	OPERATIONAL	FOOD SUPPLY	ASSUMED UNUSABLE	90 MAN DAY SUPPLY + CONTINGENCY	90 MAN DAY SUPPLY + CONTINGENCY	300 MAN DAY SUPPLY + CONTINGENCY	300 MAN DAY SUPPLY + CONTINGENCY
STORAGE CONTAINERS (11) (FWD COMPT)	PARTIAL AVAILABILITY						
GALLEY STORAGE	OPERATIONAL						
FOOD TABLE	OPERATIONAL						
FOOD TRAYS (3)	OPERATIONAL						

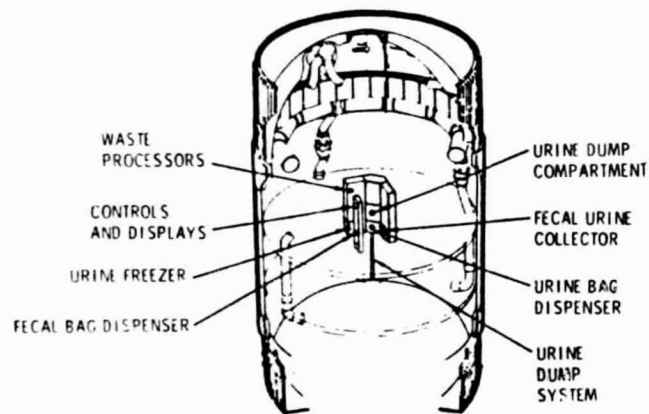
Figure 2.1.3.2-4. Food Management System Status-Refurbishment/Resupply



ITEM	ONBOARD	3 MEN/30 DAY		5 MEN/60 DAY	
		REQ	KIT	REQ	KIT
SLEEP COMPARTMENTS	3	3	0	5	2
SLEEP RESTRAINTS (FRAME + BACK)	3	3	0	5	2
COMFORT RESTRAINT AND TOP BLANKET	TBD	6	6	20	20
BOTTOM BLANKET	TBD	3	3	10	10
HEADREST COVER	TBD	6	6	20	20
LARGE BODY STRAPS	TBD	3	3	10	10
SMALL BODY STRAPS	TBD	6	6	20	20

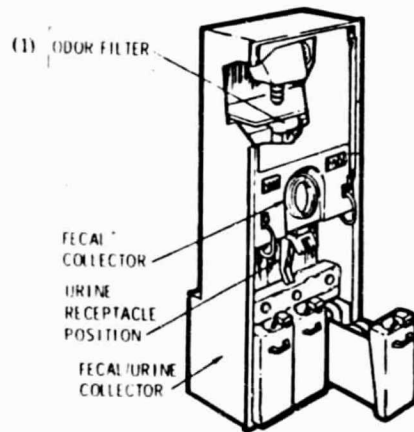
Figure 2.1.3.2-5. Sleep Accommodations Status-Refurbishment/Resupply

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EQUIPMENT	STATUS
WASTE PROCESSOR	OPERATIONAL
FECAL/URINE COLLECTOR	REFURB REQ
URINE FREEZER	OPERATIONAL
URINE DUMP	OPERATIONAL
VACUUM CLEANER	OPERATIONAL
URINE FLUSH	NOT OPERATIONAL - NOT REQ

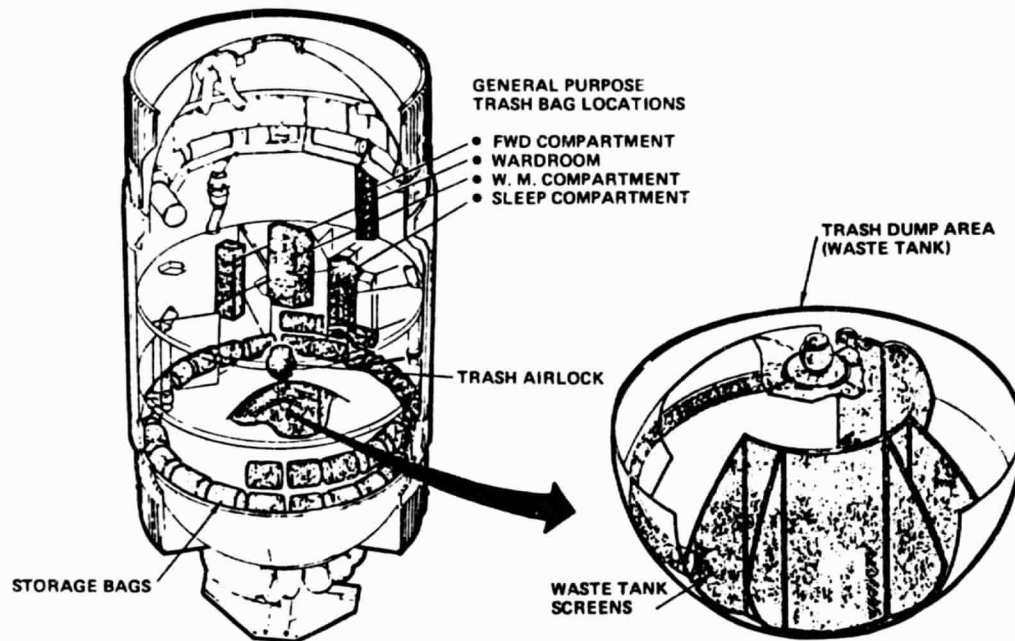
89



ITEM	ONBOARD	3 MEN, 30 DAYS*		5 MEN, 60 DAYS*	
		REQ	KIT	REQ	KIT
(1) FECAL ODOR FILTER	0	2	2	4	4
FECAL BAGS	90	73	0	241	151
FECAL CONTINGENCY BAGS	88	2	0	5	0
URINE COLLECTION BAGS	0	50	50	165	165
URINE RECEIVERS	?	13	13	42	42
URINE COLLECTION HOSES	?	13	13	42	42
URINE SEPARATOR FILTER	5	2	0	4	0
VACUUM CLEANER BAGS	115	5	0	10	0

*BASED ON SKYLAB USE RATE + 10% CONTINGENCY

Figure 2.1.3.2-6. Waste Management System Status-Refurbishment/Resupply



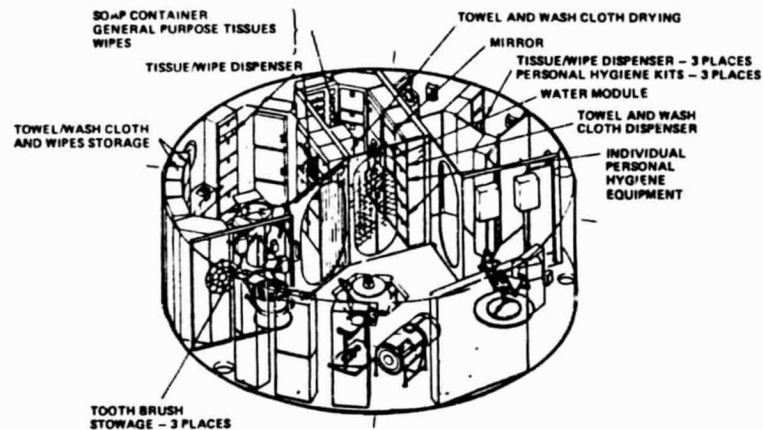
EQUIPMENT	STATUS
TRASH AIRLOCK	OPERATIONAL (656 CYCLES/750 DESIGN - 3000 QUAL)
WASTE TANK	OPERATIONAL (≈1/3 FULL - 1520 FT ³ AVAILABLE)
DISPOSAL BAGS	RESUPPLY REQUIRED

ITEM	ONBOARD	3 MEN, 30 DAYS*		5 MEN, 60 DAYS*	
		REQ	KIT	REQ	KIT
TRASH BAGS	120	48	-	158	38
DISPOSAL BAGS	0	32	32	108	108
URINE DISPOSAL BAGS	0	18	18	60	60
PLENUM BAGS	15	3	-	9	-
REMAINING WASTE TANK VOLUME (CUBIC FEET)	1518	125	N/A	415	N/A

*BASED ON SKYLAB USE RATE + 10% CONTINGENCY

Figure 2.1.3.2-7. Trash Disposal System Status-Refurbishment/Resupply

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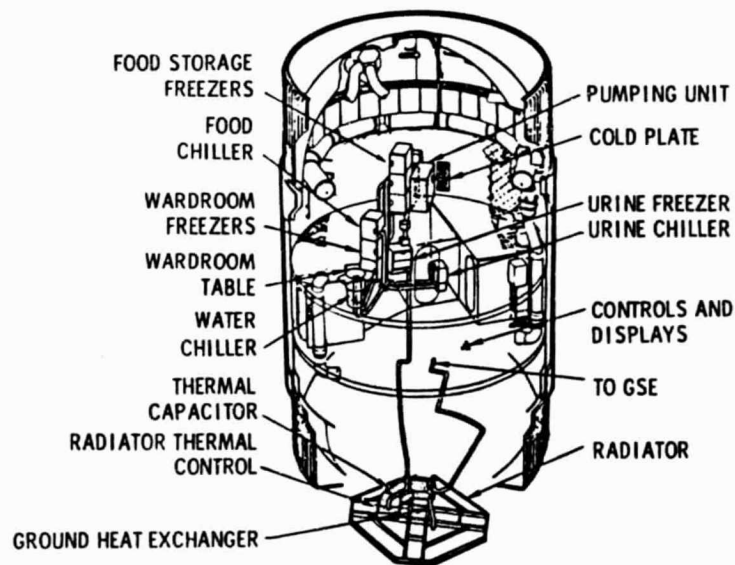
EQUIPMENT	STATUS
WATER DISPENSER IN WMC	SEE WATER SYSTEM
WASHCLOTH SQUEEZER IN WMC	SEE WATER SYSTEM
SHOWER	OPERATIONAL
BAR SOAP (11 BARS)	10 BARS
(1) LIQUID SOAP (SHOWER)**	DETERIORATED
(2) WET WIPES (7 BOXES)	DETERIORATED
UTILITY WIPES (23 BOXES)	0.3 BOX
(3) BIOCID WIPES (5 BOXES)	DETERIORATED
GENERAL PURPOSE TISSUES (11 BOXES)	3 BOXES
TOWELS (450)	142
WASHCLOTHS (840)	193
(4) TOWEL DRYING HOLDERS (24)	DETERIORATED
HYGIENE KIT (3)	EXPENDED

**QUALITY OF THESE ITEMS IS UNDETERMINED

ITEM	ONBOARD	3 MAN/30 DAY		5 MAN/60 DAY	
		REQ	KIT	REQ	KIT
WMC WATER DISPENSER*	1	1	0	1	0
WASHCLOTH SQUEEZER*	1	1	2 BAL SEALS	1	3 BAL SEALS
SHOWER*	1	1	0	1	0
SOAP BARS	54	1	0	3	0
(1) LIQUID SOAP (SHOWER)	?	?	?	?	?
TOWELS	142	54	0	180	38
WASHCLOTHS	193	114	0	378	185
HYGIENE KIT	0	3	3	5	5
(4) TOWEL DRYING HOLDERS	24	24	0	40	16
(2) WET WIPES (BOXES)	0	2	2	4	4
UTILITY WIPES (BOXES)	0	11	11	14	14
(3) BIOCID WIPES (BOXES)	0	1	1	2	2
GENERAL PURPOSE TISSUES (BOXES)	3	11	8	32	29

*PART OF WATER SYSTEM

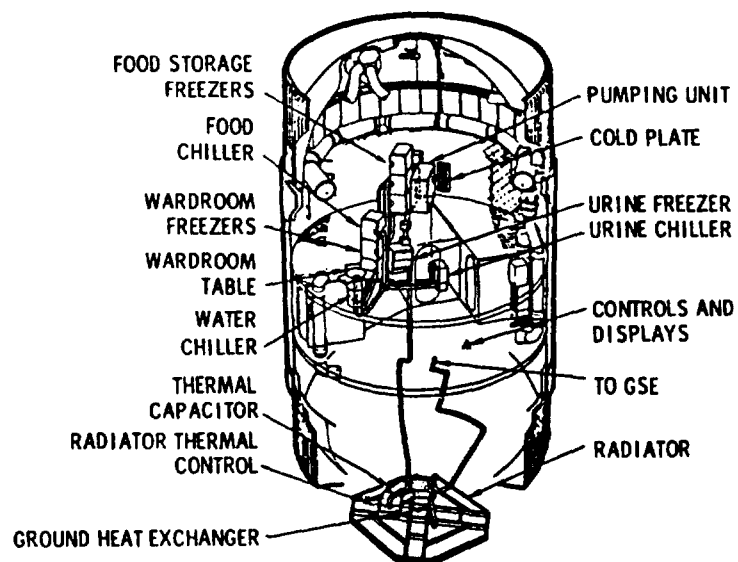
Figure 2.1.3.2-8. Personal Hygiene System Status-Refurbishment/Resupply



71

REFRIGERATION SYSTEM/EQUIPMENT	STATUS	
PRIMARY AND SECONDARY LOOPS	DISABLED	<ul style="list-style-type: none"> • VERIFY PRIMARY LOOP COOLANT; RESUPPLY IF REQUIRED
CONTROL ELECTRONICS (INVERTERS)	ACTIVE	
PRIMARY AND SECONDARY LOOP PUMPS (8)	TBD	
RADIATOR BY-PASS VALVES	BY-PASS	<ul style="list-style-type: none"> • REACTIVATE FOOD FREEZERS AND CHILLERS
THERMAL CAPACITOR	MELTED	
ACCUMULATORS	TBD	<ul style="list-style-type: none"> • REESTABLISH AUTO-DUAL LOOP OPERATION
- PRIMARY LOOP	43 PSIA	
- SECONDARY LOOP		
DATA SYSTEM	ACTIVE	
SYSTEM INTERNAL TEMPERATURES	OFF SCALE HIGH	
PRIMARY AND SECONDARY LOOPS ELECTRICALLY INDEPENDENT (PHYSICALLY DISCONNECTED)		

Figure 2.1.3.2-9. Refrigeration System Status-Refurbishment/Resupply



71

REFRIGERATION SYSTEM/EQUIPMENT	STATUS	
PRIMARY AND SECONDARY LOOPS	DISABLED	<ul style="list-style-type: none"> • VERIFY PRIMARY LOOP COOLANT; RESUPPLY IF REQUIRED
CONTROL ELECTRONICS (INVERTERS)	ACTIVE	
PRIMARY AND SECONDARY LOOP PUMPS (8)	TBD	
RADIATOR BY-PASS VALVES	BY-PASS	<ul style="list-style-type: none"> • REACTIVATE FOOD FREEZERS AND CHILLERS
THERMAL CAPACITOR	MELTED	
ACCUMULATORS		<ul style="list-style-type: none"> • REESTABLISH AUTO-DUAL LOOP OPERATION
- PRIMARY LOOP	TBD	
- SECONDARY LOOP	43 PSIA	
DATA SYSTEM	ACTIVE	
SYSTEM INTERNAL TEMPERATURES	OFF SCALE HIGH	
PRIMARY AND SECONDARY LOOPS ELECTRICALLY INDEPENDENT (PHYSICALLY DISCONNECTED)		

Figure 2.1.3.2-9. Refrigeration System Status-Refurbishment/Resupply

2.2 MISSION/PAYLOAD ANALYSES

The benefits of Skylab reuse missions were assessed by examining requirements of a representative baseline reference mission model that could be satisfied by reuse. The study team during the course of the study (1) assembled a representative mission model and (2) examined the model in order to determine the space support required to satisfy the model. The early role of Skylab reuse measured against the mission model was assessed. The benefits of reuse were summarized as presented below.

In general, Skylab reuse benefits can be categorized within three classes:

(1) For missions such as materials processing and life sciences, Skylab represents a potentially low-cost approach to achieve extended duration as opposed to the establishment of a continuously-manned facility through a new hardware start. (2) Likewise, the existence of Skylab represents an early opportunity to dedicate a facility to a given specific set of mission objectives. (3) Also of engineering interest is the availability of a long-term assessment of the effect of the space environment on both materials and equipment. Space exposure assessments made on Skylab of both existing and new materials and hardware can benefit future missions by having accurate and sufficient empirical data on the performance of manned space systems over 10-year or longer periods of time.

The sections of this report which follow describe in detail the baseline reference mission model, the requirements represented by the model, the early role of Skylab reuse and a summary of mission-oriented benefits of reuse.

2.2.1 Baseline Reference Mission Model

In order to assess the benefits of a Skylab reuse program, a baseline reference mission model was assembled at the outset of the study. The MDAC study team was assigned the task of assembling the model for three specific disciplines: (1) Materials Processing in Space, (2) Life Sciences, and (3) Space Construction/Solar Power Satellite System (SPS) Development. The model consists of a flight schedule of specific payloads over the time period of 1980 to 1991. In order to provide continuity of disciplinary development paths, the mission models also included the period from the initiation of STS operations in 1980 until the Skylab IOC in early 1984.

For the three discipline areas analyzed by the study team, payload mission models were assembled from authoritative data sources. The principal emphasis of the analysis was to define the payload support requirements (i.e., crew size, mission duration, and power demand). These sources included the NASA STS Mission Model (October 1977), the MDAC Space Station Systems Analysis Study (SSSAS), and current planning data provided by NASA to the study team. The SSSAS had relied on Outlook for Space (OFS)¹ as the major contributory source of long-range goals and objectives. Also contained in this source document are descriptions of space systems and programs to be required to the year 2000. For the Materials Processing discipline, in addition to OFS, the SSSAS utilized the results of three space processing payload equipment Phase-B studies (Contracts NAS8-31353, NAS8-31494, and NAS8-31495). These supplied the principal source of mission requirements for the earlier (circa 1980-1984 portion of the flight program). Additionally, the SSSAS executed special emphasis tasks to define the requirements for the later time period development and commercially-oriented materials processing missions.

In each of the three cases, a statement of the disciplines' total program goals and objectives is as follows:

A. Materials Processing in Space

- Scientific: Demonstrate the capabilities of studying earth process in space.
- Development: Demonstrate the utility of space to future industrial uses.
- Commercial: Conduct commercially and/or economically attractive operations in space.

B. Life Sciences

- Biomedicine: Ensure human health, safety, well-being and effective performance in space flight and apply research results to terrestrial problems.
- Space Biology: Utilize the space environment to better understand the role of gravity and other factors to terrestrial life processes.

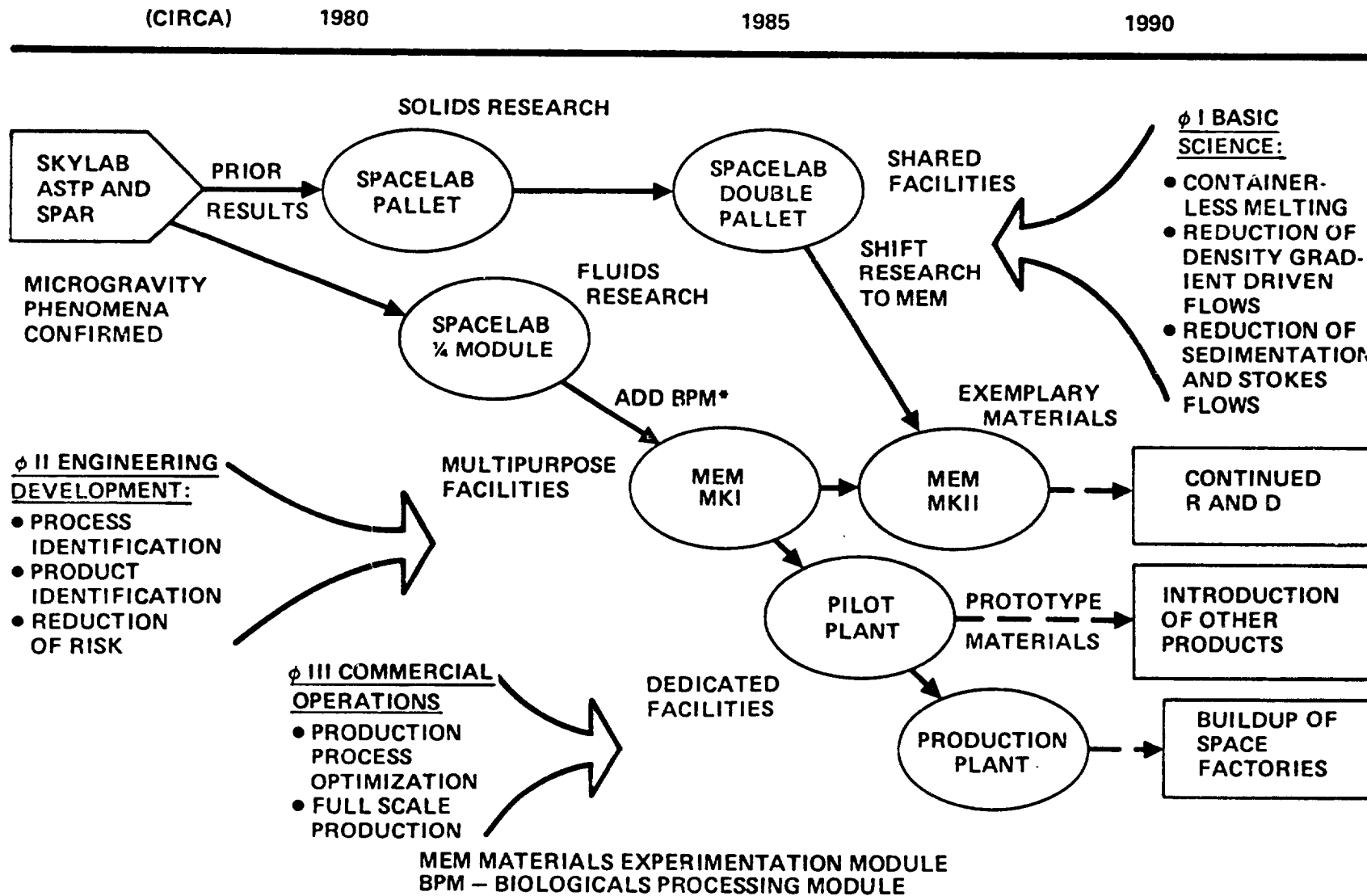
¹Report to the NASA Administrator by the Outlook for Space Study Group, NASA SP-386, January 1976.

- Advanced Technology: Utilize advanced techniques fo science and engineering to control man's environment in space and extend his capabilities.
- C. Space Construction - SPS Development
- Technology Verification: Test at the component, major element, and subsystem level to demonstrate feasibility of selected designs and design approaches, evaluate operational characteristics and assess environmental effects using the Shuttle-Sortie Mode and Power Module capabilities.
 - Proof of Concept: Demonstrate SPS test articles, major subsystems, and subscale systems evolved designs suitability for commercial SPS end items, using space platforms/SCB capabilities for construction/fabrication/assembly operations and establish and conduct test and operations in both LEO and GEO orbits.
 - Commercial Operations: Implement system development and full scale operations in space.

Activity plans (growth scenarios) were prepared by the study team which represented a development plan to satisfy the goals and objectives of these disciplines. As a further description of the plan, a flight schedule (mission model) was prepared which depicted a series of payloads identified to execute a complete program. For each distinctive payload, a data sheet was prepared delineating the physical characteristics, the mission characteristics, and a listing of typical equipment items. The individual growth scenarios and the mission models for the three discipline areas are shown in Figures 2.2.1-1 through 2.2.1-6. The data sheets are contained in Appendix C.

Using the growth scenarios, mission models, and payload description data sheets master requirements summaries were prepared for each discipline. These summaries are shown in Tables 2.2.1-1, 2.2.1-2 and 2.2.1-3. The first column of the tables is a mission identification code for the discipline area of concern. The first two digits indicate the calendar year of the flight; the last digit is an arbitrary sequence identified for the year. The next column indicates the type of mission, i.e., a Spacelab pallet, module or free-flyer. The next column is a short description of the flight objectives and is followed by a reference to the NASA STS Mission Model (October 1977) where applicable.

MATERIALS PROCESSING GROWTH SCENARIO



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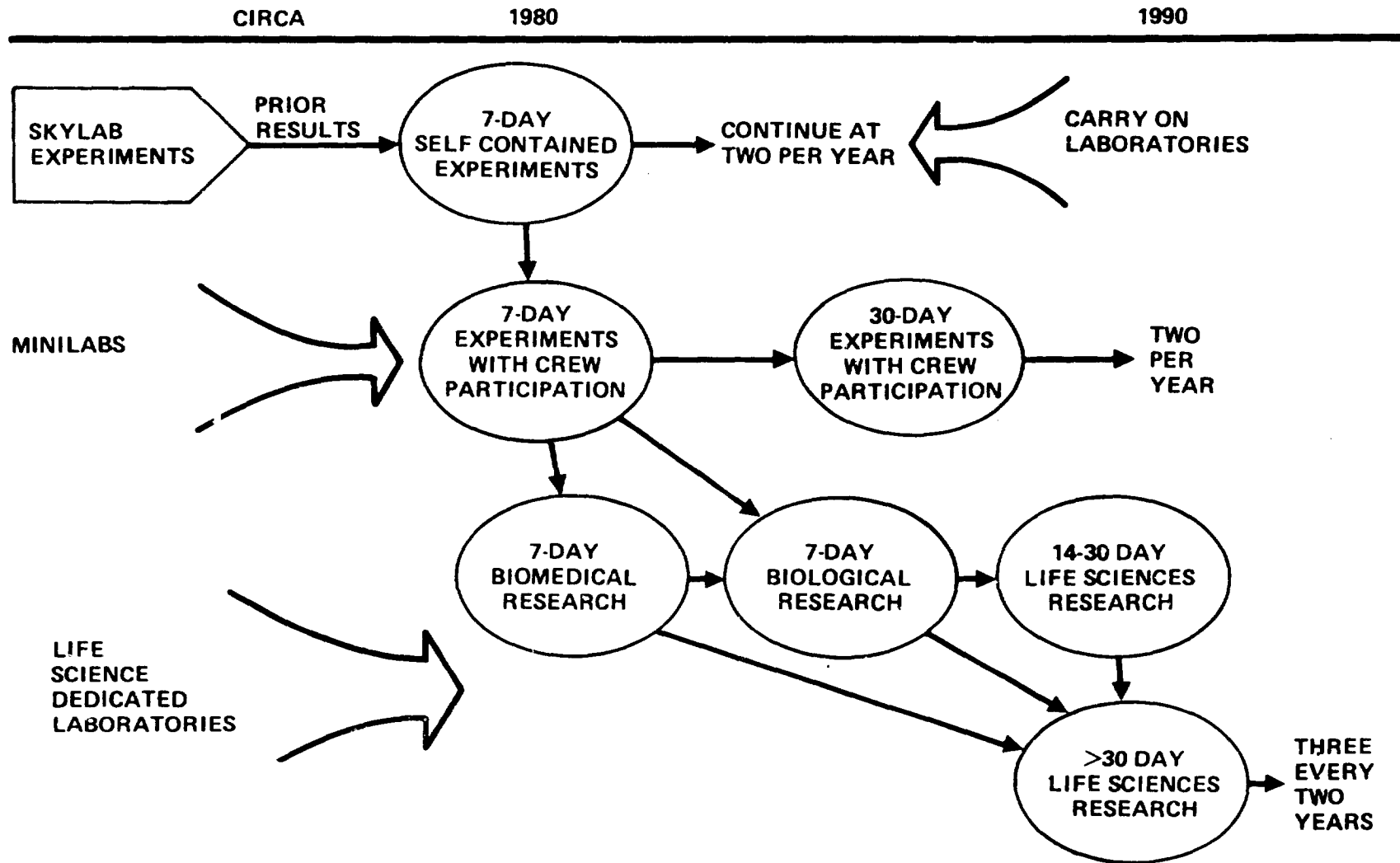
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MATERIALS PROCESSING MISSION MODEL

SPACE PROCESSING PAYLOADS/MISSIONS	CY. 19__										
	81	82	83	84	85	86	87	88	89	90	91
<u>SPACELAB MISSIONS</u>											
• PALLETS _____	1	3	2	6	6						
• MODULES _____	1	1	1	1							
<u>GROWTH MISSIONS</u>											
• MEM _____				4	3	3	2	2	2	2	2
• PILOT PLANT _____							2	2	2	2	2
• PRODUCTION PLANT _____								1	1	1	1
TOTAL MISSIONS PER YEAR	2	4	3	11	9	3	4	5	5	5	5
											$\Sigma = 56$ MISSIONS

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LIFE SCIENCES GROWTH SCENARIO



77

LIFE SCIENCES PAYLOAD/MISSIONS	CY 19__											
	80	81	82	83	84	85	86	87	88	89	90	91
<u>CARRY ON LABS</u>			1	2		1		1			1	
• MEDICAL			[Bar spanning 82-91]									
• BIOLOGY	1	1	1		2	1	1	1	1	1	1	2
• TECHNOLOGY		1					1		1	1		
<u>MINILABS</u>		1	1		2	2		1	2			1
• MEDICAL		[Bar spanning 81-91]										
• BIOLOGY		1	1	1		1	1	1	1	2		
• TECHNOLOGY				1			1	1	1	1		1
<u>DEDICATED LABS</u>			1									
• MEDICAL			[Bar spanning 82-83]							1		
• MED/BIOLOGY					1	1						
• BIOLOGY								1				
• TECH/BIOLOGY												1
TOTAL MISSIONS PER YEAR	1	4	5	4	5	6	4	6	7	5	3	5
											$\Sigma = 55$	
LEGEND	SHUTTLE TENDED		PERMANENTLY MANNED									MISSIONS

Figure 2.2.1-4. Life Sciences Mission Model

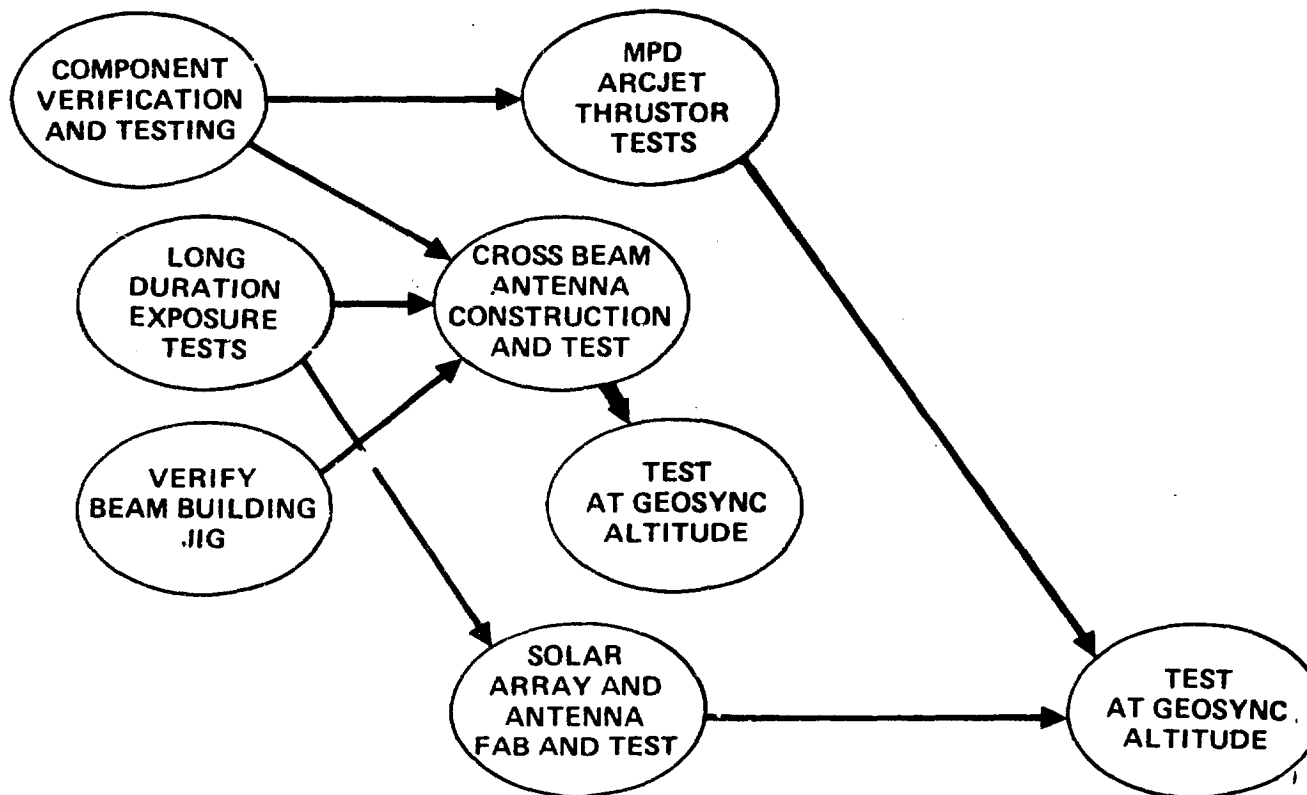
SPACE CONSTRUCTION – SPS DEVELOPMENT

(CIRCA)

1980

1985

1990



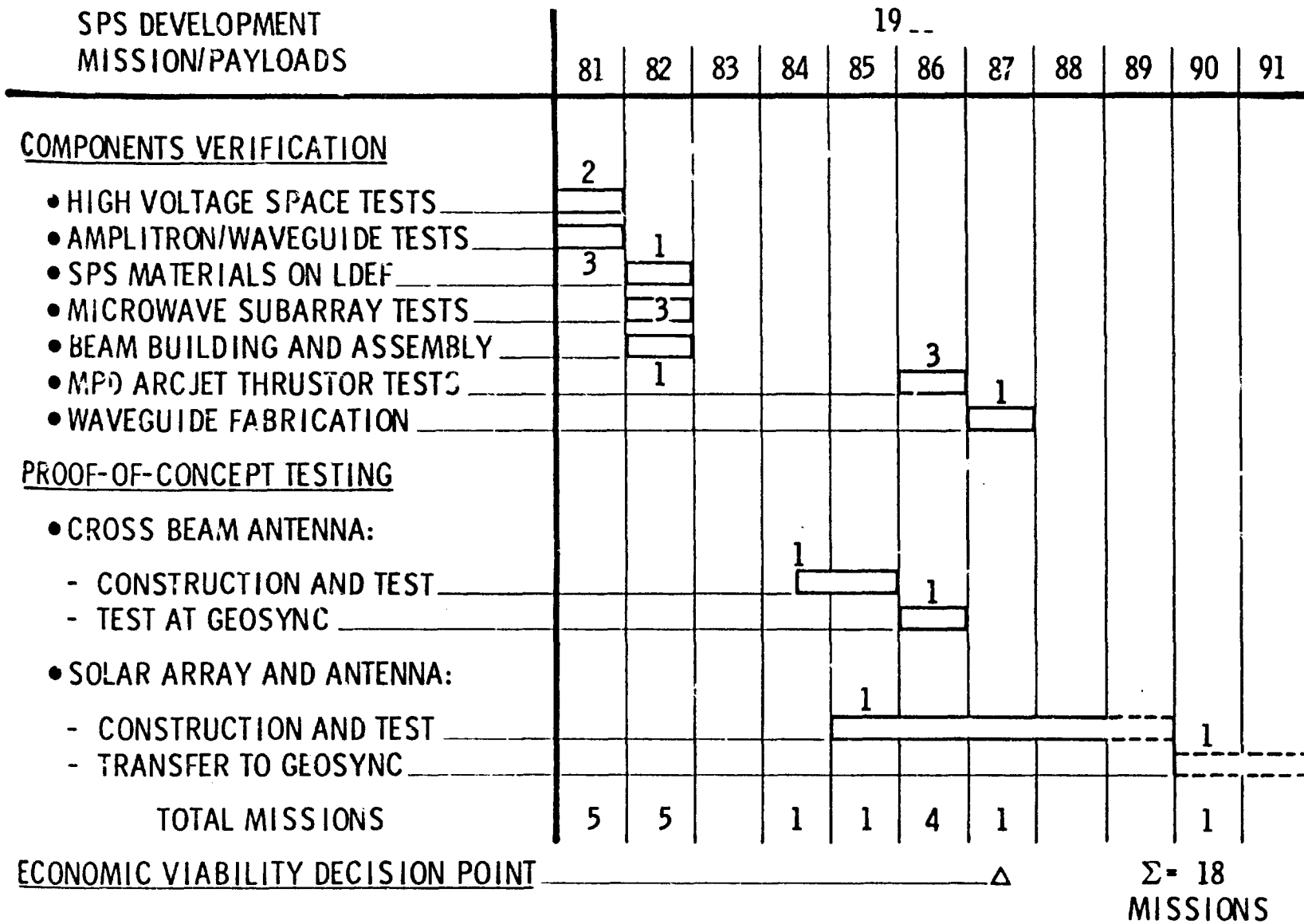


Figure 2.2.1-6. Space Construction - SPS Development Mission Model

Table 2.2.1-1 (Page 1 of 2)

MATERIALS PROCESSING FLIGHT AND REQUIREMENTS SUMMARY
(prepared March 1, 1978)

Mission		Typical Mission Goals and Objectives for Flight	NASA SYS MM(10-77)		Payload Characteristics					Maximum Requirements		
Flt ID	Type		Flt #	Ref. Code	Dur-d	Crew	Pwr-kW	Wt-lb	Dim-ft	Man-days	Max Pwr	Max Crew
81-1	SP	Conduct furnace experiments	81-9	BKCK01	7	2	5	10,500	10x15	35	5	3
81-2	SM	Conduct fluids experiments	81-7	BKCH01	7	2-3	2	35,673 ⁽¹⁾	48.5x15			
82-1	SP	Continue furnace research	82-8	BKCK01	7	2	5	10,000	10x15	63	5	3
82-2	SP	Continue furnace research	82-9	BKCK01	7	2	5	10,000	10x15			
82-3	SP	Continue furnace research	82-14	BKCK01	7	2	5	10,500	10x15			
82-4	SM	Continue fluids research	82-7	BKCX01	7	2-3	2	2,000	--			
83-1	SP	Add float zone capability	83-2	BKCK01	7	2	5	10,500	10x15	49	5+	3
83-2	SP	Duplicate furnace capability	83-8	BKCK01	7	2	5	21,000	20x15			
83-3	SM	Add bioprocessing module	83-12	BKCX01	7	3	2	7,000	--			
84-1	SP	Add ECPM capability	84-1	BKCK01	7	2	5	10,500	10x15	(105)	8	3
84-2	SP	Add ELS capability	84-5	BKCK01	7	2	5	9,000	10x15			
84-3	SP	Add MLS capability	84-18	BKCK01	7	2	5-8 ⁽²⁾	10,500	10x15			
84-4	SP	Continue extended research	84-27	BKCK01	7	2	8	10,500	10x15			
84-5	SP	Continue extended research	84-28	BKCK01	7	2	8	10,500	10x15			
84-6	SP	Continue extended research	84-29	BKCK01	7	2	8	10,500	10x15			
84-7	SM	Continue extended research	84-7	BKCX01	7	3	2	7,000	--			
84-8	SPDF ₁	Demonstrate development capability	Concept not specifically included in MM	14	2	8	22,000	30x15	(208)			
84-9	SPDF ₁	Initiate exemplary production		30	2	8	22,000	30x15				
84-10	SPDF ₁	Refine processor operation		30	2	8	22,000	30x15				
84-11	SPDF ₁	Continue development activities		30	2	8	22,000	30x15				
85-1	SP	Continue scientific research	85-4	BKCK01	7	2	8	10,500	10x15	636	8	3
85-2	SP	Continue scientific research	85-7	BKCK01	7	2	8	10,500	10x15			
85-3	SP	Continue scientific research	85-26	BKCK01	7	2	8	10,500	10x15			
85-4	SP	Continue scientific research	85-28	BKCK01	7	2	8	10,500	10x15			
85-5	SP	Continue scientific research	85-31	BKCK01	7	2	8	10,500	10x15			
85-6	SP	Continue scientific research	85-5	BPSK01	13	2	8	10,500	10x15			
85-7	SPDF ₁	Initiate prototype production	85-9	BKCX01	60 ⁽³⁾	3	8	22,000	30x15			
85-8	SPDF ₁	Support scientific experiment			60 ⁽³⁾	3	8	22,000	30x15			
85-9	SPDF ₁	Continue research and development			60	3	8	22,000	30x15			
86-1	SPDF ₂	Continue development capabilities	86-27 86-36	BQ	90	3	15	25,000	30x15	810	15	3
86-2	SPDF ₂	Continue extended R&D	86-34	BK								
86-3	SPDF ₂	Continue extended R&D	86-35	BK								

TABLE 2.2.1-1 (Page 2 of 2)
 MATERIALS PROCESSING FLIGHT AND REQUIREMENTS SUMMARY
 (prepared March 1, 1978)

Mission		Typical Mission Goals and Objectives for Flight	NASA STS MM(10-77)		Payload Characteristics					Maximum Requirements		
Flt ID	Type		Flt #	Ref. Code	Dur:d	Crew	Pwr:kw	Wt:lb	Dim:ft	Man-days	Max Pwr	Max Crew
87-1	SPDF ₂	Continue extended R&D	87-27	BQ	90	3	15	25,000	30x15	1,260	20	4
			87-36	BQ								
87-2	SPDF ₂		87-37	BQ	90	3	15	25,000	30x15			
87-3	PP		87-34,5	BK	90	4	20	32,000	40x15			
87-4	PP	Demonstrate pilot production	87-38	BP	90	4	20	32,000	40x15			
88-1	SPDF ₂	Continue extended R&D	88-30	BQ	90	3	15	25,000	30x15	2,340	25	7
88-2	SPDF ₂	Continue extended R&D	88-39	BQ	90	3	15	25,000	30x15			
88-3	PP	Add new proto-materials	88-40	BQ	90	4	20	32,000	40x15			
88-4	PP	Add new proto-materials	88-37	BK	90	4	20	32,000	40x15			
			88-38	BK								
88-5	PROD	Initial commercial production	88-41	BP	180	7	25	50,000	40x15			
89-1	SPDF ₂	Continue extended R&D	88-27	BQ	90	3	15	25,000	30x15	6,300	50	14
89-2	SPDF ₂	Continue extended R&D	88-36	BQ								
			88-37	BQ								
89-3	PP	Continue pilot plant activities	88-34	BK	90	4	20	32,000	40x15			
89-4	PP	Continue pilot plant activities	88-35	BK	90	4	20	32,000	40x15			
89-5	PROD	Add new products	88-38	BP	360	14	50	100,000	2 @ 50x15			
90-1	SPDF ₂	Continue extended R&D	90-32	BQ	90	3	15	25,000	30x15	6,300	75	14
90-2	SPDF ₂	Continue extended R&D	90-41	BQ								
			90-42	BQ								
90-3	PP	Continue pilot plant activities	90-39	BK	90	4	20	32,000	40x15			
90-4	PP	Continue pilot plant activities	90-46	BK	90	4	20	32,000	40x15			
90-5	PROD	Add new products	90-43	BP	360	14	75	150,000	3 @ 50x15			
91-1	SPDF ₂	Continue extended R&D	91-26	BQ	90	3	15	25,000	30x15	6,300	100	14
91-2	SPDF ₂	Continue extended R&D	91-35	BQ								
			91-36	BQ								
91-3	PP	Continue pilot plant activities	90-33	BK	90	4	20	32,000	40x15			
91-4	PP	Continue pilot plant activities	90-34	BK	90	4	20	32,000	40x15			
91-5	PROD	Add new products	90-37	BP	360	14	100	200,000	4 @ 50x15			

Legend: SP - Spacelab Pallet
 SM - Spacelab Module
 ECPM - Electromagnetic containerless processing module
 ELS - Electrostatic levitation system
 MLS - Monodisperse latex system
 SPDF - Space Processing Development Facility
 PP - Pilot Plant Module
 PROD - Commercial Production Module
 MM - Mission Model

General Note: Microgravity environment level maintenance requirements vary approximately 10⁻³g. Scheduling of more severe (10⁻²g) requirements are critical.

Notes: (1) Characteristics of whole module.
 (2) 25 kW Power Module available.
 (3) Desire to leave facility on orbit to economize startup procedures.

TABLE 2.2.1-2 (Page 1 of 2)
 LIFE SCIENCES FLIGHT AND REQUIREMENTS SUMMARY
 (prepared March 14, 1978)

Mission		Typical Mission Goals and Objectives for Flight	NASA SYS MM(10-77)		Payload Characteristics				Maximum Requirements			
Flt ID	Type		Flt #	Ref. Code	Dur-d	Crew	Pwr-kW	Wt-lb	Vol ft ³	Man-days	Max Pwr	Max Crew
80-1	C	Biological studies of organisms		(1)	7*	1	.1	55	4.5	7	.1	1
81-1	C	Biological studies		(1)	7**	1	.1	55	4.5			
81-2	C	Technology Experiments		(1)	7**	1	.2	55	4.5			
81-3	H	Biological studies of early responses	81-10	BJAH01	7**	3	.6	480	26	28	.6	3
81-4	H	Biological studies of early responses	81-11	BJAX01	7*	1	.2	686	69			
82-1	C	Medical studies of human responses		(1)	7*	3	.5	30	2.5			
82-2	C	Biological studies		(1)	7**	1	.1	55	4.5			
82-3	H	Medical research	82-7	BJAX01	7**	3	.6	480	26			
82-4	H	Biological research	82-10	BJAH01	7*	1	.2	686	69	35	2.8	3
82-5	L	Test of concept	82-11	BJAH01	7**	1	2.8	6830	Module			
83-1	C	Medical studies		(1)	7**	3	.5	30	2.5			
83-2	C	Medical studies		(1)	7**	3	.5	30	2.5			
83-3	H	Biological research	83-4	BJAH01	7*	1	.2	606	69	14	.6	1
83-4	H	Concept verification	83-5	BJAH01	7	1	.6	440	49			
84-1	C	Biological studies		(1)	7*	1	.1	55	4.5			
84-2	C	Biological studies		(1)	7*	1	.1	55	4.5			
84-3	H	Medical research	84-7	BJAX01	7**	3	.6	480	26			
84-4	H	Medical research	84-19	BJAH01	7**	3	.6	480	26	49	3.8	3
84-5	L	Animal holding facility test	84-20	BJAH01	7**	1	3.8	7429	Module			
85-1	C	Medical Studies		(1)	7*	3	.5	30	2.5			
85-2	C	Biological studies		(1)	7**	1	.1	55	4.5			
85-3	H	Medical research	85-9	BJAX01	7**	3	.6	480	26			
85-4	H	Biological research	85-9	BJAX01	7**	1	.2	686	69	208	3.8	3
85-5	H	Medical research-adaptation	85-14	BJAH01 (2)	30**	3	2.0	2020	180			
85-6	L	Medical/biological study of adaptation	85-15	BJAH01 (2)	30*	3	3.8	7700	Module			
86-1	C	Biological studies		(1)	7*	1	.1	55	4.5			
86-2	C	Technology experiments		(1)	7**	1	.2	55	4.5			
86-3	H	Biological research	86-16	BJ (3)	7*	1	.2	686	69	14	.6	1
86-4	H	Concept verification	86-17	BJ (3)	7	1	.6	440	49			
87-1	C	Medical studies		(1)	7*	3	.5	30	2.5			
87-2	C	Biological studies		(1)	7**	1	.1	55	4.5			
87-3	H	Medical research			7**	3	.6	480	26			
87-4	H	Biological research	87-14	BJ (3)	7	1	.6	440	49	>134	1.1	3
87-5	H	Concept verification	87-15	BJ (3)	30*	3	1.1	2022	210			
87-6	L	Long term biological effects			>90**	3	4.0	6600	Module			

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TABLE 2.2.1-2 (Page 2 of 2)
 LIFE SCIENCES FLIGHT AND REQUIREMENTS SUMMARY
 (prepared March 14, 1978)

Mission		Typical Mission Goals and Objectives for Flight	NASA STS MM (10-77)		Payload Characteristics					Maximum Requirements		
Flt ID	Type		Flt #	Ref. Code	Durd	Crew	Pwr:kw	Wt-lb	Vol-ft ³	Man-days	Max Pwr	Max Crew
88-1	C	Biological studies		(1)	7*	1	.1	55	4.5			
88-2	C	Technology experiments		(1)	7**	1	.2	55	4.5			
88-3	M	Medical research			7**	3	.6	480	26			
88-4	M	Biological research	88-20	BJ (3)	7*	1	.2	686	69			
88-5	M	Concept verification	88-21	BJ (3)	30**	3	2.0	2020	180	432	2.8	3
88-6	M	Medical research-adaptation			30	1	.6	550	150			
88-7	L	Medical study of physiological changes			90**	3	2.8	7480	Module			
89-1	C	Biological studies		(1)	7*	1	.1	55	4.5			
89-2	C	Technology experiments		(1)	7**	1	.2	55	4.5			
89-3	M	Biological research			7*	1	.2	686	69			
89-4	M	Concept verification	89-16	BJ (3)	7	1	.6	440	49	118	1.1	3
89-5	M	Biological research-adaptation	89-17	BJ (3)	30*	3	1.1	2022	210			
90-1	C	Medical studies		(1)	7*	3	.5	30	2.5			
90-2	C	Biological studies		(1)	7**	1	.1	55	4.5			
90-3	L	Study long term effects	90-22 90-23	BJ (3) BJ	>90	3**	4.0	6600	Module	>90	4.0	3
91-1	C	Biological studies		(1)	7*	1	.1	55	4.5			
91-2	C	Biological studies		(1)	7*	1	.1	55	4.5			
91-3	M	Medical research-adaptation			30**	3	2.0	2020	180			
91-4	M	Concept verification	91-15	BJ (3)	30	1	.6	550	150	>150	4.0	3
91-5	L	Test advanced life support systems	91-16	BJ (3)	>90	3**	4.0	8800	Module			

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Legend: C - Carry-on Payload
 M - Minilab
 L - Life Science Dedicated Lab
 MM - Mission Model

Notes: (1) Carry-on payloads are not included in the NASA STS Mission Model but could be accommodated on most any STS flight.
 (2) NASA STS Mission Model shows 14-day duration.
 (3) NASA STS Mission Model shows 30-day duration.
 * Acceleration level of 10^{-4} G for 90% of time required.
 ** Acceleration level of 10^{-3} G for 90% of time required.

Table 2.2.1-3
SOLAR POWER SATELLITE (SPS) DEVELOPMENT FLIGHT AND REQUIREMENTS SUMMARY
(prepared March 2, 1978)

Mission		Typical Mission Goals and Objectives for Flight	NASA STS MM(10-77)		Payload Characteristics					Maximum Requirements		
Flt ID	Type		Flt #	Ref. Code	Durcd	Crew	Pwr-kW	Wt-lb	Vol-ft ³	Man-days	Max Pwr	Max Crew
81-1	SP	High voltage space test #1	81-9	BEBK01	7	1	0.5	110	2			
81-2	SP	Ampliftron test	81-11	BEBK01	7	1	0.5	110	2			
81-3	SP	Waveguide test	81-9	BEBK01	7	1	6	110	2	35	6	1
81-4	SP	High voltage space test #2	81-11	BEBK01	7	1	6	110	2			
81-5	SP	Ampliftron/waveguide test	81-8	Pickaback	7	1	6	110	2			
82-1	FF	SPS materials on LDEF	82-5	ALBA01	360	--	--	TBD	TBD			
82-2	SP	Microwave subarray test #1	82-8	BEBK01	7	1	4	300	60			
82-3	SP	Microwave subarray test #2	82-9	BEBK01	7	1	4	300	60	81	5	2
82-4	SP	Microwave subarray test #3	82-5	Pickaback	7	1	4	300	60			
82-5	STS	Beam building and assembly	--	(2)	30	2*	5	33,000	6,600			
84-1	STS	Cross beam antenna construction	--	(2)	485	3 (1)	6	13,000	2,600	360	6	3
85-1	STS	Cross beam antenna test at GEO	--	(2)	900	3***	12	54,500	10,000	--	--	--
86-1	STS	MPD Arcjet thruster test #1	--	(2)	7	1	17.5	5,000	1,000			
86-2	STS	MPD arcjet thruster test #2	--	(2)	7	1	17.5	5,000	1,000			
86-3	STS	MPD arcjet thruster test #3	--	(2)	7	1	17.5	5,000	1,000	21	17.5	1
86-4	FF**	Solar array construction	--	(2)	360	--	80	13,000	2,600			
87-1	STS	Waveguide fabrication	--	(2)	30	2***	5	TBD	TBD	60	5	2
90-1	FF**	Solar array test at GEO	--	(2)	360	--	NA	54,500	10,000	--	--	--

Legend:

SP - Spacelab pallet
 FF - Free-Flyer
 STS - Shuttle-tended Sortie
 MPD - Magneto-plasma-dynamic
 MM - Mission Model

Notes:

(1) manned period - 120 days
 (2) not included in NASA Mission Model

* EVA for 3 days
 ** At GEO
 ***2 EVA for TBD days

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The next five columns contain the payload characteristics in terms of mission duration, crew size, power, and physical properties of the payload. The last three columns of the tables summarize for the year in question the total man-days, the maximum power level encountered, and the maximum crew size called for during the year. Each table is accompanied by explanatory notes and legends.

2.2.2 Mission Requirements

Using the mission model and payload characteristics as described above, mission requirement summaries were prepared for each of the three discipline areas. The companion studies provided similar inputs for the disciplines of astronomy/astrophysics, solar-terrestrial obstructions, earth viewing, and space construction-communications. In particular, requirements were delineated by discipline for (1) electrical power, (2) crew support, and (3) flight duration as reflected by the baseline mission model. Additionally, the flight frequency and total manned mission days were summarized for each year in the time frame of 1980-1991. These summaries are presented in Figures 2.2.2-1 through 2.2.2-5. The entries on Figures 2.2.2-1, 2.2.2-2, and 2.2.2-3 represent the typical maximum of each requirement within a particular discipline. The cross-hatched entries represent support requirements that are probably beyond the capability of a Skylab reuse mission.

Evaluation of Figure 2.2.2-1 shows that the materials processing payloads size the electrical power requirement in the mission model. By way of contrast, the Life Sciences, in terms of bus power to the payload, have the lowest power demand. It should be noted, that with the exception of materials processing (cross-hatched area in the late 1980s), the Skylab operational facility can support any individual payload in the mission model.

Figure 2.2.2-2 demonstrates that crews of from three to seven (Skylab potential growth) are adequate for all disciplines except for materials processing late in the 1980s. However, it is significant to note that if longer mission durations are available, as reflected by the requirements shown in Figure 2.2.2-3, the same work can be accomplished per unit time with smaller crews than expected from shorter duration flights.

Figure 2.2.2-1

41547

CANDIDATE PAYLOADS/MISSIONS - DETAIL ELECTRICAL POWER REQUIREMENTS-KW

DISCIPLINE AREAS	CALENDAR YEAR 19__											
	80	81	82	83	84	85	86	87	88	89	90	91
MATERIALS PROCESSING	-	5.0	5.0	5.5	8.0	8.0	15	20	25	50	75	100
LIFE SCIENCES	0.1	0.6	2.8	0.6	3.8	3.8	0.6	1.1	2.8	1.1	4.0	4.0
ASTRONOMY/ ASTROPHYSICS	-	2.7	3.0	3.0	3.5	4.5	6.0	8.3	8.5	15	20	20
SOLAR-TERRESTRIAL OBSERVATIONS	-	2.0	2.0	3.8	4.0	4.0	4.5	4.5	5	5.5	6.0	6.0
EARTH VIEWING	-	-	4.2	4.3	4.6	5.0	*	*	*	*	*	*
COMMUNICATIONS/ SPS DEVELOPMENT	-	6.0	5.0	4.4	6.0	4.8	17	6.0	8.0	8.0	10	10
SKYLAB REUSE PROGRAM PHASE	II (LIMITED VISITS)			III (REACTIVATION)			IV (OPERATIONAL FACILITY)					

*MISSIONS COMBINED WITH
COMMUNICATIONS

Figure 2.2.2-2

41550

CANDIDATE PAYLOADS/MISSIONS - CREW SUPPORT REQUIREMENTS

DISCIPLINE AREAS	CALENDAR YEAR 19__											
	80	81	82	83	84	85	86	87	88	89	90	91
MATERIALS PROCESSING	-	3	3	3	3	3	3	4	7	14	14	14
LIFE SCIENCES	1	3	3	1	3	3	1	3	3	3	3	3
ASTRONOMY/ ASTROPHYSICS	-	2	2	2	2	4	4	4	4	6	6	6
SOLAR-TERRESTRIAL OBSERVATIONS	-	2	2	4	4	4	4	4	6	6	6	6
EARTH VIEWING	-	2	2	4	4	4	*	*	*	*	*	*
COMMUNICATIONS/ SPS DEVELOPMENT	-	1	2	3	4	4	6	6	6	6	6	6
SKYLAB REUSE PROGRAM PHASE	II (LIMITED VISITS)			III (REACTIVATION)			IV (OPERATIONAL FACILITY)					

* MISSIONS COMBINED WITH
COMMUNICATIONS

Figure 2.2.2-3

41549

CANDIDATE PAYLOADS/MISSIONS - FLIGHT DURATION REQUIREMENTS

DISCIPLINE AREAS	CALENDAR YEAR 19__												
	80	81	82	83	84	85	86	87	88	89	90	91	
MATERIALS PROCESSING	-	7	7	7	30	60	> 90	—————→					
LIFE SCIENCES	7	7	7	7	7	30	7	> 90	> 90	30	> 90	> 90	
ASTRONOMY/ ASTROPHYSICS	-	7	14	7	30	45	48	56	> 60	> 60	> 60	> 60	
SOLAR-TERRESTRIAL OBSERVATIONS	-	14	14	7	28	56	56	> 60	> 60	> 60	> 60	> 60	
EARTH VIEWING	-	-	7	7	7	42	*	*	*	*	*	*	
COMMUNICATIONS/ SPS DEVELOPMENT	-	17	14	14	14	28	56	> 60	> 60	> 60	> 60	> 60	

SKYLAB REUSE
PROGRAM PHASE

II
(LIMITED VISITS)

III
(REACTIVATION)

IV
(OPERATIONAL FACILITY)

* MISSIONS COMBINED WITH
COMMUNICATIONS

CANDIDATE PAYLOADS/MISSIONS

DISCIPLINE AREAS	CALENDAR YEAR 19__											
	80	81	82	83	84	85	86	87	88	89	90	91
MATERIALS PROCESSING	-	2	4	3	11	9	3	4	5	5	5	5
LIFE SCIENCES	1	4	5	4	5	6	4	6	7	5	3	5
ASTRONOMY/ ASTROPHYSICS	-	4 (1)	3 (1)	4 (1)	7 (6)	8 (4)	5 (4)	4 (3)	4 (3)	4	3	3
SOLAR-TERRESTRIAL OBSERVATIONS	-	1	2	1	3 (1)	1	1	1	1	1	1	1
EARTH VIEWING	-	-	3 (1)	5 (1)	2	2	*	*	*	*	*	*
COMMUNICATIONS/ SPS DEVELOPMENT	-	5	7	2	4	4	6	3	2	2	3	2
SKYLAB REUSE PROGRAM PHASE	II (LIMITED VISITS)			III (REACTIVATION)			IV (OPERATIONAL FACILITY)					

* MISSIONS COMBINED WITH COMMUNICATIONS

Figure 2.2.2-5

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**CANDIDATE PAYLOADS/MISSIONS
ORBITAL FACILITY REQUIREMENTS
TOTAL NUMBER OF MANNED MISSION DAYS**

DISCIPLINE AREAS	CALENDAR YEAR 19__											
	80	81	82	83	84	85	86	87	88	89	90	91
MATERIALS PROCESSING	-	14	28	21	153	228	270	360	540	720	720	720
LIFE SCIENCES	7	28	35	28	35	88	28	>168	178	58	>104	>164
ASTRONOMY/ ASTROPHYSICS	-	33 (7)	28 (14)	28 (7)	155 (148)	229 (187)	228 (192)	192 (144)	224 (168)	320	240	240
SOLAR-TERRESTRIAL OBSERVATIONS	-	14	28	7	42 (28)	56	56	84	84	180	180	180
EARTH VIEWING	-	-	21 (7)	49 (7)	68	112	*	*	*	*	*	*
COMMUNICATIONS/ SPS DEVELOPMENT	-	35	72	28	148 (141)	317 (289)	133	220	180	200	240	240
SKYLAB REUSE PROGRAM PHASE		II (LIMITED VISITS)			III (REACTIVATION)		IV (OPERATIONAL FACILITY)					

* MISSIONS COMBINED WITH
COMMUNICATIONS

() - SUBSET OF MISSIONS WHERE ORBIT REQUIREMENTS MATCH SKYLAB MISSION

Figure 2.2.2-6 summarizes the distribution of crew activities and task performance measured during the Skylab missions. The noted empirical data shows two important results derived from detailed analysis of crew activities experienced during the Skylab missions: (1) distribution of crew time, and (2) efficiency of repeated tasks as a function of mission duration. It was observed that, on the average, about eight hours of a 24-hour period to be available for payload work; the remainder being required for personal activities and station-keeping tasks. The second observation was a marked improvement in task efficiency as measured by the time required to perform specific experiment-related tasks as the mission progresses. The data shown describes "learning curve" averages between 72 percent (very good) and 87 percent (good) for three major biomedical experiments. For example, at the outset of Skylab-4, the M171 metabolic activity medical experiment required an aggregate of 82 minutes to perform; at the end of the mission, the same experiment required a mere 18 minutes to complete or a savings of about one hour of crew time.

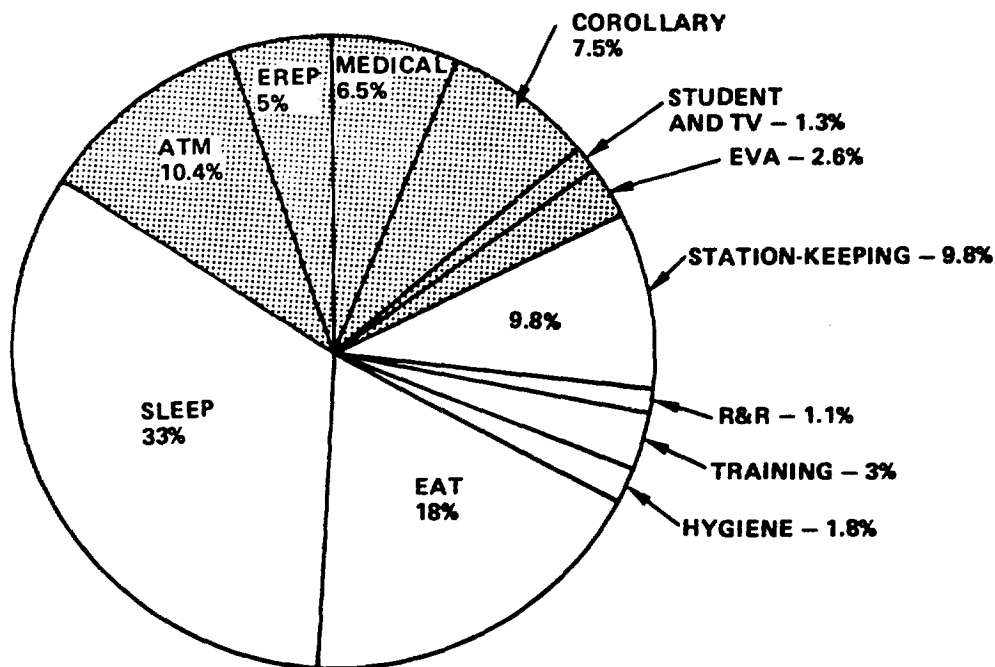
Conclusions that can be drawn from the Skylab crew experience are twofold: (1) on the average, only about eight hours per day are available for payload useful work, and (2) with adequate provisions for crew accommodations, considerable improvement in task efficiency can be experienced on longer missions. This means that given Skylab class accommodations, the same workload can be accomplished on one 49-day mission by a crew of three that otherwise could be derived from seven seven-day missions with crews of eight.

Table 2.2.2-1 contains data which summarizes nine major functional and physical requirements along with the range of each as described in the mission model. With the notable exception of payload viewing requirements, which are severely limited in the Shuttle-tended operational mode, in general most of the payloads detailed in the mission model can be accommodated by the baseline Skylab/25 kW fully operational configuration.

The larger capacity materials processing payloads are probably beyond the capability of Skylab to support. However, these industrial "class" facilities, which are scheduled late in the mission model timeframe (approximately 1990 and beyond) would require the engineering development activities which are the

Figure 2.2.2-6

CREW PERFORMANCE IMPROVEMENT



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EXPERIENCE DURING EXTENDED DURATION SKYLAB MISSION

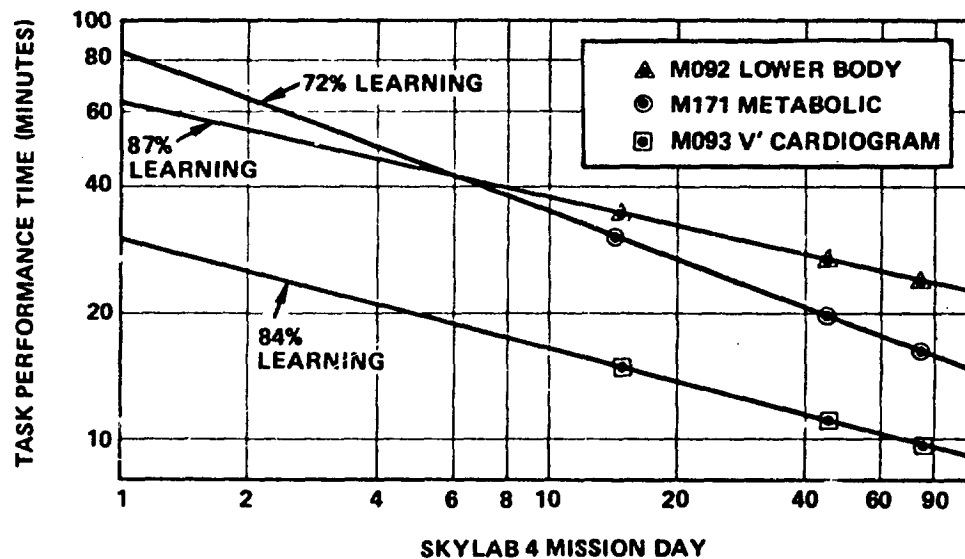


Table 2.2.2-1

CANDIDATE PAYLOAD/MISSION REQUIREMENTS SUMMARY

SUPPORT REQUIREMENT	REQUIREMENT RANGE	BASELINE SKYLAB ACCOMMODATION
• MISSION DURATION	7 TO CONTINUOUS	UP TO 90 OR MORE DAYS
• CREW SIZE	1 TO 14 PERSONS	UP TO 7 PERSONS
• POWER DEMAND	1 TO 100 kW	UP TO 22 kW
• THERMAL CONTROL	CRYO TO 5000°C	UP TO 22 kW REJECTION
• VIEWING	EARTH/SUN/STELLAR	LIMITED IN SHUTTLE TENDED ANY ORIENTATION CONTINU- OUSLY MANNED
• FINE POINTING	$1^{\circ} - 1 \text{ SEC}$	OK
• ACCELERATION LIFE SCIENCES MATERIALS PROCESSING	$10^{-3} - 10^{-4} \text{G}$ 90% OF TIME $\leq 10^{-4} \text{G}$	OK
• DATA RATES	TO 16 MBPS + VIDEOTAPE AND FILM	OK (ASSUMES TDRSS AVAILABILITY)
• PAYLOAD DIMENSIONS	UP TO 61M DIA	OK

precursor missions to these industrial operations in space which are well within the capabilities of the baseline operation Skylab.

2.2.3 Early Skylab Role

Figure 2.2.3-1 represents a generalized Skylab reuse scenario with the four program phases delineated across the lower part of the figure. While there are important activities that could be accomplished during the reboost and inspection phase of the program scenario, such as examination and retrieval of materials subjected to long duration exposure in space, the major achievements of the program would accrue from Phases III and IV of the program. This section of the report addresses these early roles of Skylab reuse within the context of the three previously outlined discipline areas, materials processing, life sciences, and space construction.

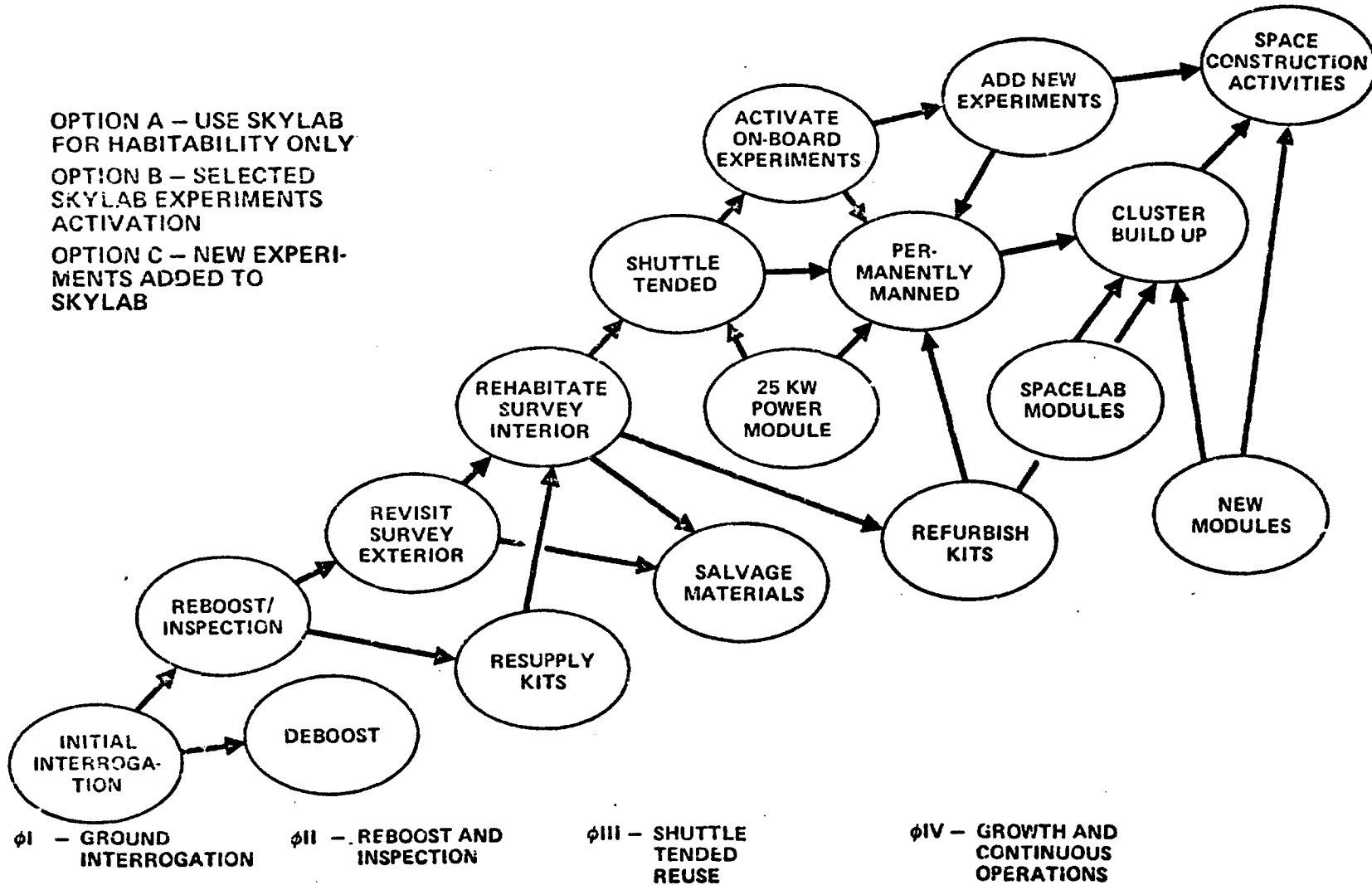
Of fundamental importance to any manned space flight program, is the issue of habitability. Crew-compatible habitability features are essential for longer duration (e.g., greater than 30 days) missions if maximum performance is to be achieved by the crew. The general and individual crew member support of manned missions provided by Skylab reuse as a habitable facility is a major early role for Skylab.

Skylab can provide a commodious basic facility for living and working in space compared to the smaller volume and intimate conditions to be experienced in the Orbiter. Skylab offers proven accommodations which can be expected to result in higher physical work output during longer missions. The study has shown that the increased personal privacy provided by the Skylab to be an important consideration. The larger free volume was found in the forward work area to be of value for providing accurate assessments of work/rest cycles and operational task time standards essential for planning future space construction missions. The study also concluded, based on the findings of the prior Skylab missions, that a vigorous exercise function is mandatory for 14-day and longer missions. A variety of exercise equipment and ample free volume can be accommodated effectively by Skylab, resulting in maintenance of overall crew physical condition.

Materials Processing in Space - The materials processing scenario and baseline mission model, as previously described, relies on Spacelab module and pallet

SKYLAB REUSE SCENARIO

OPTION A - USE SKYLAB FOR HABITABILITY ONLY
 OPTION B - SELECTED SKYLAB EXPERIMENTS ACTIVATION
 OPTION C - NEW EXPERIMENTS ADDED TO SKYLAB



sortie payloads for the timeframe of 1981 to 1985. The phase-in of the Materials Experimentation Module during the latter part of this period will be coincident with the availability of the 25 kW Power Module in 1984. The thrust of this initial Spacelab work will be aimed primarily at meeting the scientific objectives of the program with a limited number of selected materials being investigated. During this period, the role and usefulness of Skylab reuse will be minimal. During Shuttle-tended operational mode, the Skylab reuse scenario would not be particularly attractive due to level of disturbances from the attitude control system which are expected to be outside of the acceptable limits of the experiments.

For the development activities of this scenario, as opposed to the scientific activities, the early role of Skylab appears more favorable. Skylab would prove beneficial to the materials processing program by utilizing the OWS working volume for setting up a limited-scale prototype production facility. For example, if early results proved promising, limited production of economically attractive quantities of monodispersed polymers, such as latex spheres in the 10-50 micron size range, could be accommodated. While of a more speculative nature, the production of exemplary quantities of pharmaceuticals required for clinical testing might also be accomplished.

The potential benefits of Skylab reuse (1985-1986) might also be derived by taking advantage of the lower Skylab cabin pressure. While this point was explored on only a limited basis during the study, researchers in the biopharmaceuticals field expressed interest in these possibilities. With appropriate modifications, a portion of the OWS could be operated as a cold room (4°C) which may be required by certain bioprocessing activities.

Additional dedicated modules could be berthed to the interface module. Candidates are the Materials Processing Modules (MEM MKI and MEM MKII) as well as internationally- or privately-owned processing modules. In these cases, the OWS would serve as a low-cost option for a habitation facility.

The study also examined reuse possibilities offered by the M512 Materials Processing in Space Facility. After inquiries into the end-of-mission status of the facility, it was concluded that only limited use of this facility would be possible. The M512 facility, contaminated at the conclusion of Skylab-4

could be utilized for additional flammability testing. Skylab experiment M479, Zero Gravity Flammability, was the last in a series of flammability tests as applied to spacecraft. It was performed on February 4, 1974, on Day 81 of Skylab-4. As a continuing engineering study, this investigation could address the following areas of concern in an early reuse mission: (1) fire detection, (2) ignition, (3) propagation rates, (4) critical gap distances, (5) other fuels, and (6) extinguishment.

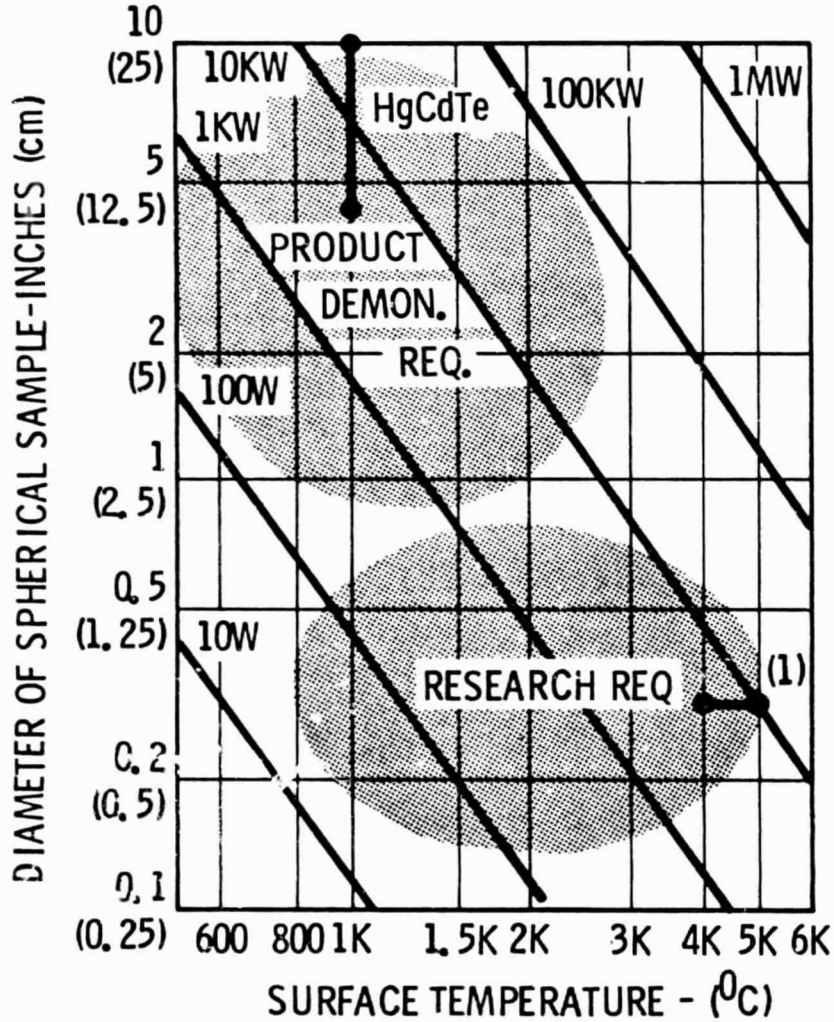
Materials processing activities evidence a substantial growth in orbital support requirements. The examples shown on Figure 2.2.3-2 describe the characteristics and underlying physical considerations resulting in growth in (1) electrical power requirements and (2) longer mission duration.

The nomograph on the left side of the illustration depicts the power required to maintain a spherical radiating source at a constant temperature, assuming that all the energy is lost from the radiating body to the surrounding space. This assumption represents the limiting (i.e., highest power) case. In practice, the immediate envelope will be at an absolute temperature approximating the source rather than the ambient temperature. Nevertheless, the required power to maintain a 12.5 cm (five-inch diameter) sample at a representative 1000°C is substantial (approaching 100 kW). For the most part, the basic scientific research requirements can be satisfied by relatively small samples (2 cm diameter) but spanning a temperature range to 4000°C. As shown by the shaded area on the figure, these requirements result in power levels ranging from 20 to 20,000 watts. In contrast, the sample sizes significant to demonstrate exemplary materials production range from 2.5 cm to 15 cm in diameter. Here again, the power required range from 1 kW to 90 kW.

The requirements for longer (7-30 days) duration missions have been generated from a number of technical considerations, two examples of which are shown on the facing chart. One of several materials that has been studied extensively is mercury cadmium telluride which has scientific and military applications as an infrared detector in the four to 10 micron range. Production in one-g of large size, uniform samples of this material has been hampered by effects that processing in space should eliminate. Theory suggests that in order to produce large size ultra-uniform samples of the material, the ratio of thermal gradient to solidification speed (G/R as shown on the chart) needs to be

MATERIALS PROCESSING REQUIREMENTS DRIVERS

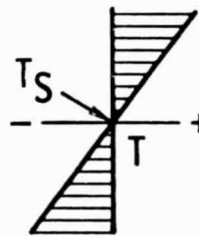
WHY HIGHER POWER?



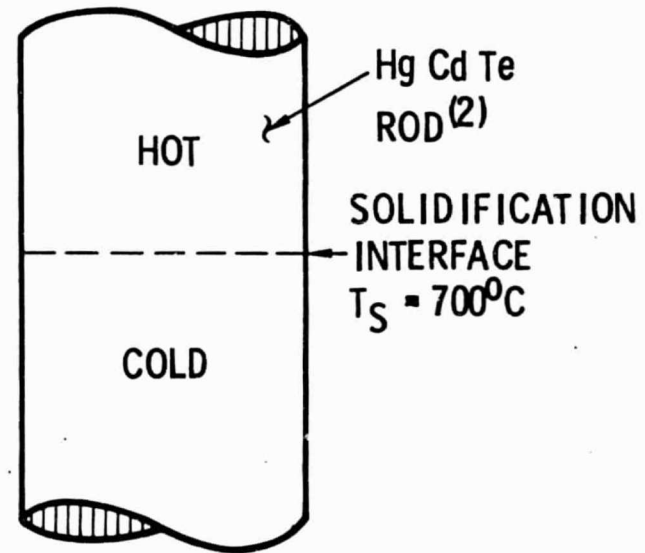
WHY LONGER DURATION?

FOR ULTRA-UNIFORMITY:
 $G/R > 10^8$

TEMPERATURE GRADIENT
 $G \approx 500^\circ/\text{mm}$



ROD SPEED
 $R \approx .1 \text{ TO } 1 \text{ mm/HR}$



$D \approx 10 \text{ TO } 25 \text{ cm}$

- (1) HIGH TEMPERATURE LEVITATION STUDIES
- (2) IR SENSORS

increased to greater than 10^8 or approximately a thousand times greater than can be produced on earth.

In the processing of a single rod of the material, about one diameter's length of movement is required to establish uniformity at the beginning of the processing run. A similar amount of material is lost at the end of each run. Allowing an equivalent three diameters of production to be a practical lower limit, at a speed of 1 millimeter per hour, 21 days would be required to produce a 50 x 10 cm diameter sample. By comparison, at a rod speed of 0.1 millimeters per hour, the production of a 125 x 25 cm diameter rod would require approximately 250 days to complete. These cases probably will represent the limiting situation; the duration requirements for this class of production falls within weeks-to-months periods of continuous production.

The second example of materials processing requirements for extended-duration missions is represented by the bioprocessing area in which cell culturing is performed in space. At present, there is insufficient empirical data and hard experimental evidence to establish beyond any finite doubt that this class of processing will prove immediately successful. However, theory does suggest that bioprocessing, including either individually or in combination cell separation, culturing, production, and purification steps conducted in space, is an area of considerable promise. Culturing is a growth process where the colony of cells increases in size as the cells divide with the passage of time. Depending on the type of cells involved, the colony doubling times can range from one day upward to our or more days in duration. The data shown on Figure 2.2.3-3 depict increases in colony size for various doubling periods and elapsed total times.

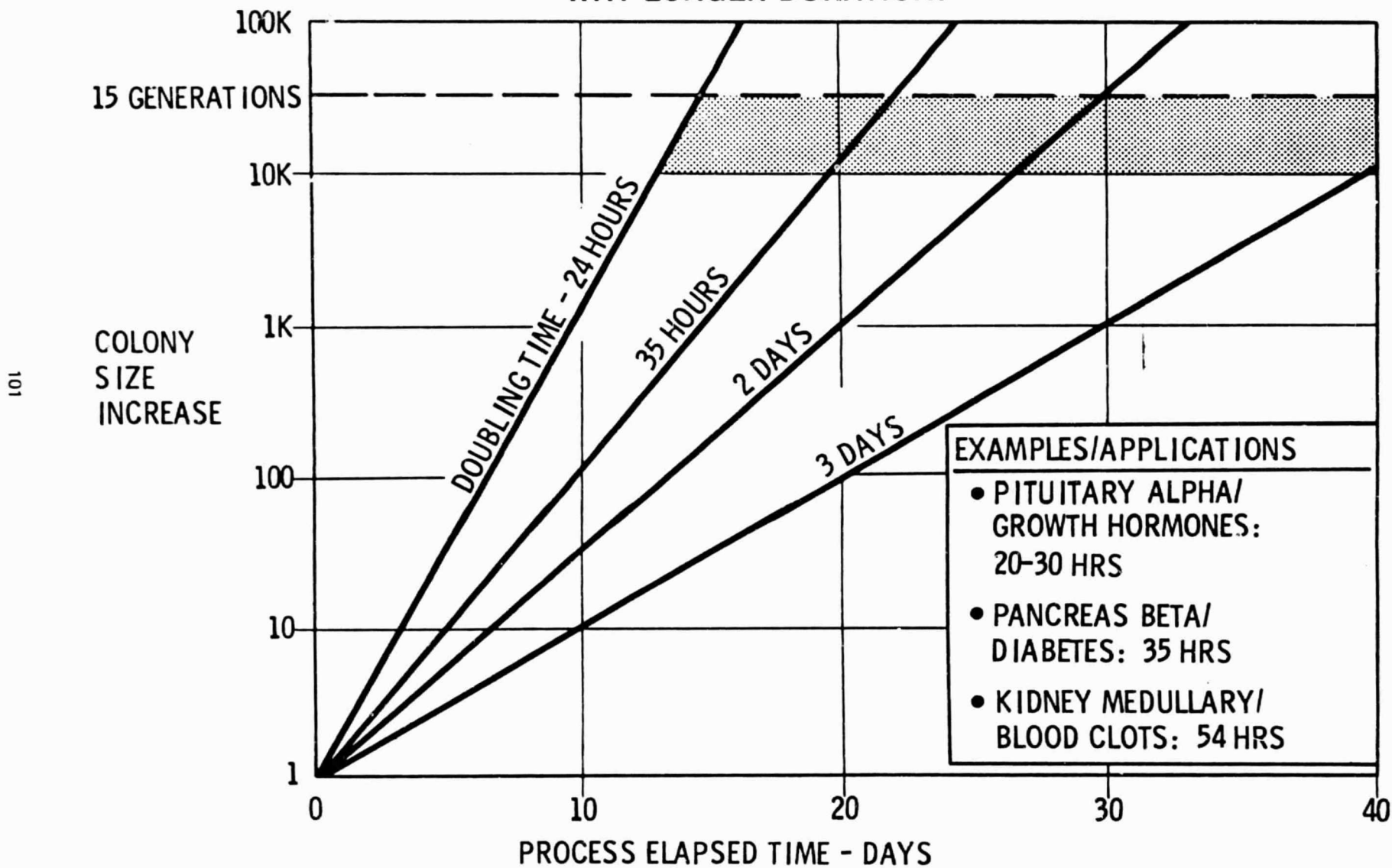
For each type of cell there is an upper limit to the number of doublings possible due to the occurrence of aging after many generations have developed from the same original source cells. This phenomena, known as "senescence," can occur after some 15 doublings. For example, in procedures including a culturing step, if the doubling time is two days then senescence could be expected to occur after 30 days into the culture period when the colony to be harvested would be about 32,000 times the size of the original group of cells. Shorter periods would fail to take full advantage of the culturing process in space.

Figure 2.2.3-3

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BIOPROCESSING REQUIREMENTS DRIVERS

WHY LONGER DURATION?



The range of time requirements for bioprocessing is shown as the shaded area on the noted figure.

Life Sciences

The Life Sciences program scenario and mission model previously described depicts one alternative to satisfying the program objectives. In addition to medical aspects, these objectives are directed at an improved understanding of the gravity's role in life processes as well as understanding the response and adaptation of life forms to the low gravity environment experienced in space facilities.

This study has found that a research advancement from the study of biological responses, to the environment of space, to adaptation studies is constrained for the most part by one parameter--mission duration. While there is not a precise division between the two research areas in terms of specific mission periods, the range of 30 to 45 days, in general, segregates the response/adaptation regimes. Hence, the life sciences program is constrained to study the first category until sufficiently long-mission durations (30 days) become a reality.

Skylab reuse missions can be particularly beneficial to the study of adaptation mechanisms. Even if the five psi atmosphere is maintained, this condition should not constrain scientific experiments from being conducted. Five psi ground controls, if indeed necessary, could be arranged; although for the most part, experiments could be designed which would filter out the differential effects of the atmospheric pressure differences.

However, the current planning for life sciences investigations in Orbiter/Spacelab defines the standard laboratory conditions to include an atmospheric pressure the same as sea level conditions (the ambient Orbiter/Spacelab environment). The principal area of investigation involves improved understanding of the role of gravity in life processes and an altered environment from the standard conditions could introduce an artifact into the data of more or less significant proportions. Hence, life sciences investigations conducted onboard Skylab at its five psi cabin pressure require additional detail planning and assessment.

If there were interest in life sciences experiments onboard Skylab, there are a number of experimental techniques which could be employed to minimize the introduction of artifacts in the data. For example, ground controls would be maintained at the Skylab cabin conditions, or experimental subjects could serve as their own controls by pre- and post flight examinations as was performed during the original Skylab mission. It is also possible that the Skylab conditions may prove to be of interest to certain investigators as summarized in Figure 2.2.3-1.

The initial objectives for life sciences modules are represented by the currently authorized program, while the follow-on experiments have been included in presliminary planning. The use of the same initial Spacelab module, basic core equipment, and selected experiments would permit an economical transition to the Life Sciences Module No. 3 in the mid-80s. Skylab onboard experiments could be effectively used to initiate this phase of the program as described on the two following charts of the Early Role of Skylab.

The study team explored reuse of Skylab onboard biomedical experiment equipment as was done for the materials processing facilities. It was determined, in contrast to materials processing experiments, that good use could be made of these existing facilities. A preliminary analysis was made of the probable experiment activities that would be conducted during these future studies and the equipment and major supplies that would be required to perform these activities. Next a preliminary evaluation was made of the extent to which the experiment equipment used during the Skylab missions could satisfy the requirements of these candidate future studies. A summary of these analyses is shown in Table 2.2.3-1 with the details of analyses contained in Appendix D.

It is apparent from the table and reinforced by the appendix data that Skylab equipment currently onboard is able to satisfy many of the major requirements of these candidate future studies--only a minimum of additional equipment and supplies would have to be brought up by the Shuttle.

Space Construction

In addition to the SPS Development Program scenario and its attendant mission model, the study team examined the other space construction possibilities

REUSE OF SKYLAB BIOMEDICAL FACILITY

CANDIDATE RESEARCH TOPICS	ADDITIONAL RESEARCH EQUIPMENT NEEDED	IMPORTANCE OF RESEARCH
A. CARDIOVASCULAR STUDIES <ul style="list-style-type: none"> ● NON-INVASIVE ● INVASIVE (ANIMAL) ● EXERCISE/FATIGUE 	<ul style="list-style-type: none"> ● EXERCISE DEVICE(S) 	<ul style="list-style-type: none"> ● ESSENTIAL FOR UNDERSTANDING OBSERVED CARDIOVASCULAR DECONDITIONING ● ESSENTIAL FOR EXTENDED SOJOURNS IN SPACE ● HELPFUL IN UNDERSTANDING CARDIOVASCULAR PHYSIOLOGY ON EARTH
B. STUDIES RELATING TO DEMINERALIZATION OF BONE <ul style="list-style-type: none"> ● DIETARY ● PHYSICAL 	<ul style="list-style-type: none"> ● CONCEPT IN BONE DENSITOMETRY – ● ANIMAL HOLDING FACILITIES 	<ul style="list-style-type: none"> ● ESSENTIAL FOR EXTENDED SOJOURNS IN SPACE ● HELPFUL IN UNDERSTANDING DISEASE/INACTIVITY/SENILITY STATES ON EARTH
C. BODY FLUID DISTRIBUTION STUDIES <ul style="list-style-type: none"> ● GAUER-HENRY ● RENAL HEMODYNAMICS 	<ul style="list-style-type: none"> ● INSTRUMENTS (SUCH AS BODY IMPEDANCE) 	<ul style="list-style-type: none"> ● IMPORTANT FOR UNDERSTANDING HUMAN BONE PHYSIOLOGY IN 0-G – POSSIBLY RELATED TO SPACE MALAISE
D. HEMATOLOGY STUDIES <ul style="list-style-type: none"> ● VALIDATION 	<ul style="list-style-type: none"> ● BLOOD CELL COUNTING TECHNIQUES SUITABLE TO 0-G ENVIRONMENT 	<ul style="list-style-type: none"> ● ESSENTIAL FOR UNDERSTANDING OBSERVED LOSS OF RED CELL MASS ● ESSENTIAL FOR EXTENDED SOJOURNS IN SPACE
E. HUMAN PERFORMANCE <ul style="list-style-type: none"> ● SENSORY CUES ● SPACE SICKNESS 	<ul style="list-style-type: none"> ● CINEPHOTOGRAPHIC/VIDEO RECORDING ● TASK RELATED TEST APPARATUS 	<ul style="list-style-type: none"> ● VERY IMPORTANT FOR SPACE CONSTRUCTION EQUIPMENT DESIGN AND TECHNIQUES DEVELOPMENT

including a Skylab reuse scenario. This augmented scenario is shown in Figure 2.2.3-4.

This augmented scenario developed by the study shows that the construction equipment and procedures required to implement construction projects can be developed with a dual approach employing both the Orbiter and Skylab. In the initial phases, the Orbiter would support development of the automated equipment (e.g., beam builder) as currently planned and the Skylab would concentrate on construction technique/procedure development. This would include extra-vehicular activity (EVA) tasks under internal vehicle activity (IVA) conditions in the OWS and EVA assembly of small structures on the OWS (e.g., thermal shield).

In the latter space construction development phase, a small development facility could be installed as an integral part of the thermal shield. This construction facility could be used for both assembly technique development and the assembly of initial construction projects (e.g., solar power satellite-test articles). Skylab orbital inclination of 50° is satisfactory for LEO testing of SPS test articles. Transfer to LEO can be achieved by providing approximately 16 percent additional velocity over that required from a 28.5° inclination orbit.

The large open volume of the second deck of the OWS can be utilized as a development shop for a number of various space construction related activities. Small scale construction projects could be undertaken to assess, for example, the effectiveness of tools and holding fixtures in a safe environment. The configuration shown in Figure 2.2.3-5 is representative of such a test setup.

The early role of Skylab in this regard can be part of a well-planned space construction development program. As an intermediate step between ground-based neutral buoyance tests and space-based EVA support construction projects, IVA performed in the OWS can serve to demonstrate and refine work standards left uncertain by the groundwork alone.

Primary objectives might include:

- o Provide mandatory empirical data base of guidelines and criteria to support future space construction projects by:

Figure 2.2.3-4

AUGMENTED SPACE CONSTRUCTION SCENARIO WITH SKYLAB SUPPORT

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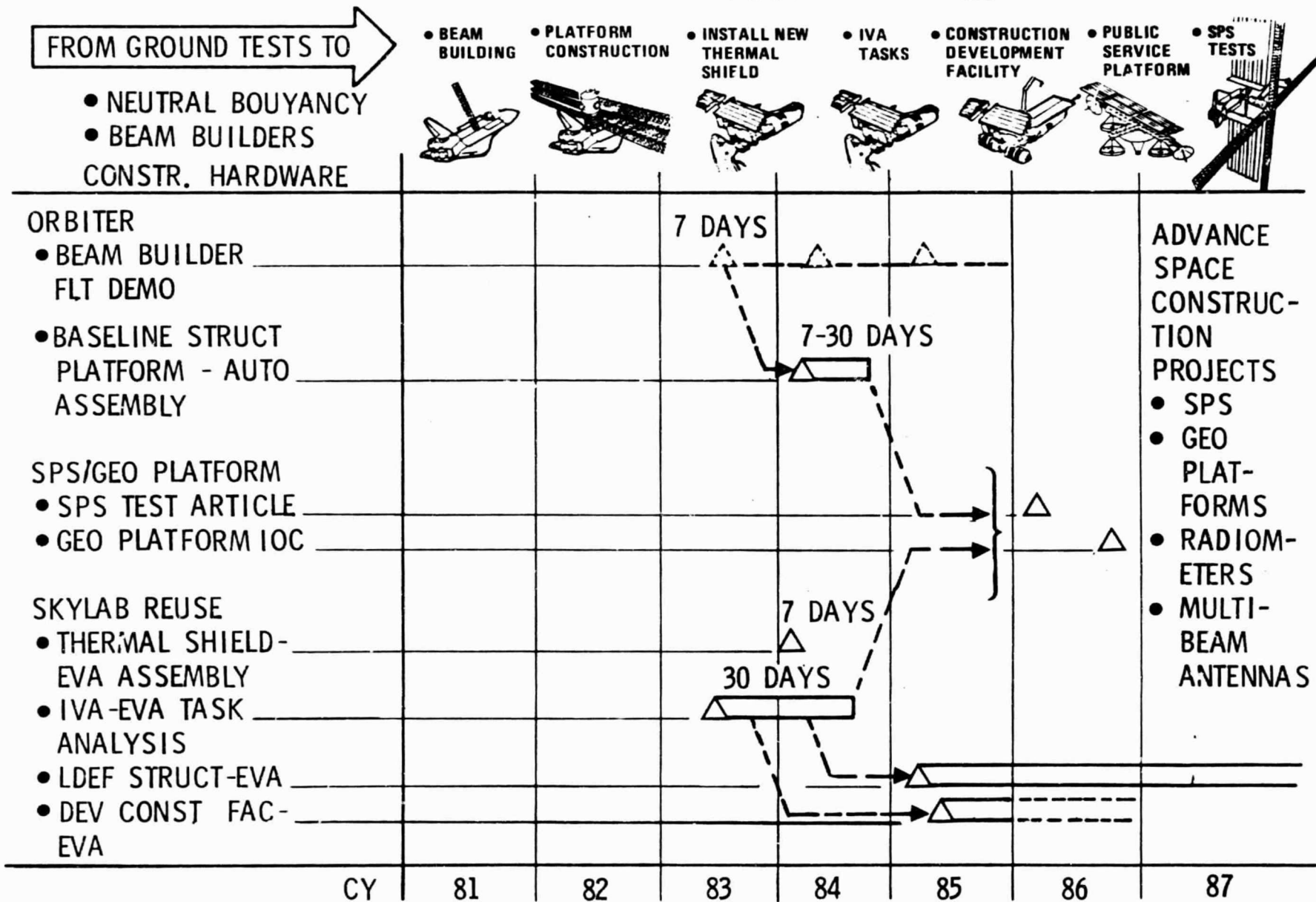


Figure 2.2.3-5

SKYLAB EARLY ROLE - SPACE CONSTRUCTION

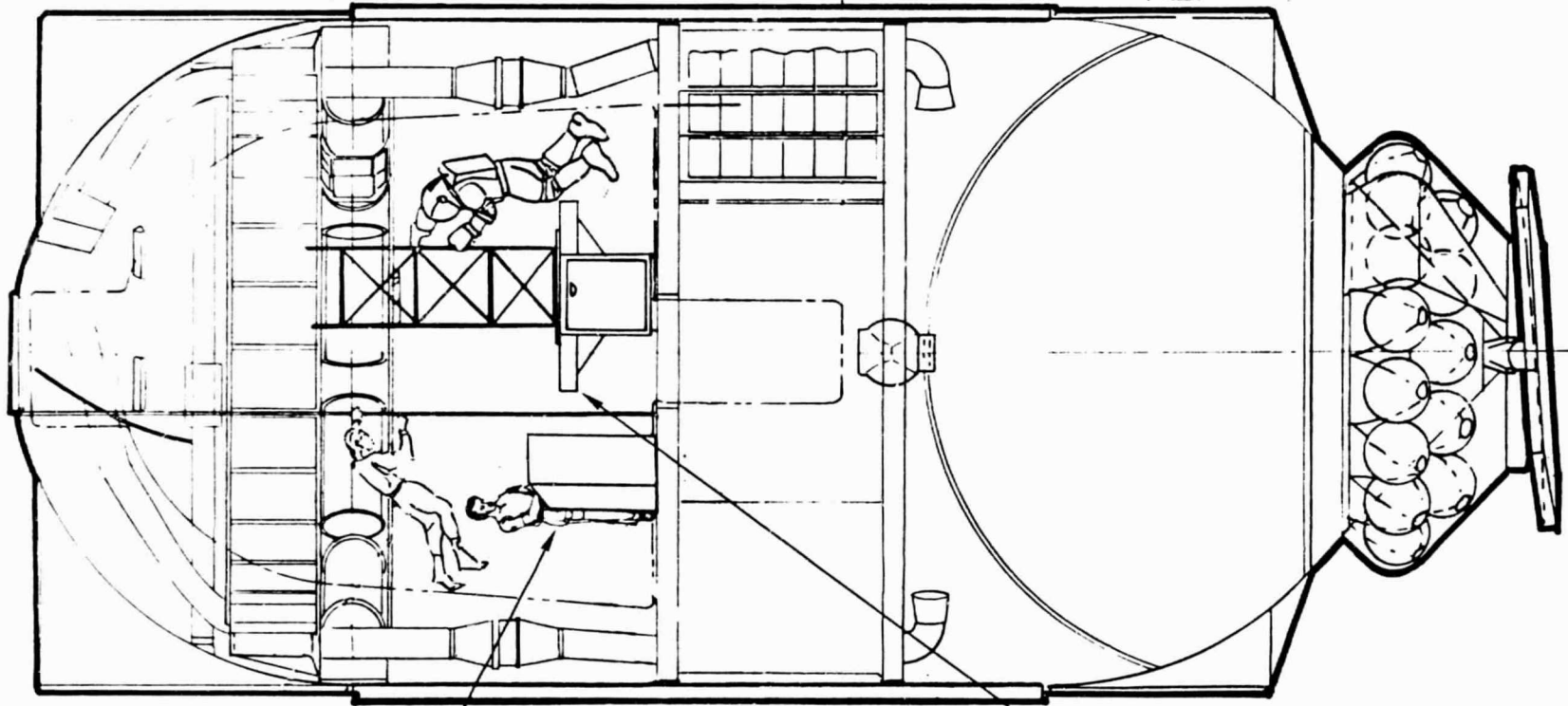
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POTENTIAL BENEFITS

- EARLY UTILIZATION OF OWS AS DEVELOPMENT SHOP
- IVA SAFE SIMULATION OF EVA

OBJECTIVES

- PROVIDE DATA FOR FUTURE PROJECTS
- PROVIDE SAFE IVA SHOP
- DEMONSTRATE AND REFINE CRITERIA



TYPICAL PROGRAM CONTENT

- REFURBISHMENT KIT INSTALLATION
- SMALL SCALE CONSTRUCTION PROJECTS
- ADVANCED TECHNIQUES DEVELOPMENT

TYPICAL EQUIPMENT

- HANDTOOLS
- RESTRAINTS
- JIGS/FIXTURES
- INSPECTION DEVICES
- TRUSSES/JOINTS

- Developing basic material selections and construction techniques, timelines and crew hand tools.
- Establishing design, costing, and scheduling factors.
- Evaluating structural element concepts, e.g., modular truss designs, truss and fittings and joints.
 - o Provide safe, efficient IVA development shop.
 - o Demonstrate and refine construction guidelines and criteria developed by assembling a fundamental structure, e.g.,
 - OWS thermal shield
 - Long duration exposure facility (LDEF)
 - Small space construction facility
 - o Utilize Skylab refurbishment tasks as surrogate space construction tasks.

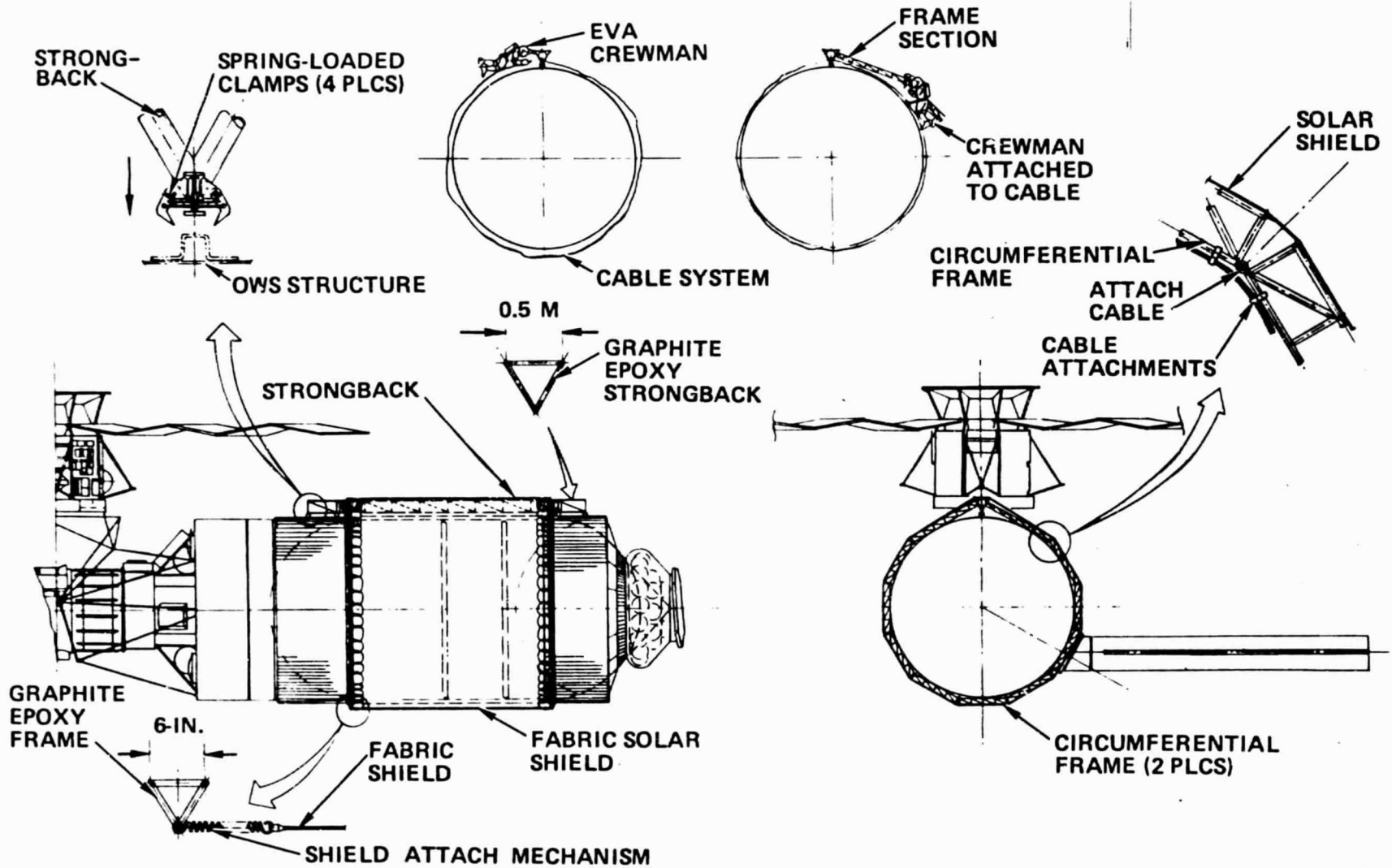
The study team also examined the space construction area from the standpoint of replacement of the thermal shield, the use of Skylab as a long duration exposure facility, and the use of Skylab as a construction base. In each case, an orbital configuration was prepared to illustrate the reuse scenario.

Considering instrument pointing for all the disciplines, it is seen that an all-attitude requirement is reflected on the Skylab cluster. In contrast to the one-sided thermal shield that was deployed during the original Skylab mission, in the future during continuously manned reuse missions, a 360° thermal shield should be considered. The shield can be either hard or soft. The final choice will be the result of detailed thermal and meteoroid analyses including the results from the ground interrogation program.

Figure 2.2.3-6 illustrates a new thermal shield approach. The soft cover thermal shield is a coated fabric (similar to the existing parasol) attached to a triangular frame which provides a base for advanced external experiments and construction installations. The framework consists of one 1.0 M x 10.0 M lg triangular strongback and two segmented circumferential frames on which the soft cover is attached.

After the present thermal shield is removed and stowed, two crewmen would translate the strongback to the -Z axis of the OWS and attach the four, spring-loaded clamps to the selected hat stringer. One crewman then deploys a cable

SKYLAB REUSE THERMAL SHIELD REFURBISHMENT KIT



from the drum on the strongback and translates around the OWS and attaches to the strongback. The second crewman repeats the operation at the opposite end. Sections of the circumferential frames are attached to the cable system by the crewman who is also attached to the cable. Following assembly of the frames, the soft fabric cover is attached and stretched around the OWS. Upon completion of the cover installation, the cables are tightened to add rigidity to the assembly.

The Skylab thermal shield installation, previously described, is configured to accept installation of a Long-Duration Exposure Facility. Figure 2.2.3-7 illustrates the concept. Currently planned LDEF experiment trays can be accommodated by addition of triangular beams spanning the circumferential frames with intermediate beams completing the framework required to accept the 38-inch x 50-inch trays. The installation shown would accept 70 LDEF standard experiment trays.

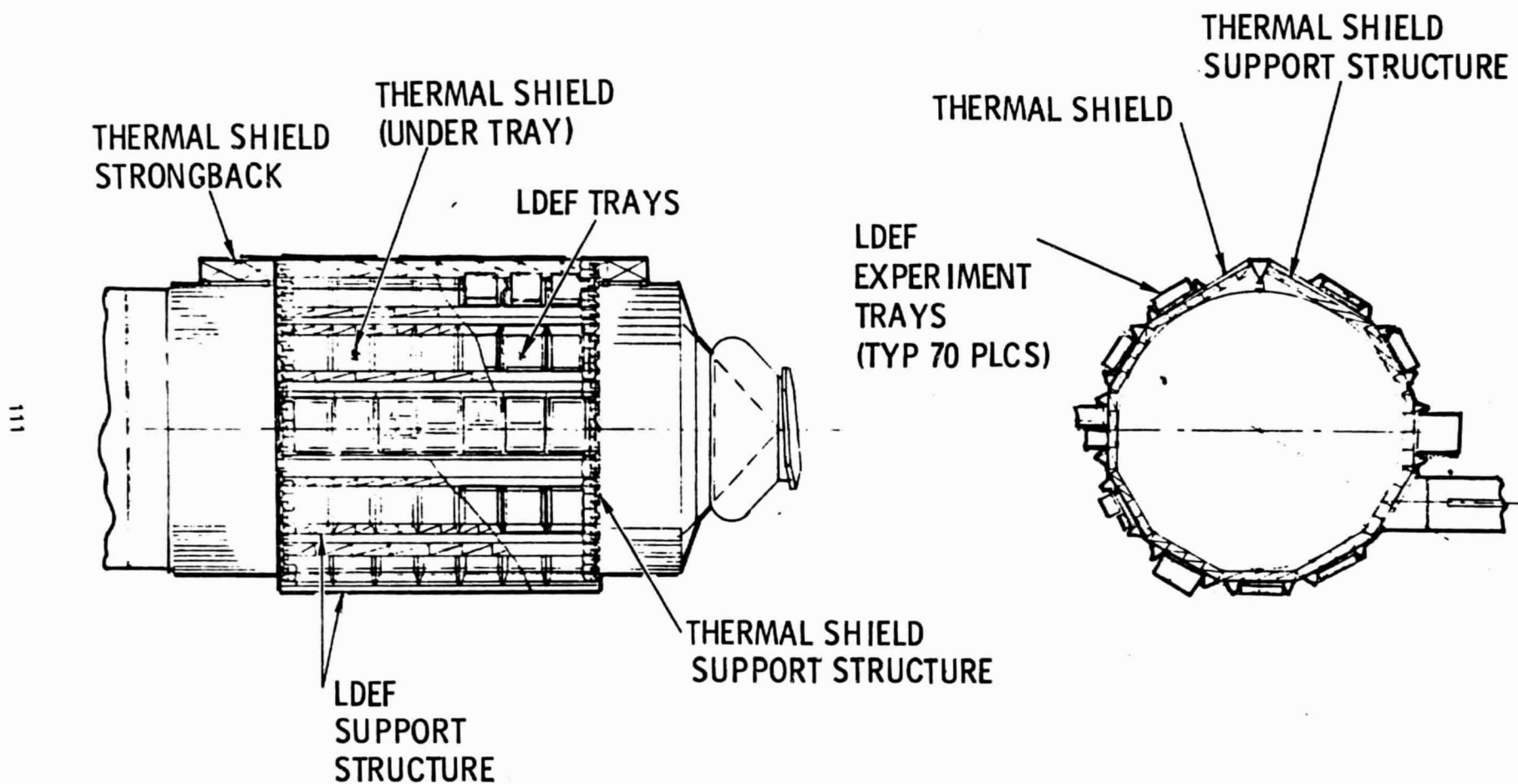
Installation, retrieval, and transporting the experiment trays between the Orbiter payload bay and Skylab would require crew EVA probably supported by the manned maneuvering unit (MMU). Tray attachment to the Skylab support structure would use a zero-g device easily operated by an EVA crewman (e.g., spring clips, single hand clamps, etc.). The experiment tray space environment (e.g., attitude and acceleration levels) would be coordinated with overall Skylab mission objectives, thus experiment objectives should be compatible with Skylab's local environment. As Skylab reuse is being evaluated on the basis of a 10-year lifetime, exposure time would be virtually unlimited, allowing experiments or portions of experiments to be retained in the space environment for extended periods of time.

The configuration studied by the team permits the addition of an early external construction base for assembly of large elements such as: solar power satellite test articles, geostationary platforms, radiometer antennas, multi-beam antennas, etc.

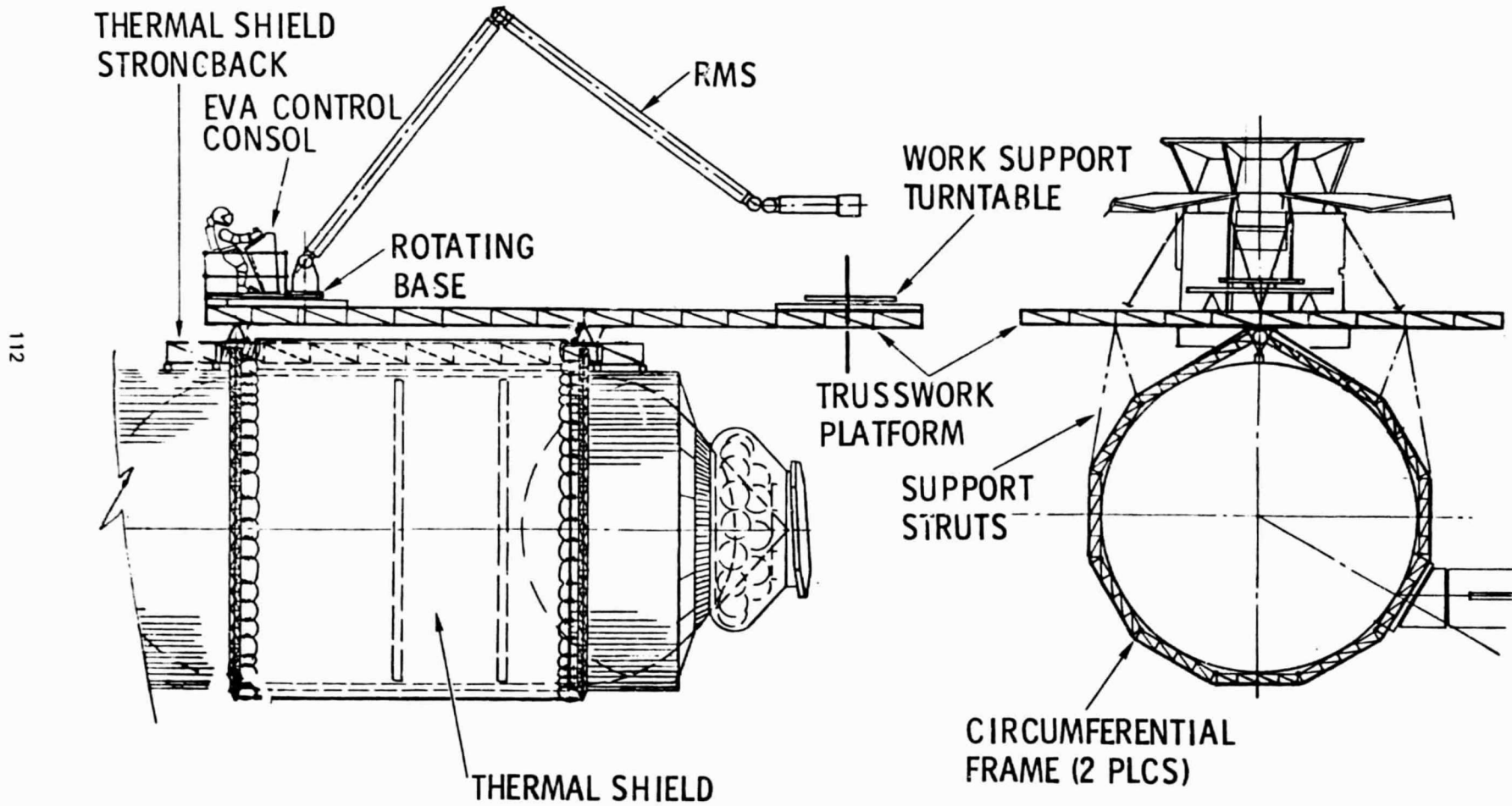
The configuration shown in Figure 2.2.3-8 consists of triangular trusswork attached to the thermal shield strongback and supported from the circumferential frames. Longitudinal trusswork provided the platform on which to assemble the objective element.

Figure 2.2.3-7

SKYLAB REUSE LONG DURATION EXPOSURE INSTALLATION



SKYLAB REUSE INITIAL CONSTRUCTION FACILITY



An Orbiter RMS is mounted on a turntable to provide a manipulator reach of much of the assembly activity zone. A control console is located on the rotating base where an EVA crewman has direct visual control of virtually all RMS operations. An additional turntable can be added for assembly of objective elements thus assuring assembly operations within limits of the manipulator.

Benefits of Skylab Reuse

There are three categories of benefits resultant from Skylab reuse that were evaluated by the study team. First of all, Skylab offers large volume living quarters to accommodate up to seven persons; secondly, reuse can provide a means of extending the orbital capabilities to satisfy the needs of six discipline areas of use; and lastly the reuse scenario provides a low-cost approach to investigation of long-duration, continuously-manned, operations which may represent the most significant benefit of all.

Some of the beneficial habitability features of Skylab are private sleeping areas, pleasant and well-equipped galley and eating areas, ample space for work and eating areas, ample space for work and exercise, effective trash management capabilities, and free volume for rest and relaxation. Space is available to accommodate a sick bay and to provide for the isolation of individual crew members if such measures are required.

2.3 MISSION ACCOMMODATION AND CONFIGURATIONS

The technical issue of interfacing new hardware with existing semi-autonomous hardware (i.e. Skylab cluster) was evaluated to determine both compatibility features and key design requirements. The elements which were assessed included the full spectrum of hardware types. These were the following:

- (1) multidiscipline payloads for operational compatibility and constraints,
- (2) 25 kW Power Module for identification of interface-compatibility modifications, and
- (3) interface module requirements identification and concept definition.

2.3.1 Mission/Payloads Compatibility Analyses

One of the benefits expected from a Skylab reuse mission involves the accommodation of a multidiscipline or a combined disciplines flight program. For example, there are interesting possibilities to assign several disciplines to a particular flight where facilities could be shared and resources utilized without major conflicts or compromise to any particular area. The study examined these possibilities with the data used in the assessment summarized in Table 2.3.1-1. As shown in the table, eight basic requirements were examined ranging from orbital parameters to power demand. The six discipline areas analyzed were grouped two at a time, three at a time, and four at a time, respectively. For each payload/grouping-requirement pairing, a compatibility assessment was made of the pairing on a three point scale. A solid bullet in the body of the table indicates a compatible matching, an open circle represents a partially compatible or non-conflicting grouping while an "x" indicates an incompatible situation.

Four of the requirements do not present problems of compatibility to any of the discipline mixes (i.e., orbit type, mission duration, timeframe, and power demand are not constraining requirements). On the other hand, crew skills requirements are a constraint. However, due to the accommodations of crew sizes up to seven during Skylab reuse missions, adequate provisions could be made to provide individual payloads with their own specialists. Vehicle orientation represents perhaps the single most constraining requirement due to the differences in the required pointing directions of the various remote sensors in the astronomy, solar-terrestrial and earth-viewing disciplines. While the study did not address specific solutions to this problem, the inherent conflicts of these disciplines represents an operational constraint in payload mixing and matching. A somewhat different situation is observed, however, in the data type constraints. In this case, each payload produces a unique type of data and the accommodation and management of the data is an important consideration. As such, these conflicts do not limit the mixing of payloads with different data requirements. Similarly, equipment sharing across disciplines cannot be expected to occur except in cases where general purpose equipment is required.

The study concludes that the overall outlook is favorable for payload mixing and matching of disciplines during Skylab reuse missions.

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TABLE 2.3.1-1
 REQUIREMENTS ASSESSMENT FOR MIXED PAYLOADS

DISCIPLINE MIX	MISSION/PAYLOAD REQUIREMENTS							
	1-ORBIT TYPE	2-MISSION DURATION	3-TIME FRAME	4-POWER DEMAND	5-CREW SKILLS	6-VEHICLE ORIEN.	7-DATA TYPE	8-EQUIPMENT SHARING
AB	●	●	●	○	○	●	○	○
AC	●	○	●	○	X	●	X	X
AD	●	○	●	○	X	○	X	X
AE	●	○	○	○	X	X	X	X
AF	●	○	●	○	X	X	X	X
BC	●	○	●	○	X	●	X	X
BD	●	○	●	○	X	○	X	X
BE	●	○	○	○	X	○	X	X
BF	●	○	●	○	X	○	X	X
CD	○	●	●	○	○	○	○	○
CE	○	●	○	○	○	X	○	○
CF	○	●	●	○	○	X	○	X
DE	○	●	○	○	○	○	○	○
DF	○	●	●	○	○	○	○	X
EF	○	●	○	●	○	○	○	○
ABC	●	○	●	○	X	○	X	X
ABD	●	○	●	○	X	○	X	X
ABE	●	○	○	○	X	X	X	X
ABF	●	○	●	○	X	X	X	X
ACD	●	○	●	○	X	○	X	X
ACE	●	○	○	○	X	X	X	X
ACF	●	○	●	○	X	X	X	X
ADE	●	○	○	○	X	X	X	X

CE	0	●	0	0	0	X	0	X
CF	0	●	●	0	0	X	0	X
DE	0	●	0	0	0	0	0	0
DF	0	●	●	0	0	0	0	X
EF	0	●	0	●	0	0	0	0
ABC	●	0	●	0	X	0	X	X
ABD	●	0	●	0	X	0	X	X
ABE	●	0	0	0	X	X	X	X
ABF	●	0	●	0	X	X	X	X
ACD	●	0	●	0	X	0	X	X
ACE	●	0	0	0	X	X	X	X
ACF	●	0	●	0	X	X	X	X
ADE	●	0	0	0	X	X	X	X
ADF	●	0	●	0	X	X	X	X
AEF	●	0	0	0	X	X	X	X
BCD	●	0	●	0	X	0	X	X
BDE	●	0	0	0	X	X	X	X
BCF	●	0	●	0	X	X	X	X
BDE	●	0	0	0	X	0	X	X
BDF	●	0	●	0	X	0	X	X
BEF	●	0	0	0	X	0	X	X
CDE	0	●	0	0	0	X	0	0
CDF	0	●	●	0	0	X	0	X
CEF	0	●	0	0	0	X	0	X
DEF	0	●	0	0	0	0	0	0
ABCD	●	0	●	0	X	0	X	X
ABCE	●	0	0	0	X	X	X	X
ABCF	●	0	●	0	X	X	X	X
ABDE	●	0	●	0	X	X	X	X
ABDF	●	0	●	0	X	X	X	X
ABEF	●	0	●	0	X	X	X	X
ACDE	●	0	●	0	X	X	X	X
ACDF	●	0	●	0	X	0	X	X
ACEF	●	0	●	0	X	X	X	X
ADEF	●	0	●	0	X	X	X	X

2 FOLDBOUT FRAMES

ABCF	●	o	●	o	X	X	X	X
ABDE	●	o	●	o	X	X	X	X
ABDF	●	o	●	o	X	X	X	X
ABEF	●	o	●	o	X	X	X	X
ACDE	●	o	●	o	X	X	X	X
ACDF	●	o	●	o	X	o	X	X
ACEF	●	o	●	o	X	X	X	X
ADEF	●	o	●	o	X	X	X	X
BCDE	●	o	o	o	X	o	X	X
BCDF	●	o	o	o	X	X	X	X
BCEF	●	o	●	o	X	X	X	X
BDEF	●	o	o	o	X	o	X	X
CDEF	o	●	o	o	o	X	o	o

LEGEND:

DISCIPLINE AREAS:

- A - - - - - MATERIALS PROCESSING
 B - - - - - LIFE SCIENCES
 C - - - - - ASTRONOMY/ASTROPHYSICS
 D - - - - - SOLAR-TERRESTRIAL OBSERVATIONS
 E - - - - - EARTH VIEWING/RESOURCES
 F - - - - - COMMUNICATIONS/SPS DEVELOPMENT

REQUIREMENTS:

- - - - - - COMPATIBLE
 X - - - - - NOT COMPATIBLE
 o - - - - - PARTIALLY COMPATIBLE

2.3.2 25 kW Power Module

A 25 kW PM, as configured by MSFC, for use with Shuttle/Spacelab Sortie and free-flying missions, was baselined into the Skylab reuse study. During the Skylab Reuse Study, the contractors conducted a task to: (1) assess the PM characteristics, (2) provide requirements for augmenting PM capabilities, (3) determine impacts to PM design and (4) define a PM berthing mission. The following topics treat these four tasks.

2.3.2.1 The PM characteristics by subsystem are as follows:

Structure

- o 2 ATM Racks
- o New Solar Array Support Structure
- o Shuttle Compatible Docking Mechanism

Thermal Control

- o 4 Shuttle Radiators
- o 64 Spacelab Cold Plates
- o Shuttle Fluid Subsystems
- o 5-10 kW Rejection Available to User with Orbiter Attached

Communications and Data Management

- o 1 NASA Standard Comm and Data Mgmt Module (Multi-Mission Spacecraft)
- o 7 ATM Signal Conditioner and Multiplexer Assemblies
- o Interfaces with TDRSS
- o No Experiment Data Transmission
- o 2 OMNI Antennas

Electrical Power

- o 59 kW SEP Developed Solar Array
- o 12 Batteries
- o 12 Chargers and Regulators
- o 11 kW Average 15 kW Peak Available to User

Stabilization and Control

- o 3 ATM CMG's and Assoc. Electronics
- o 9 ATM Rate Gyros and Assoc. Electronics

Stabilization and Control (Cont.)

- o 2 ATM Digital Computer and ATM Software
- o 2 ATM Sun Sensor and Electronics

2.3.2.2 Requirements for Augmenting PM Capabilities

The reuse study produced no decisive rationale to impact PM with required or desired augmented capabilities for the Skylab cluster. If CMGs, in addition to the package already baselined into the PM are required to replace degraded CMGs in the cluster, our study indicates less overall impact by designing them into the Interface Module. Clearly, provisions for resupply of breathing gases (O_2-H_2), N_2 for thruster attitude control, potable water resupply, etc., can be more effectively integrated into a logistics module or the IM, both of which are in the preliminary requirements and conceptual design phases.

2.3.2.3 Impacts on PM Design

The reuse study has revealed the following impacts to the PM design:

- o The most favorable Skylab cluster arrangement including the PM is to dock the PM to the IM with the PM on the solar side of the cluster having its X-axis parallel to the Skylab Z-axis with the PM minus Z-axis forward (pointing away from Skylab). This arrangement produces an interference for the PM study configuration between the pair of radiators mounted on the PM plus Z-axis and the ATM. Therefore, MDAC recommends relocating the radiators, one each on the PM plus and minus Z-axis as shown in phantom in Figure 2.3.2-1.
- o MDAC recommends the addition of a standard androgynous docking mechanism (inclusive of interfacing requirements and definition for subsystems integration) between the PM and interface module. The utilities/subsystems that should be accommodated at the physical berthing interface are (1) power, (2) communications, (3) data, (4) coolant fluid, (5) control circuits, (6) atmosphere and (7) RCS propellant. All interfaces will not be used with all modules but the interfacing hardware should be designed to accommodate the total system requirement.
- o Possible modifications to Guidance and Control system software may be required. Phase-B studies and configuration evolution should reveal the requirements and thus the modification.

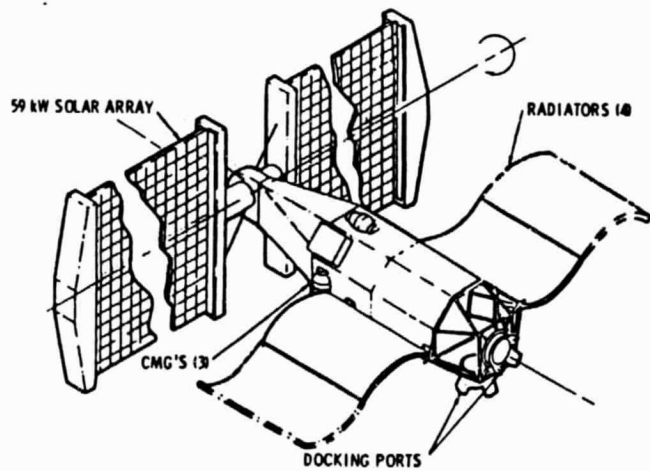


Figure 2.3.2-1. 25 kW Power Module

2.3.2.4 Power Module Berthing Mission

The berthing mission plan we recommend is based on the assumption that Skylab has been refurbished to the configuration required to immediately utilize the PM upon docking, i.e. (1) the ATM solar array panels extending over the IM have already been folded back to provide PM docking clearance, and (2) the tasks incorporating the 25 kW integration package have been accomplished. The docking mission may be directly from the Shuttle launch of a PM or with a free-flying PM previously launched.

Figure 2.3.2-2 depicts retrieval of a free-flying PM by either the Orbiter RMS or Teleoperator. The PM would have to be configured by folding the solar array and radiators to a launch configuration for stowage in the Orbiter bay. The Orbiter would then transport the PM to Skylab. The PM may be docked to Skylab with Teleoperator or berthed with the RMS from the Orbiter berthed to Skylab. The dock/berth operation shown in Figure 2.3.2-3 would be identical whether the PM docking mission originated from orbit retrieval or direct launch.

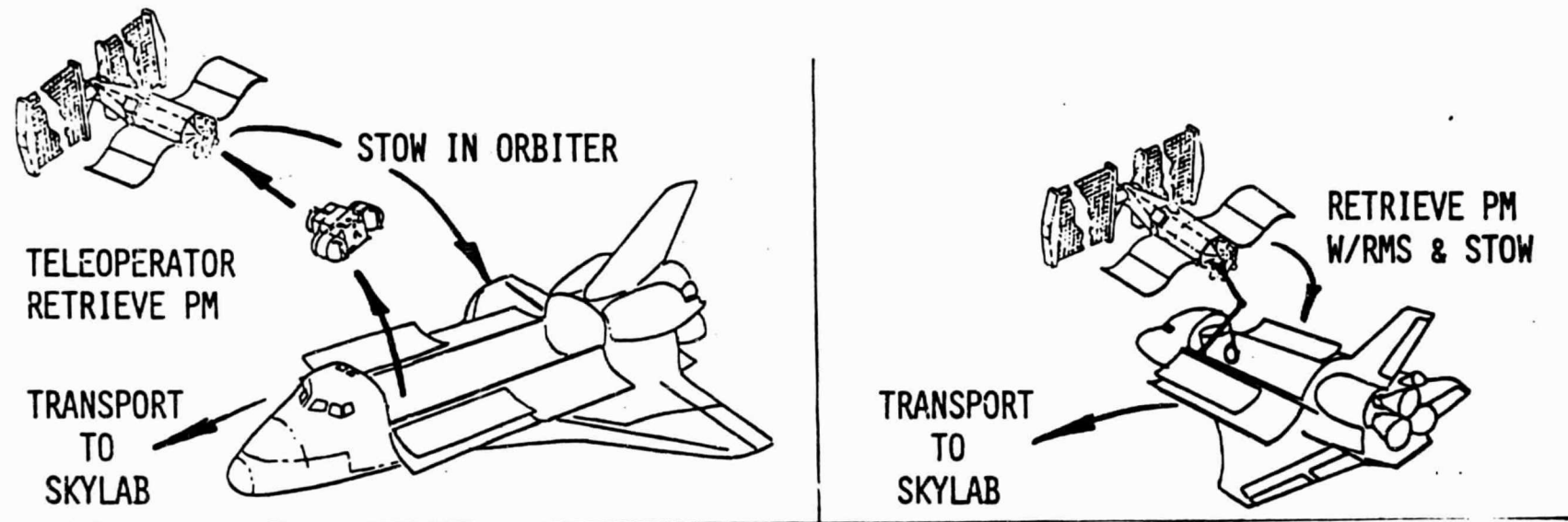


Figure 2.3.2-2. On Orbit PM Retrieval

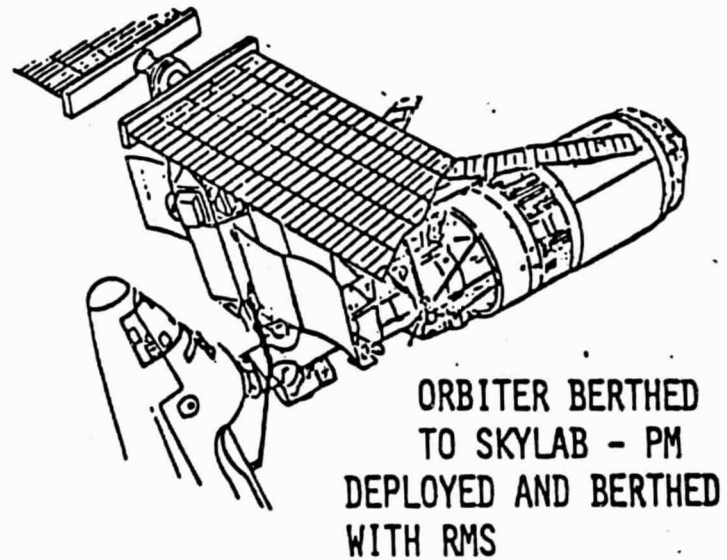
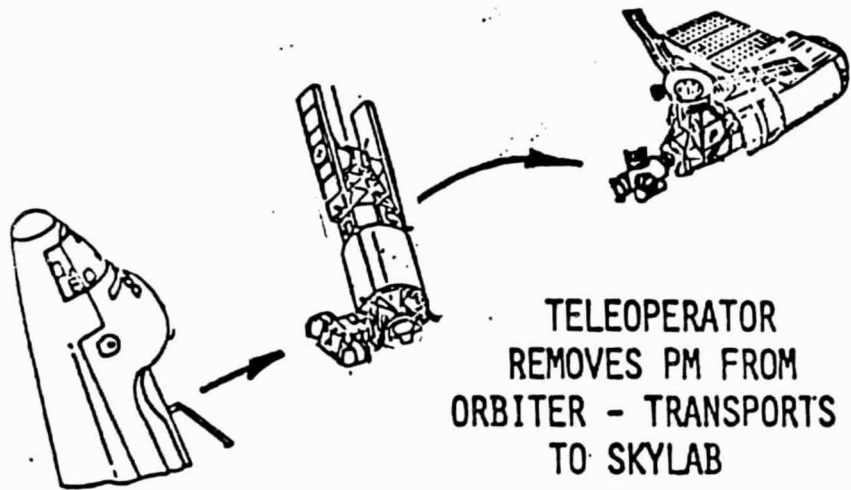


Figure 2.3.2-3. PM Docking Mission

2.3.3 Interface Module - Augmented Capabilities Concept

The reactivation and reuse of Skylab imposes additional operational/design requirements upon the basic Skylab cluster. This situation has developed from the following design drivers:

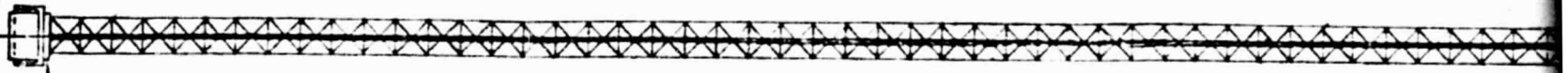
- o Operational Space Transportation System in lieu of Apollo
- o Candidate payloads with greater power demands
- o Extended (continuously-manned) missions requiring logistics resupply of consumables/expendables
- o Advanced Spacelab modules/payloads
- o Potential of increased crew EVA in support of space construction
- o Selected replacement of Skylab subsystems/components

Each of these elements has contributed specific major requirements to the Skylab. In the reuse study, these were evaluated with regard to providing a candidate approach which was compatible with both the Space Transportation System and the Skylab architecture. The salient characteristics of the Skylab (i.e., single end-docking port and previous thermal control-attitude relationships) dictated that a multi-port docking capability be provided at the logical location, the end docking port. A Skylab reuse configuration is shown in Figure 2.3.3-1. The following technical descriptions expand upon the initial design drivers to define the specific details which were considered.

- o Operational Space Transportation System in Lieu of Apollo - In adapting the Skylab to be compatible with the Orbiter, three characteristics are paramount: (1) the Orbiter's androgynous docking mechanism rather than the original Apollo's drogue and probe. Figure 2.3.3-2 shows details of the STS androgynous docking mechanism; (2) the Orbiter's external envelope requiring increased clearance over the cone-shaped Apollo command module; (3) the increased docking loads due to the Orbiter's 97,500 Kg (215,000 lbs) orbital mass vs the Apollo command and service modules' mass of 13,500 Kg (30,000 lbs).

The first two requirements can be most readily met through the use of an adapter for tunnel which provides the necessary standoff docked clearance and the unique docking mechanism at opposite ends. Figure 2.3.3-3 represents the basic interface module's primary structure. The basic element of the Interface Module is the 1.60M (63.0 in) diameter x 7.67M (302 in) long tunnel section which provides the interface between the Skylab and Orbiter with minimum clearance between

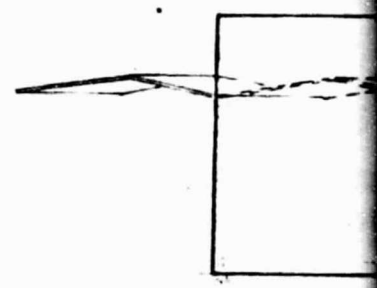
FOLDBOUT FRAME



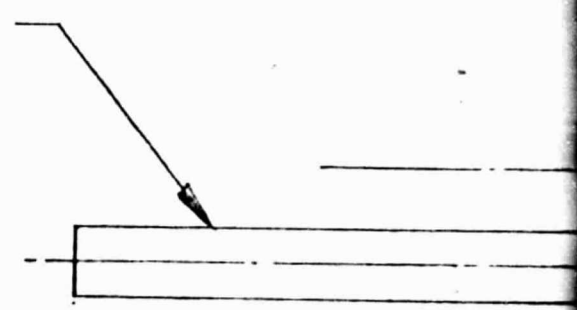
34.0 M



25 KW POWER MODULE



DWS SOLAR ARRAY



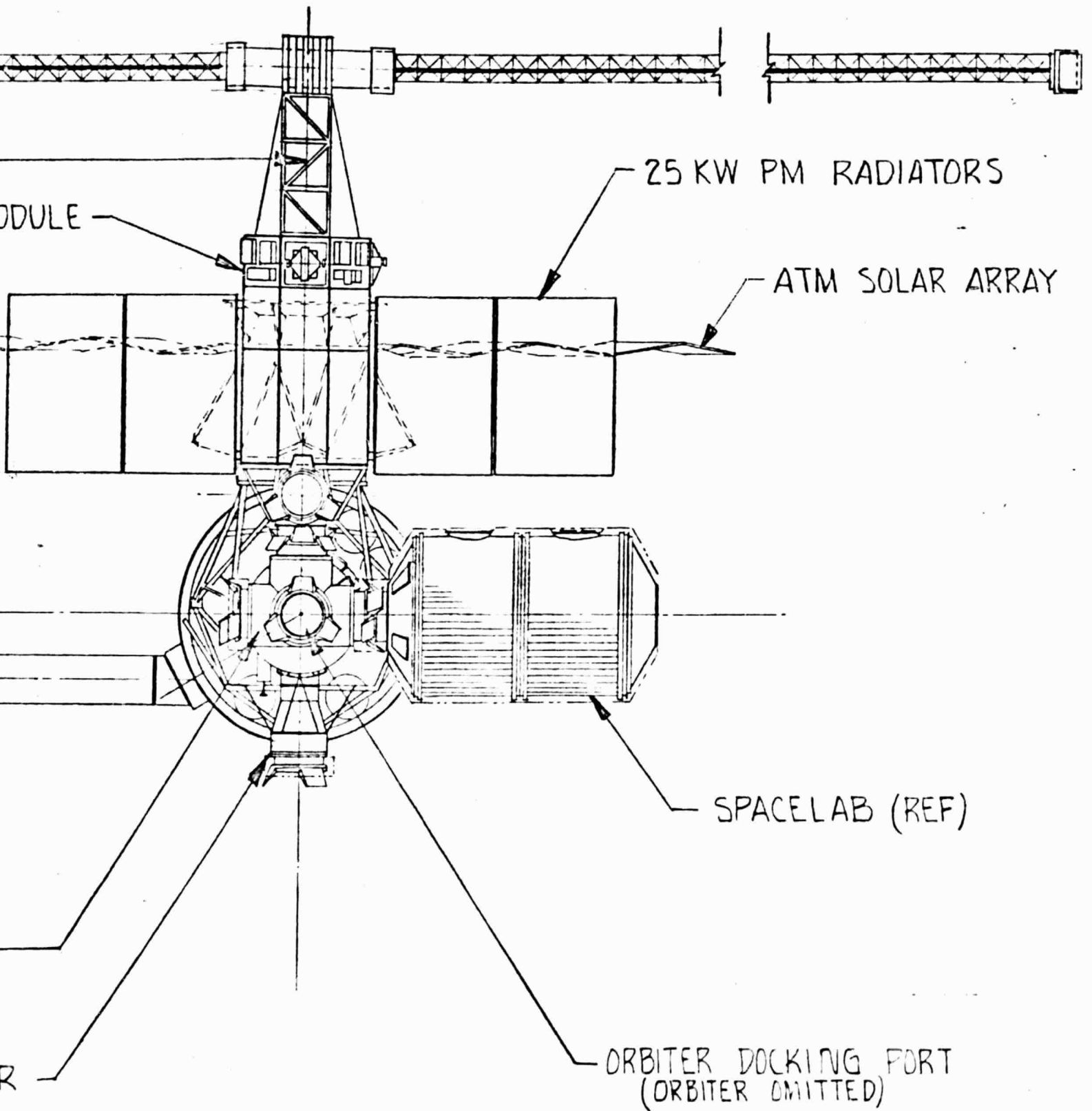
INTERFACE MODULE



DOCKING ADAPTER
LOGISTICS PORT
(EMER. ORBITER DOCKING)



2 FOLLOUT FRAME



MODULE

25 KW PM RADIATORS

ATM SOLAR ARRAY

SPACELAB (REF)

ORBITER DOCKING PORT
(ORBITER OMITTED)

VIEW 13-13

3

FOLDOUT FRAME

ORBITER

5 KW POWER MODULE
SOLAR ARRAY INSTL
(4 SEPS ARRAYS)

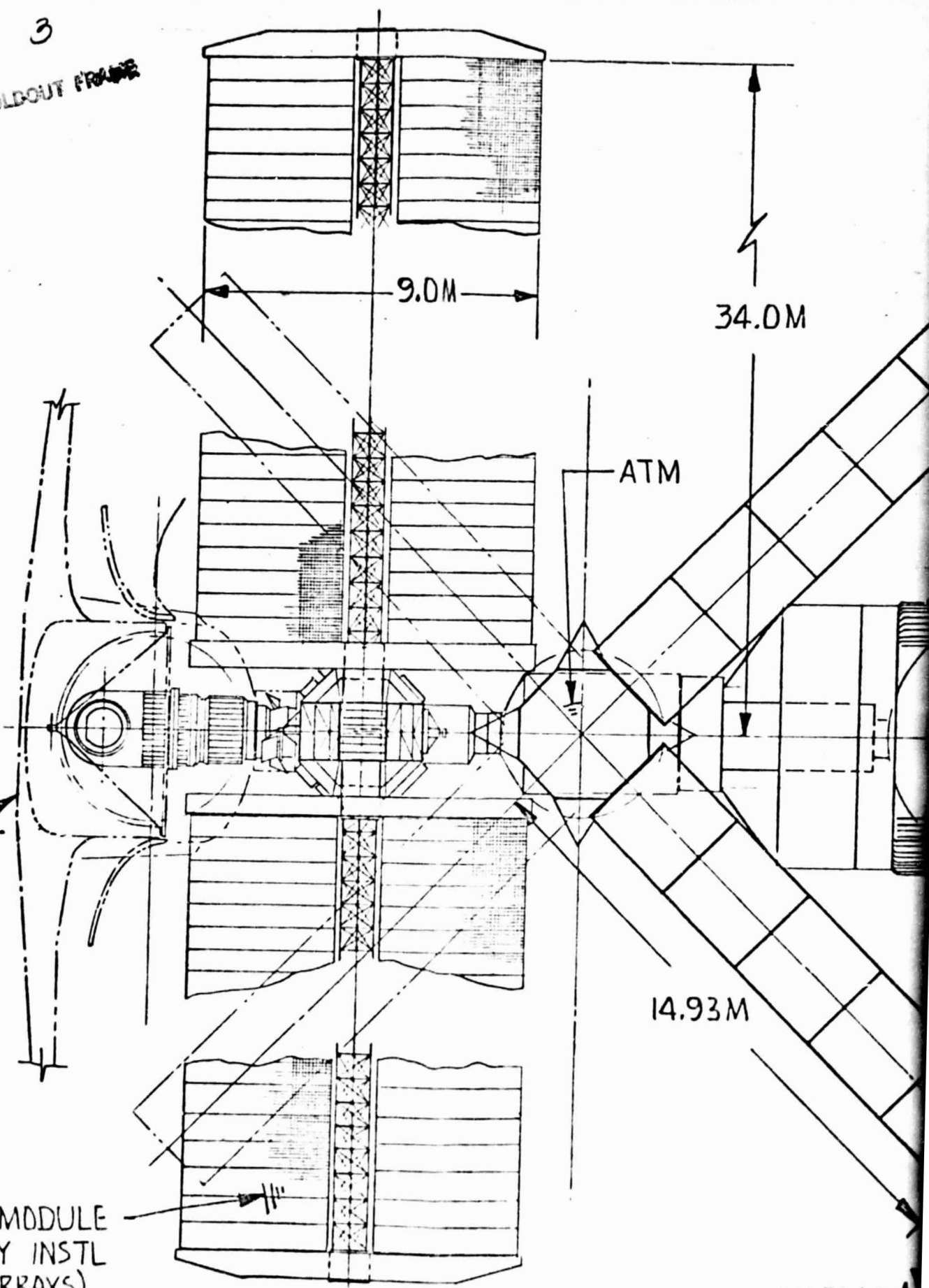
9.0M

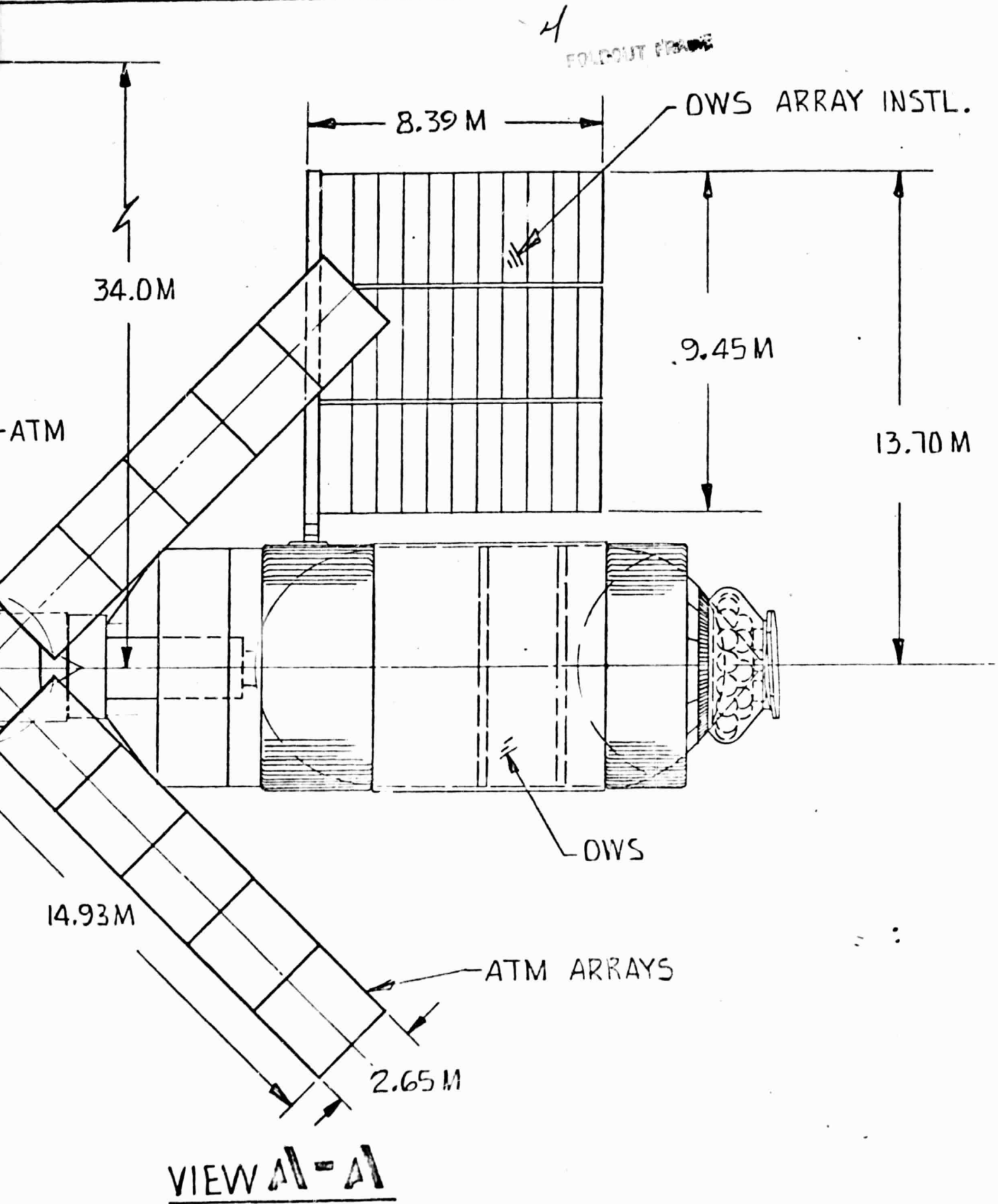
34.0M

ATM

14.93M

VIEW A





13 →



FOLDOUT FRAME

25 KW POWER MODULE

PM RADIATOR

ATM SOLAR ARRAY REMOVED
(Z PLCS)

1.0M DIA
HATCH

$X_0 = 582.0$
 $X_0 = 619.0$

$X_0 = 660.0$

357.9

3

5.65

$Z_0 = 515.0$

8.8 M

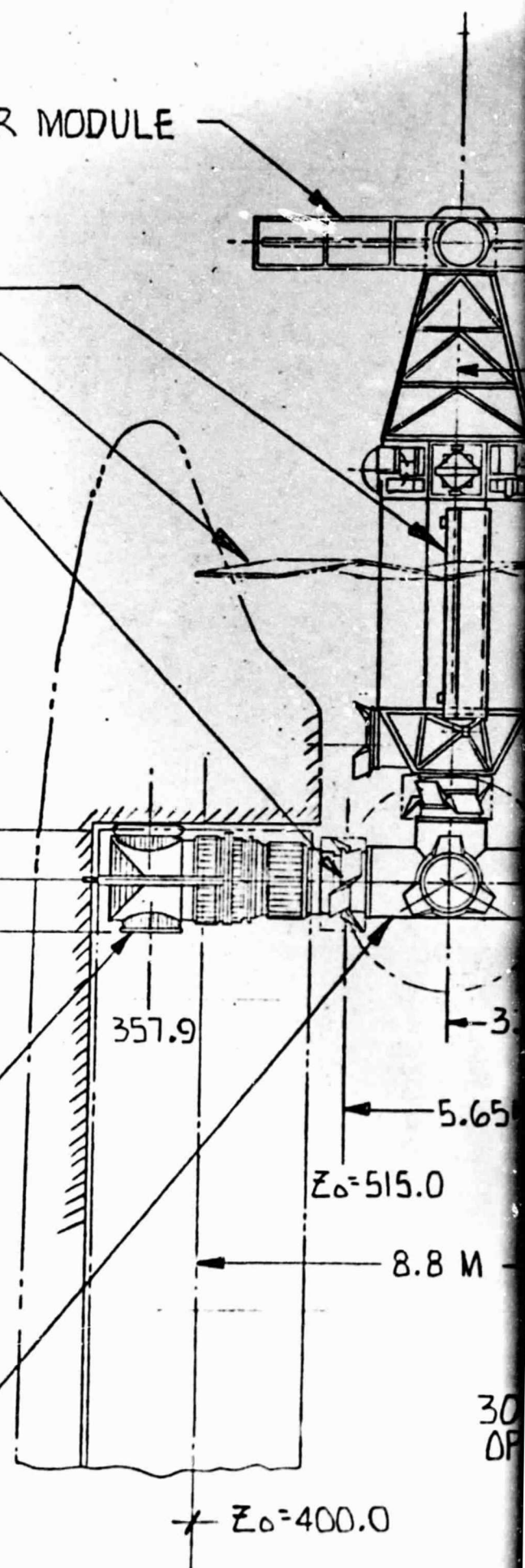
ORBITER
AIRLOCK/DOCKING
MODULE

13 →

INTERFACE MODULE
(1.5M DIA)

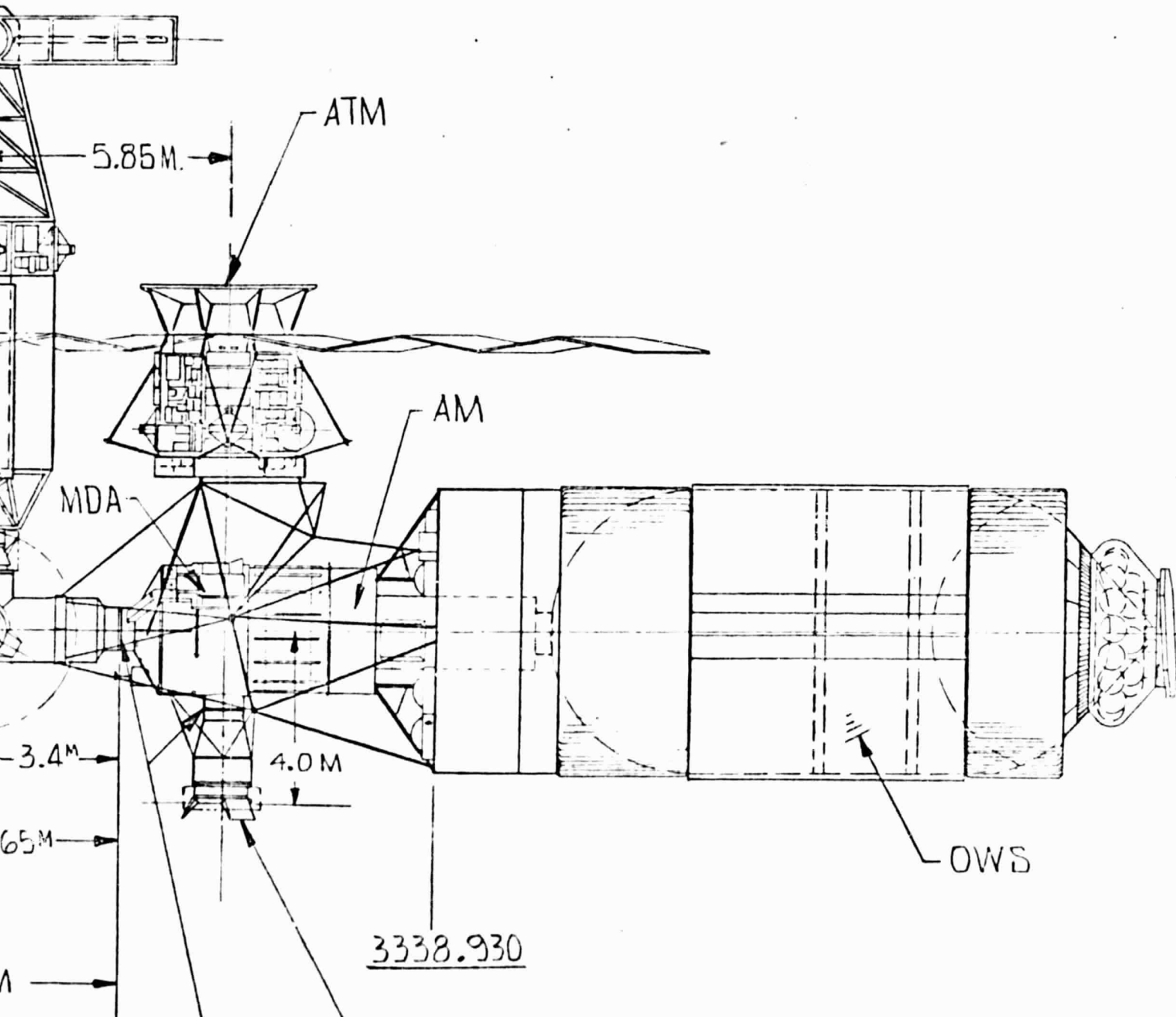
$Z_0 = 400.0$

30
OF





FOLDOUT FRAME



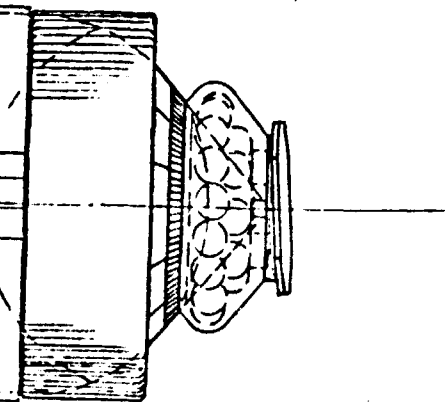
30.0 IN DIA. OPENING

DOCKING ADAPTER / LOGISTICS PORT (EMER. ORBITER DOCKING)

A

7

FOLDOUT FIGURE



OWS

PORT

Figure 2.3.3-1. Skylab Reuse Configuration

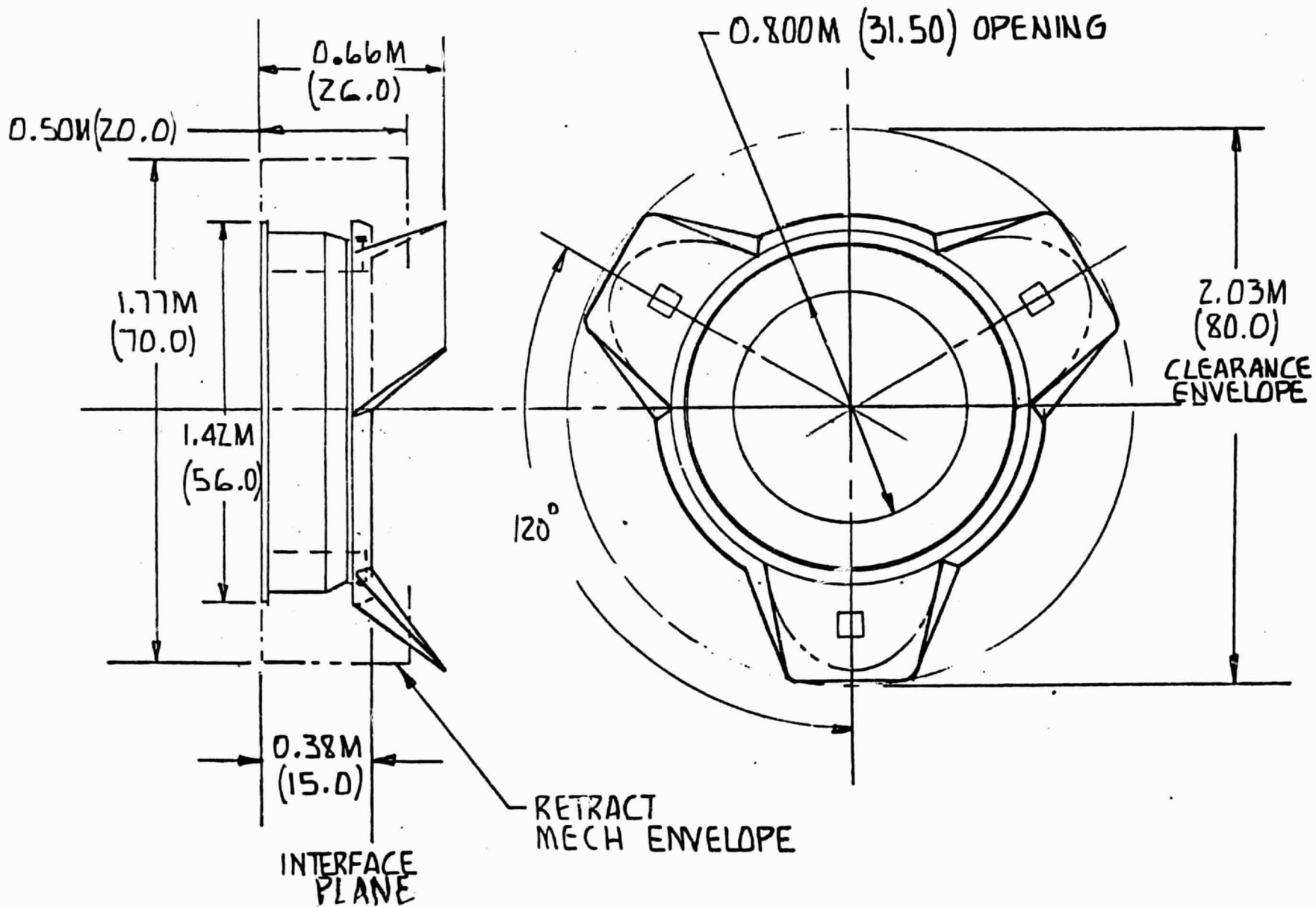
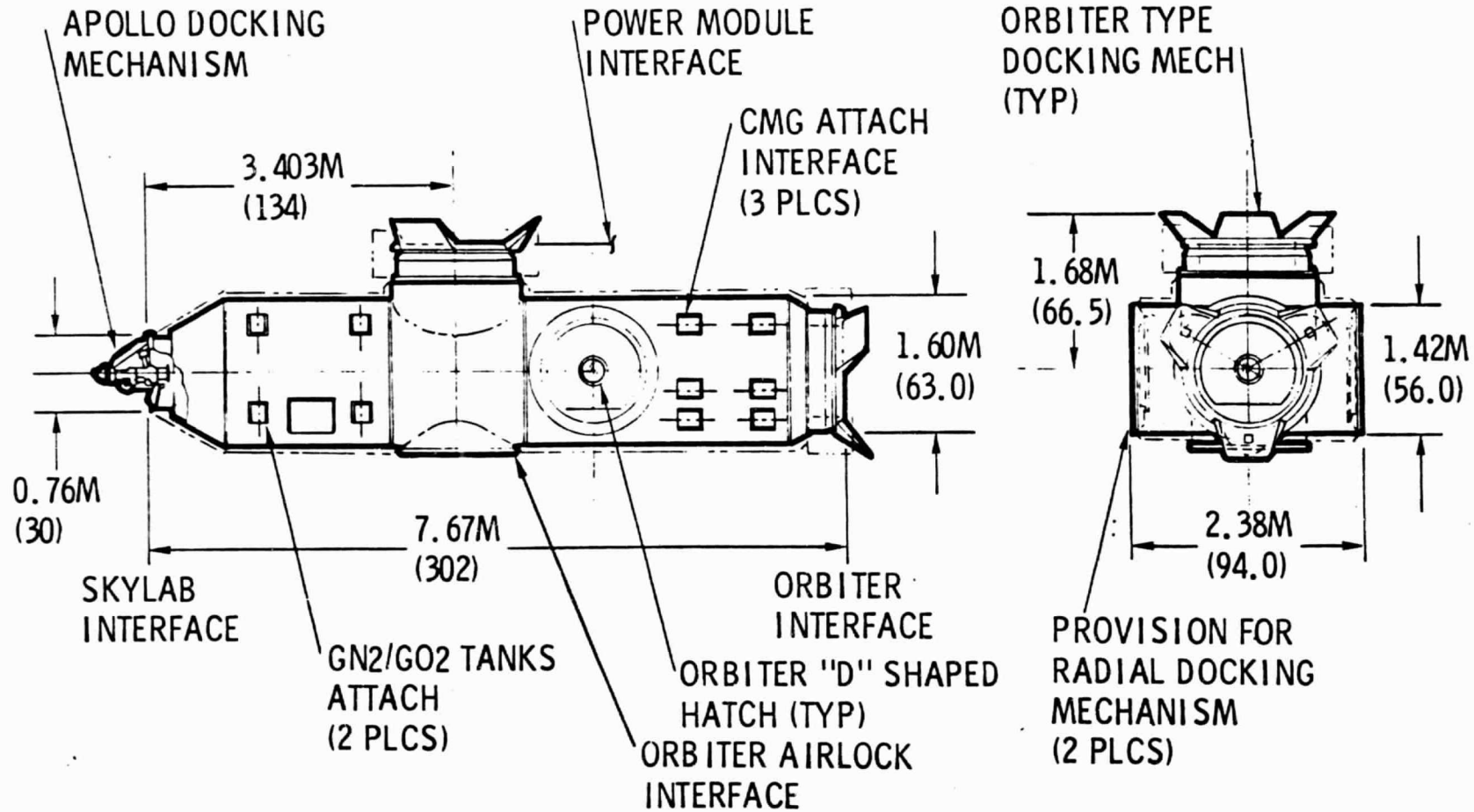


Figure 2.3.3-2. STS Androgynous Docking Mechanism

INITIAL INTERFACE MODULE CONFIGURATION

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docked elements. The 63.0-inch diameter selected makes the tunnel structure compatible with tooling developed for the Orbiter to Spacelab tunnel. With regard to the final point (i.e., Orbiter to Apollo mass difference), preliminary evaluation indicates that the Apollo drogue and probe and the supporting structure can take the higher docking loads. A detail stress analysis must be conducted to verify this condition in a Phase B study.

The next three design drivers impose additional docking requirements upon the Skylab reuse.

- o Candidate Payload with Greater Power Demands - Two factors contribute to the need for additional Skylab power: (1) condition of the original system and (2) new candidate payloads which have power levels greater than the Skylab (plus Orbiter excess) can provide. The first requirement results from the original loss of one orbital workshop array and the subsequent failure of power components due to the orbital duration power by 12% and the Apollo telescope mount power by 50%. In addition, by the tentative 1984 IOC, there will be a total solar cell degradation of approximately 20%. Thus the available power in the initial operational time frame will be on the order of 5.5 kW of this 3.5 kW to 4.5 kW will be required to operate the Skylab cluster, leaving 1.0 kW to 2.1 kW for payload support. Thus, with the exception of conducting small suitcase or low-power onboard experiments, additional power will be required. The present NASA/MSFC plan and basic Skylab Reuse Study groundrule is to utilize the 25 kW Power Module for both the initial Shuttle-tended missions and follow-on continuously-manned missions.

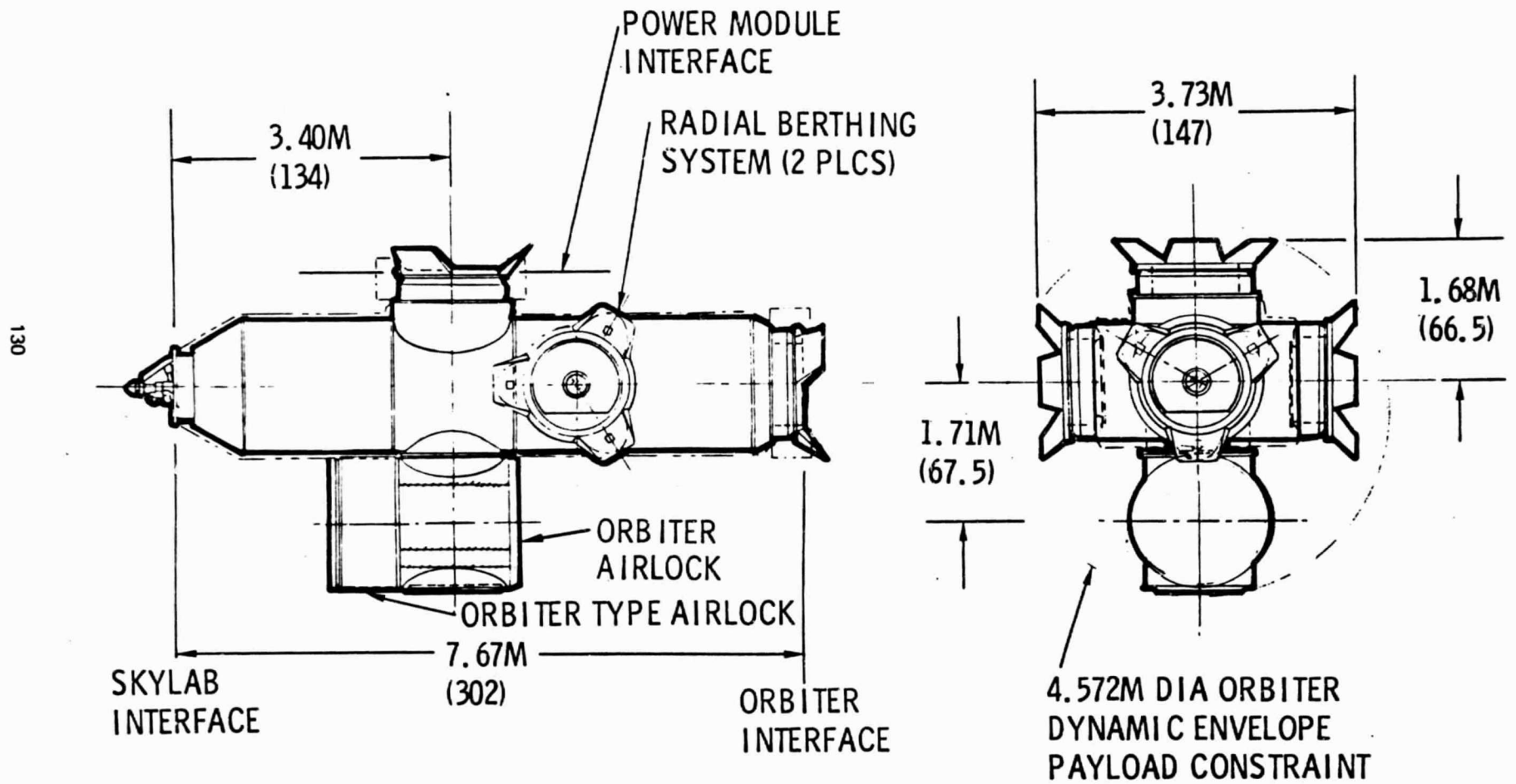
This operational approach leads to a requirement for an additional docking port and subsystem interfaces. The next two items also require docking interfaces, all of which are shown in Figure 2.3.3-4.

- o Extended (Continuously-Manned) Missions requiring Logistics Resupply of Consumables/Expendables - Reuse of Skylab will entail consideration of the resupply of both crew and vehicle consumables and expendables. The Skylab-A missions were fully presupplied with limited items delivered in the Apollo Command Module. The reuse study results are discussed in Section 2.4.4.4 of this report. The recommended concept, based upon reuse study results, is a

Figure 2.3.3-4

41533

INTERFACE MODULE INCREASED CAPABILITY



pressurized module of the Spacelab class. Thus, a second supplemental docking port is established as a requirement. In this application the logistics module would provide supplies for 60 to 120 days using two classes of interface/transfer: (1) crew transfer through shirtsleeve activities and (2) subsystem expendables through external transfer lines equipped with manual (i.e., EVA task) for automatic disconnects.

o Advanced Spacelab Modules/Payloads - New advanced payloads will be assigned to the Skylab reuse missions consistent with current scientific and technology programs. The original experiments have either exhausted their potential, do not provide sufficient additional objectives, or are not current with recent interests and technology, and therefore, do not constitute a full payload program. Selected original experiments, however, can support early experiment tasks or can augment current programs. There are several candidates to be considered in the add-on manned module option: (1) Spacelabs which have been equipped for sortie Shuttle missions but would benefit from longer mission duration and (2) Spacelabs dedicated to the reuse program. Both classes would require berthing ports which permit direct crew shirtsleeve access. These accommodations are also shown in Figure 2.3.3-4.

o Increased Crew EVA Tasks - The original Skylab configuration had the EVA airlock in the main Airlock Module which placed it in a location that blocked the main crew longitudinal passageway. Thus, when the airlock was in operation, the access to and from the OWS was blocked. In the initial reuse missions with three crew members and limited EVA in airlock or the Orbiter's airlock could be used. However, several factors mitigate against the continued use of this airlock: (1) potential of high frequency (i.e., virtually daily) EVA in support of space construction, (2) increased crew size with two shifts would require full access to the OWS, and (3) the new Orbiter pressure suits (EMU) is autonomous and requires life support and battery recharging. On this basis, the study evaluation resulted in the recommendation to incorporate provisions for the addition of an airlock derived from the basic Orbiter unit (reference Figure 2.3.3-4).

o Selected Skylab Subsystems Replacement - Assessment of current Skylab's subsystem status (e.g., two of three CMGs functioning), projection of remaining operational lifetime, and mission operations planning (e.g., will the Skylab be

required to operate in unmanned mode without the 25 kW Power Module berthed to provide stabilizations and control) resulted in the decision to provide mounting provisions (scars). These are shown in the noted figure. Figure 2.3.3-5 identifies the optional kits and Figure 2.3.3-6 conceptually depicts the installation locations for both the addition of either CMGs or high pressure tanks. The additional provisions incorporated in the basic tunnel structure will accept optional subassemblies. The subassemblies listed can be delivered to the Skylab cluster in kit form and installed on the Interface Module by EVA crewmen. All subassemblies are bolt-on configurations minimizing the crew operation.

As an alternate procedure, the Interface Module optional kits can be installed prior to launch and the completely assembled module delivered to the cluster on the initial flight.

Based on the previous support requirements and candidate Skylab reuse configuration the Interface Module must provide numerous subsystem interconnects. Figure 2.3.3-7 schematically identifies the various types of subsystems interfaces which must be accommodated. A number of these subsystems would require outlets and/or control stations within the Interface Module (e.g., communications, caution/warning, thermal control, etc.).

Guidelines and Criteria

In conjunction with the fundamental assessment and conceptual definition of the Interface Module, a set of preliminary requirements were developed for guidance in this study and as a baseline to assist in planning follow-on activities. An initial task in a Phase B study should include review and expansion of this preliminary set. These requirements are summarized in Table 2.3.3-1.

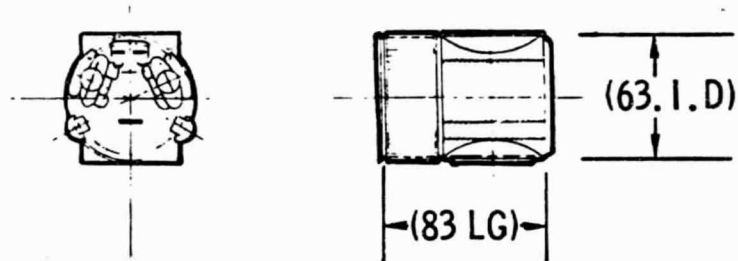
Interface Module Configurations - Cases I, II, and III

In the latter phase of this study, three mission models or reactivation refurbishment options were defined. These provided the foundation for: (1) detail operational planning and buildup sequence development; (2) cost analysis and program comparison; and (3) definition of operational/design requirements. This baseline information was directly applied to the final conceptual definition of the Interface Module. The three reactivation options identified as Cases I, II, and III, are technically described in this volume, Section 2.4.4. The programmatic and cost information comprise the basis of the programmatic volume. Case I

INTERFACE MODULE OPTIONAL ASSEMBLIES

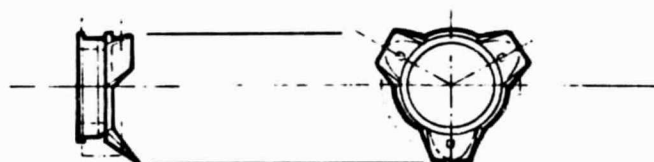
AIRLOCK MODULE

- ORBITER MODEL
- 2 MAN CAPABILITY
- SUIT STORAGE/DRYING
- PORTABLE O₂ SYS
- 5 MIN BLOWDOWN



RADIAL BERTHING MECH

- PASSIVE SYSTEM
- ORBITER UNIT
- BOLTED ASSEMBLY



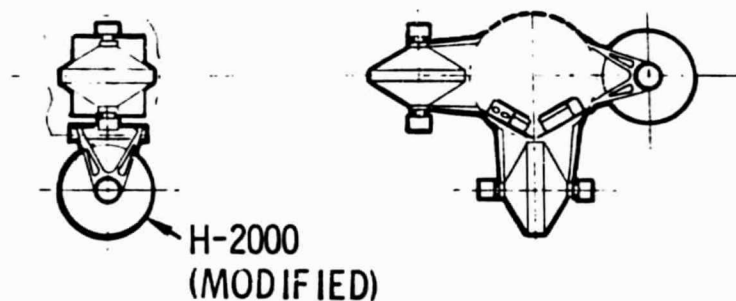
ATMOSPHERE SUPPLY TKS

- (1) GO₂ TK - 822 LBS O₂ USEABLE
- (2) GN₂ TKS - 440 LBS N₂ USEABLE
- SKYLAB TANKS



CMG INSTALLATION

- 3 MODIFIED SKYLAB CMG'S WITH ASSOC ELECTRONICS
- INCREASED CLUSTER CONTROL



INTERFACE MODULE CONCEPT OPTIONAL KITS

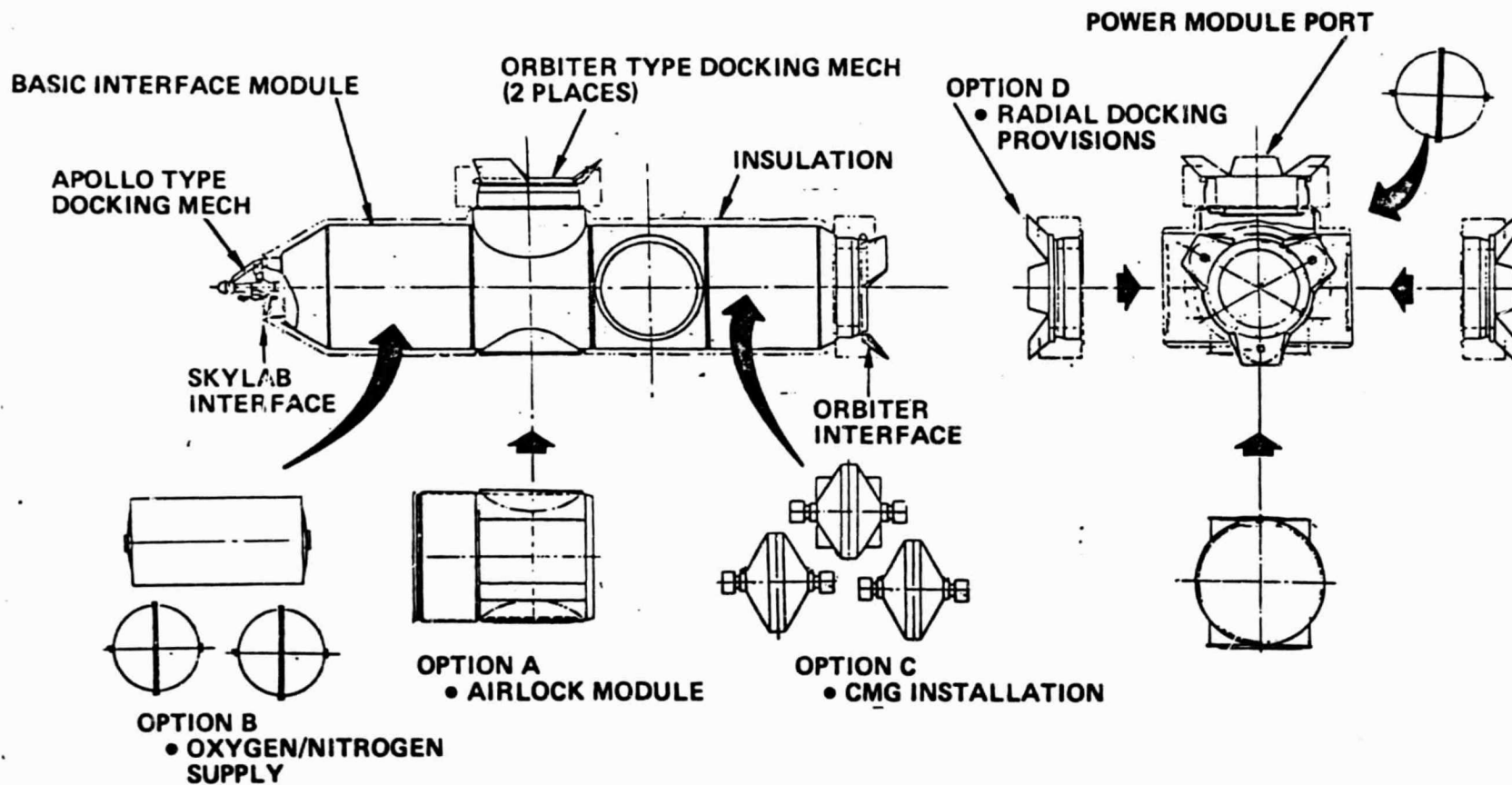
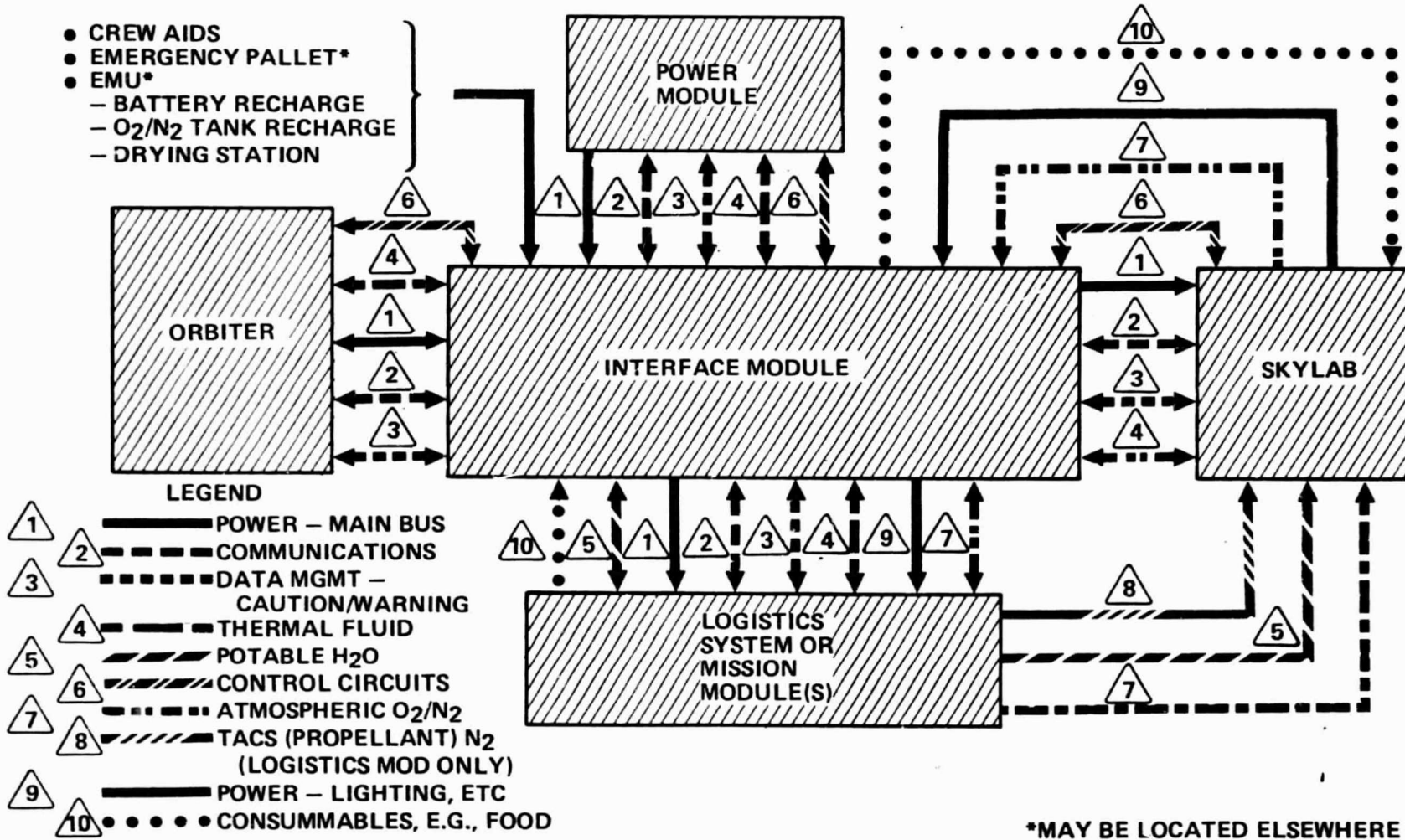


Figure 2.3.3-7

46530

SKYLAB REUSE CLUSTER TYPICAL UTILITY INTERFACES



*MAY BE LOCATED ELSEWHERE

Table 2.3.3-1
INTERFACE MODULE
PRELIMINARY GUIDELINES AND CRITERIA

General

- o Provide structural interface between the Power Module, Skylab, Orbiter, and specialized mission equipment.
- o Include sufficient volume and provisions for an emergency retreat center for Skylab crew.
- o All berthing ports to be androgenous except for the CSM/MDA system interfacing with the MDA Apollo probe.
- o Incorporate subsystem interface provisions necessary to support Orbiter/Power Module, Orbiter/PM/Skylab, Orbiter/PM/Skylab/mission equipment.
- o Berthing ports to be located to avoid restriction of viewing envelopes and to minimize shadowing of Power Module, Skylab instruments and radiators.
- o Berthing provisions interfacing with the Skylab MDA shall be compatible with the Apollo CSM/MDA docking system defined in document no. (TBD).

Operational

- o Provide a shirtsleeve environment between Orbiter, Skylab, Logistics Module and Payload Module.
- o Include an airlock with an operating pressure range of 5 psia to 14.7 psia.
- o Utility interfaces should be manually connected.
- o Utilities passing through the interface to be routed to avoid hatch opening/closing restrictions.
- o Permit attachment and removal of Orbiter and Power Module without major cluster changes.
- o Mobility aids shall be provided along all IVA/EVA routes and at each hatch.
- o Internal communications (duplex voice, caution and warning tones, and video) shall be available within the IM and at all active docking ports.

Design

- o Safety factors used for structural design shall be as follows:

Strength

Ultimate - A factor of safety of 2.0 shall be applied to the ultimate strength.

Table 2.3.3-1 (Continued)
INTERFACE MODULE
PRELIMINARY GUIDELINES AND CRITERIA

Yield - A factor of safety of 1.5 shall be applied to the yield strength.

Windows

Ultimate - A factor of safety greater than 3.0 with redundant panes.

- o The external dimensions of the module shall be (TBD) M diameter and (TBD) M in length and contained during launch within a dynamic envelope of 4.6 M (15 ft) diameter and (TBD) M (TBD ft) length. The nominal inside diameter shall be greater than 1 meter except at the MDA interface.
 - o The structure shall be designed for an oxygen/nitrogen mixture at 14.7 psi maximum internal pressure.
 - o Docking/berthing provisions shall be incorporated to accommodate the Orbiter, Skylab, 25 kW Power Module and two support modules/pallets.
 - o The berthing ports and hatches shall be sized for a minimum 40-inch opening similar to the Orbiter "D" shaped airlock hatch, except at the MDA interface.
 - o Each pressure hatch shall have a window.
-

mission (MSFC Baseline Reference) event sequencing assures that the current Skylab subsystems would consider to function properly through Phase II (i.e., Shuttle-tended refurbishment activities and that additional power is not needed. Therefore, the primary interface requirement is a docking adapter to permit Orbiter docking with the Skylab. This initial adapter can be returned to earth for incorporation into the full interface module as shown in outboard profile in Figure 2.3.3-8. Accordingly, this configuration benefits the program funding rate through the evolutionary approach. In all cases, the appropriate mounting provisions (scan) would be built into the basic structure. To accomplish this series buildup assembly, bolted flanges are necessary at both the intermediate body joint (i.e., between the adapter section and the center body) and for the Apollo probe mechanism.

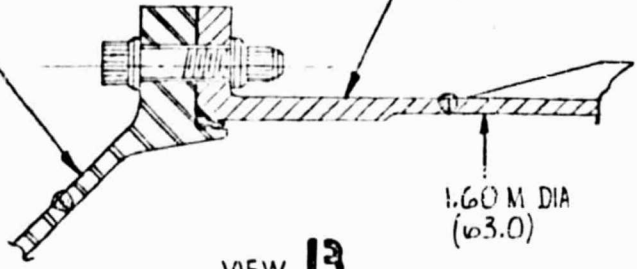
The alternate all-up Interface Module is shown in outboard profile in Figure 2.3.3-9. In this configuration, it is possible to weld all of the primary structure as the complete Interface Module structure is delivered to orbit and berthed to Skylab. A configuration of this type meets the mission sequence for Cases II and III. Additional kits can be added based upon the specific problems.

The paramount advantage of the augmented kitting concept is the inherent flexibility which permits real-time decisions necessary to meet the exigencies of a dynamic program.

FOLDOUT PAGE

SKYLAB INTERFACE SECTION (REF)

CENTER SECTION (REF)



VIEW 13

1.60 M DIA (63.0)

0.25 M (10.0)

0.762 M (30.0)

APOLLO TYPE DOCKING MECH. (REMOVABLE) w/ INTERFACE LATCHES

EXTERNAL STORES MOUNTING PROVISIONS

OPTIONAL ATMOSPHERIC SUPPLY INSTALLATION (1) O₂ SHOWN (2) N₂ OPF

EXTERNAL STORES UMBILICAL & CYLINDER PENETRATION PROVISION

SKYLAB INTERFACE SECTION 0.838 M (33.0)

3.403 M (134.0)

INSULATION

1.422 M (56.0)

13

1.60 M I.D. (63.0)

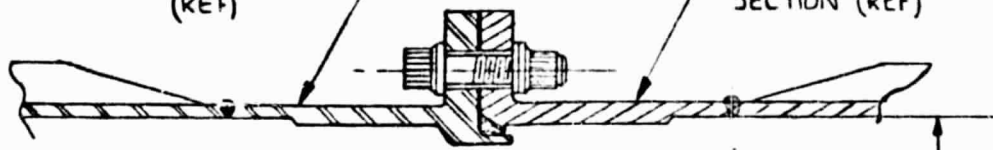
2.286 M (90.0)

SKYLAB INTERFACE

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CENTER SECTION
(REF)

ORBITER INTERFACE
SECTION (REF)



VIEW A

1.60 M DIA
(63.0)

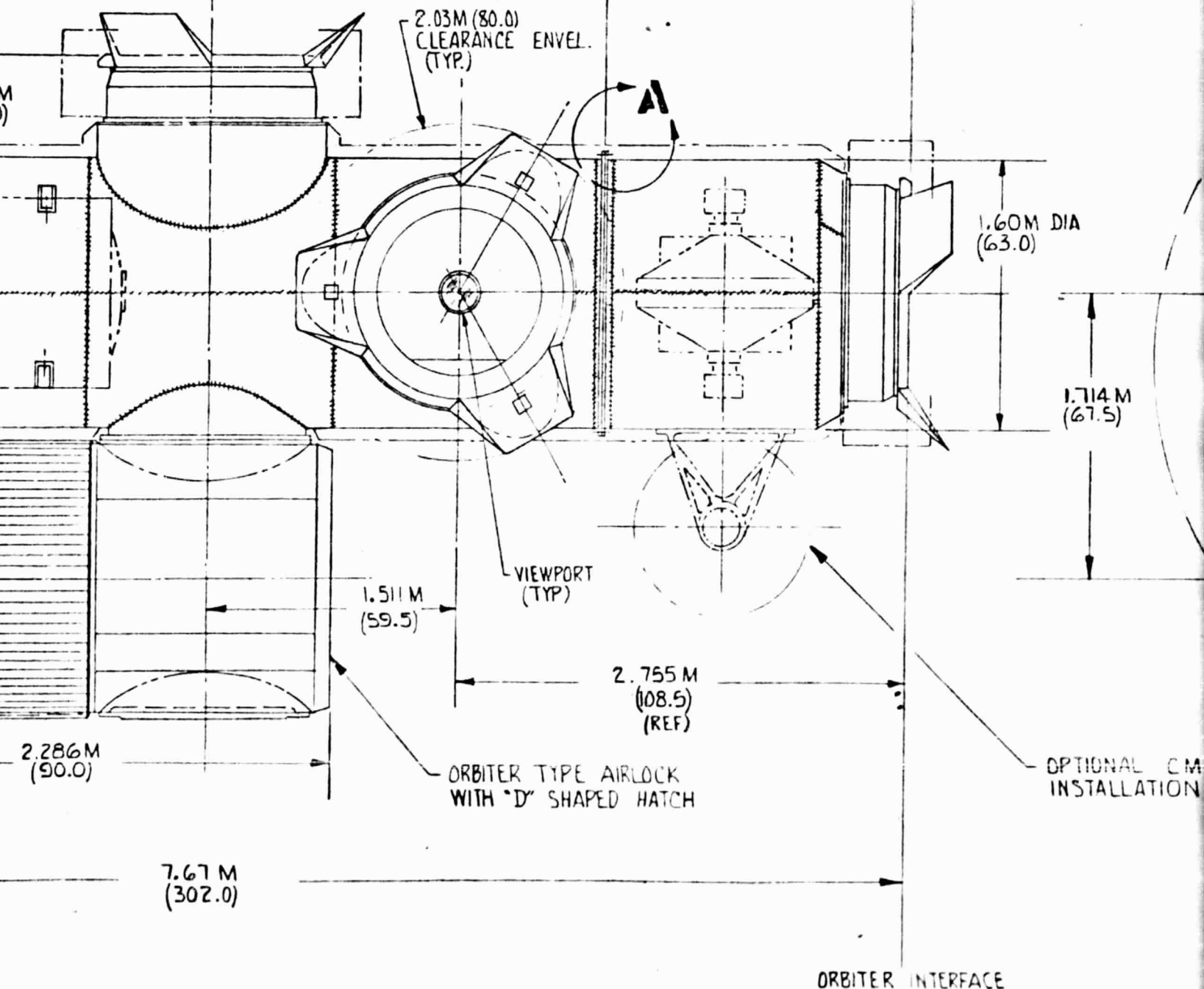
CENTER SECTION

ORBITER INTERFACE
SECTION

4.95 M
(195.0)

1.87 M
(74.0)

2.03 M (80.0)
CLEARANCE ENVEL.
(TYP.)



1.60 M DIA
(63.0)

1.714 M
(67.5)

1.511 M
(59.5)

VIEWPORT
(TYP)

2.755 M
(108.5)
(REF)

2.286 M
(90.0)

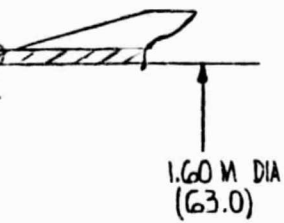
ORBITER TYPE AIRLOCK
WITH 'D' SHAPED HATCH

OPTIONAL CM
INSTALLATION

7.67 M
(302.0)

ORBITER INTERFACE

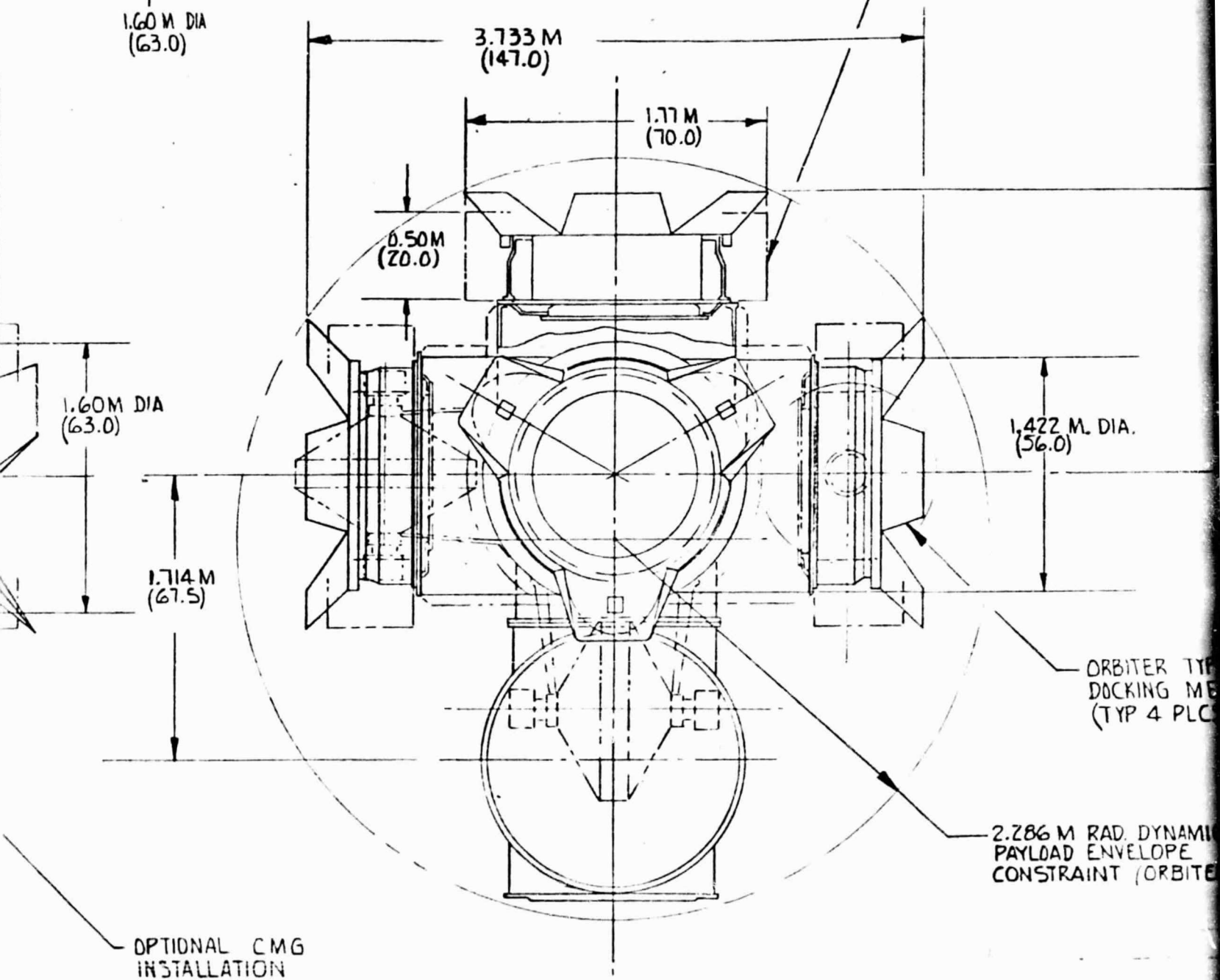
ORBITER INTERFACE
SECTION (REF)



3

FOLDOUT FRAME

DOCKING SYSTEM
MECHANISM ENVELOPE (T)



INTERFACE

FOLLOUT FRAME

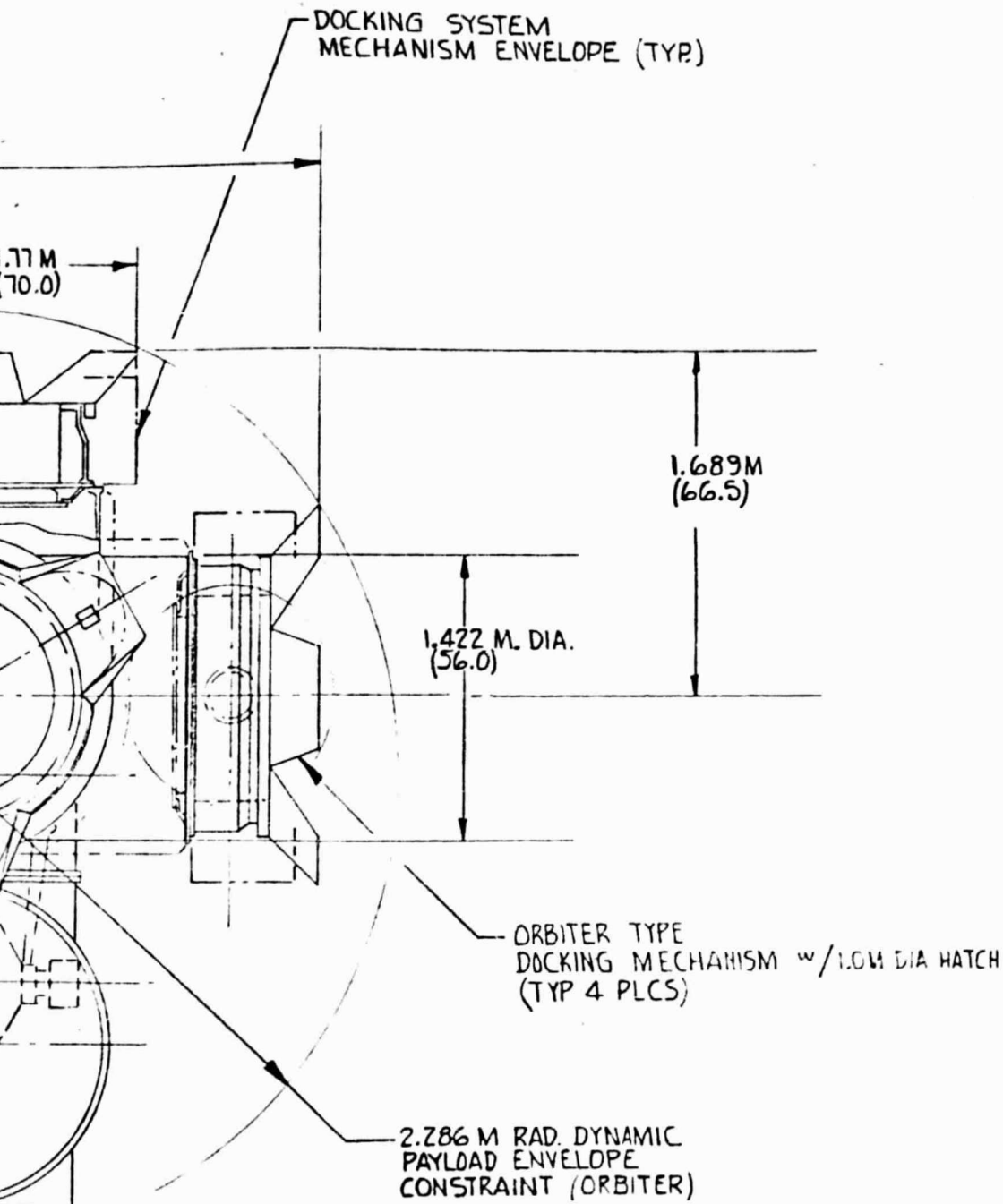
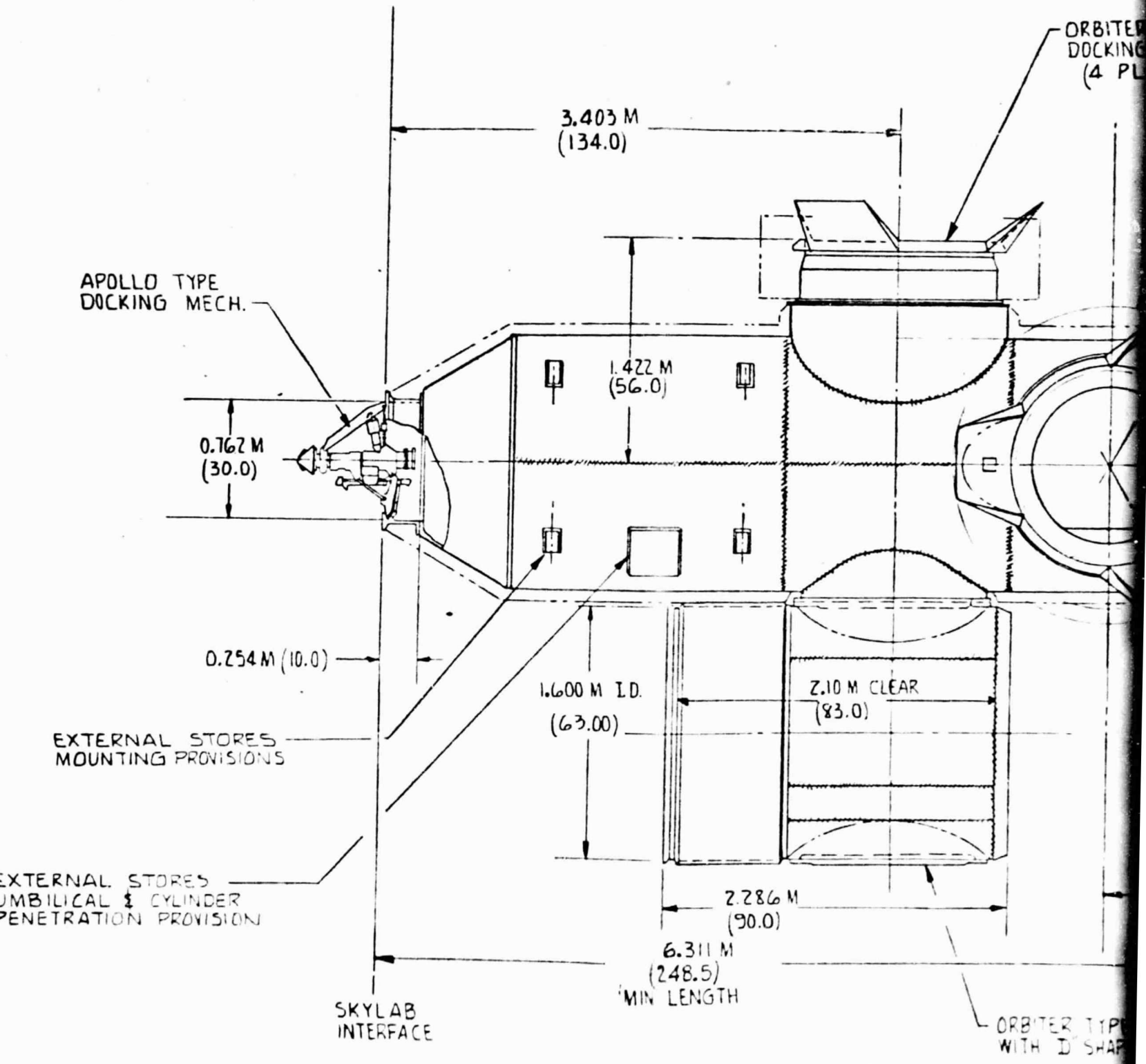


Figure 2.3.3-8

1
EXPLODED VIEW



2

FOLBOUT FRAME

ORBITER TYPE DOCKING MECH. (4 PLCS)

2.03 M (80.0) CLEARANCE ENVELOPE (TYP)

INSULATION

DOCKING SYSTEM MECHANISM ENVELOPE (TYP)

1.60 M (63.0)

0.38 M (15.0)

ORBITER INTERFACE

1.524 M (60.0)

ORBITER TYPE AIRLOCK WITH "D" SHAPED HATCH

7.67 M (302) MIN. LENGTH WITH CMG PACKAGE

3.733 M (147.0)

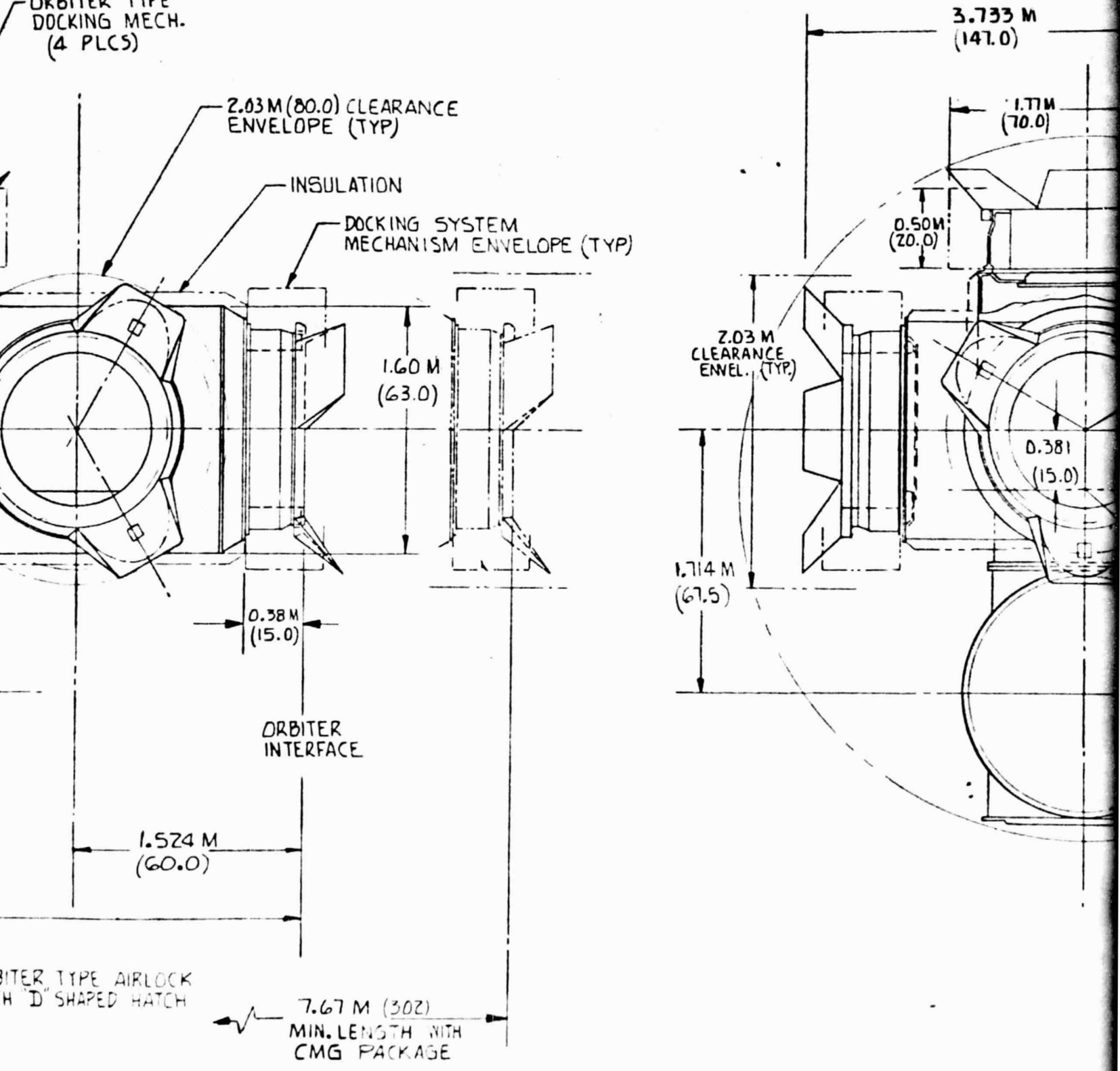
1.77 M (70.0)

0.50 M (20.0)

2.03 M CLEARANCE ENVEL. (TYP)

0.381 (15.0)

1.714 M (67.5)



3 FOLDOUT FRAME

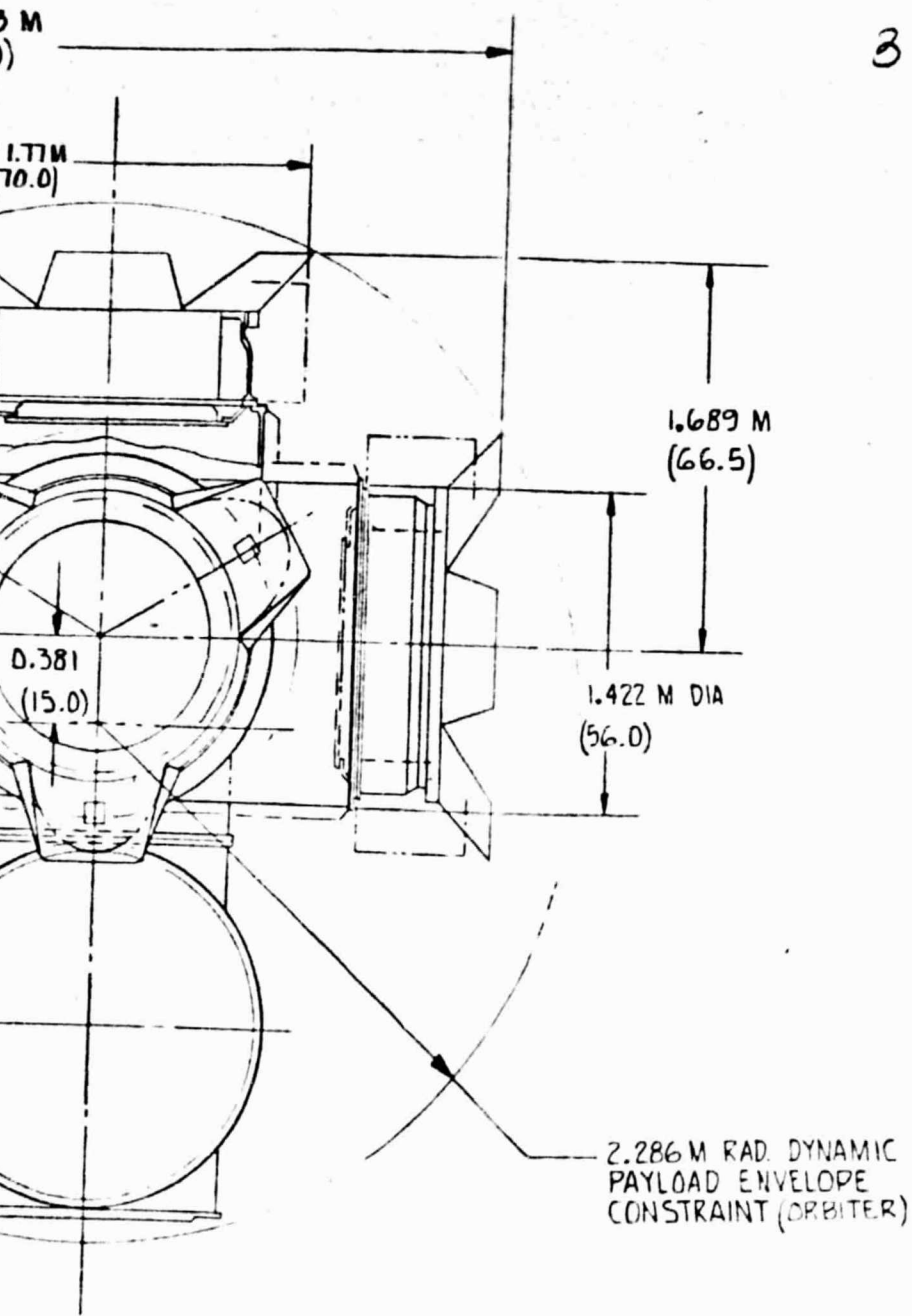


Figure 2.3.3-9

2.4 PROGRAMMATICS - INSPECTION/REFURBISHMENT PLANS, SCHEDULES AND COSTS

At the outset of the Skylab Reuse Study, the initial estimates indicated that several Orbiter flights would be required to inspect and refurbish/resupply the spacecraft to full operational capability. It would not have been beyond all possibility to have found, during interrogation, that the pressure shell had been penetrated by a micrometeoroid, that the solar array had deteriorated, or that the battery systems in the ATM and AM were not usable. However, as the study progressed and ground interrogation data were collected, Skylab was found to be in remarkably good condition. The status of the subsystems is virtually the same as the status at the End-of-Missions in 1974. Refurbishment/resupply required to reactivate and reuse Skylab is not extensive and can be accomplished in two Orbiter flights. In fact, in one reactivation option examined, the total refurbishment/resupply required to restore Skylab to full operational capability is shuttled up on only one Orbiter flight.

2.4.1 Guidelines and Criteria

Although the Skylab reuse program includes four phases, only the latter three were addressed in this study. Phase I, which is the current interrogation/reactivation phase, has been defined in related activities.

The early internal inspection and refurbishment visits to Skylab are Phase II operations (Reference Figure 2.4.3-1), which begin with the initial docking of Orbiter and extends into Phase III operations. Phase III IOC, initial operational capability, begins with docking of the 25 kW Power Module. Phase IV IOC occurs at checkout of Skylab autonomous TDRSS (Tracking and Data Relay Satellite System) communications system. Section 2.4.4, Operations and Logistics Plan treats Phase III and Phase IV operations. Phase II operations are discussed in this section.

Phase II Operational Objectives are as follows:

- o Perform initial exterior visual inspection and photographic coverage
- o Conduct interior inspection - IVA/shirtsleeve
- o Provide shuttle-tended support to Skylab for
 - o Crew safety
 - o Crew support and quarters
 - o Intercom-to-Orbiter duty officer and TDRSS voice link-to-ground
 - o Caution and warning

- o Accomplish refurbishment tasks and install kits to assure
 - o Crew safety
 - o Acceptable shirtsleeve working environment
 - o Mission critical items are functional
 - o Assure unmanned flight control reliability
 - o Reconfigure on-board subsystems for improved ground interrogation and control

and to complete Phase II overlap into Phase III

- o Develop rendezvous and docking procedures
- o Improve Orbiter support to Skylab
- o Complete all refurbishment tasks and install kits for
 - o Phase III IOC - installation of integration kit for 25 kW Power Module and
 - o Phase IV IOC - installation and checkout of autonomous TDRSS communications link

2.4.2 Refurbishment/Resupply Kits

Reuse study analyses and ground interrogation results have enabled the definition of refurb/resupply requirements and the development of kit descriptions to meet these requirements. This study approach has been to separate the supplies into three "refurb" kits, all of which could be shuttled up on one mission or separately flown up on three different missions. This was done in the interest of providing NASA a funding flexibility during the inspection/refurbishment phase. At the same time, the technical team critically assessed the equipment in each kit and assigned fly-up priorities to them. The operational procedures, installation sequences, mobility aids and their location, etc., will be developed in conjunction with the preparation of specifications and installation layouts. Following are the kit descriptions and the rationale for the fly-up criticality rating.

Kit A - has the highest criticality rating. It is mandatory for fly-up on the first revisit to Skylab. Kit A supplies are required to insure crew safety and assure accomplishment of mission critical functions. It consists of the following packages:

- o Instrumentation - signal conditioner
- o Communications - DC/DC converter, TDRSS relay, etc.
- o AM coolant loop reservice kit
- o Charcoal canisters
- o CO₂ detector cartridges

- o TACS/resupply/or other attitude damping device
- o Mobility aids

Kit B - has the second highest criticality rating and may well become equivalent to Kit A by ATP. Kit B consists of:

- o Control moment gyro package (CMGs)
- o Thermal shield
- o Mobility aids

As a mission-critical function, CMGs are required to ensure maintenance of flight stability and control of desired orientation of Skylab. The inclusion of CMGs in the kit is predicated on the belief that the ATM CMGs, active today, will most likely fail prior to a first revisit to Skylab and that CMG control for the spacecraft will be desired before the 25 kW Power Module with its CMG package is docked in 1984.

Additional criticality rating of this kit is based on considering crew performance as virtually a mission-critical function. Thus, the option of a new thermal shield has been included to further assure a shirtsleeve working environment in the habitation area of Skylab. This 360 ft solar shield has been included in order to provide information on a case in which the Orbiter/Skylab cannot be maintained in a solar inertial orientation or to prevent an unacceptably high temperature occurring during the unmanned period prior to the addition of the IMF CMGs. Further analysis of these operational conditions should be conducted to establish final attitude control and thermal conditioning requirements.

Kit C - consists of the following:

- o Tape recorders
- o 25 kW Power Module integration package
- o Atmosphere resupply
- o Communications package for Skylab to TDRSS autonomous capability
- o Crew systems accommodations
- o Miscellaneous equipment
- o Mobility aids

Except that the cabin atmosphere on Skylab will require resupply, there is no particular urgency for the integration of Kit-C into the refurbishment program. Crew safety and the assurance of mission critical functions are not immediately dependent on the incorporation of Kit-C; thus, the lower criticality rating. However, the refurbishment/resupply provided by this kit should be scheduled for timely installation as the Phase III Shuttle-tended Operations, are

dependent on docking and integration of the 25 kW Power Module and Phase IV Operations cannot commence until Skylab has an autonomous TDRSS communication link for both voice and data.

Perhaps the most significant reason to minimize the total Phase II operations is that the significant benefit Skylab has to offer the STS program is habitability support for crews conducting long-term missions. Kit-C provides the bulk of the refurbishment/resupply to enable this capability.

Docking Adapter/Interface Module

A Docking Adapter (DA) or an Interface Module (IFM) discussed in Section 2.3.3 is a new piece of hardware required for docking the Orbiter to the Skylab cluster. The utilization of the DA/IFM will be discussed in the following section on refurbishment options.

2.4.3 Schedules and Costs of Refurbishment Options

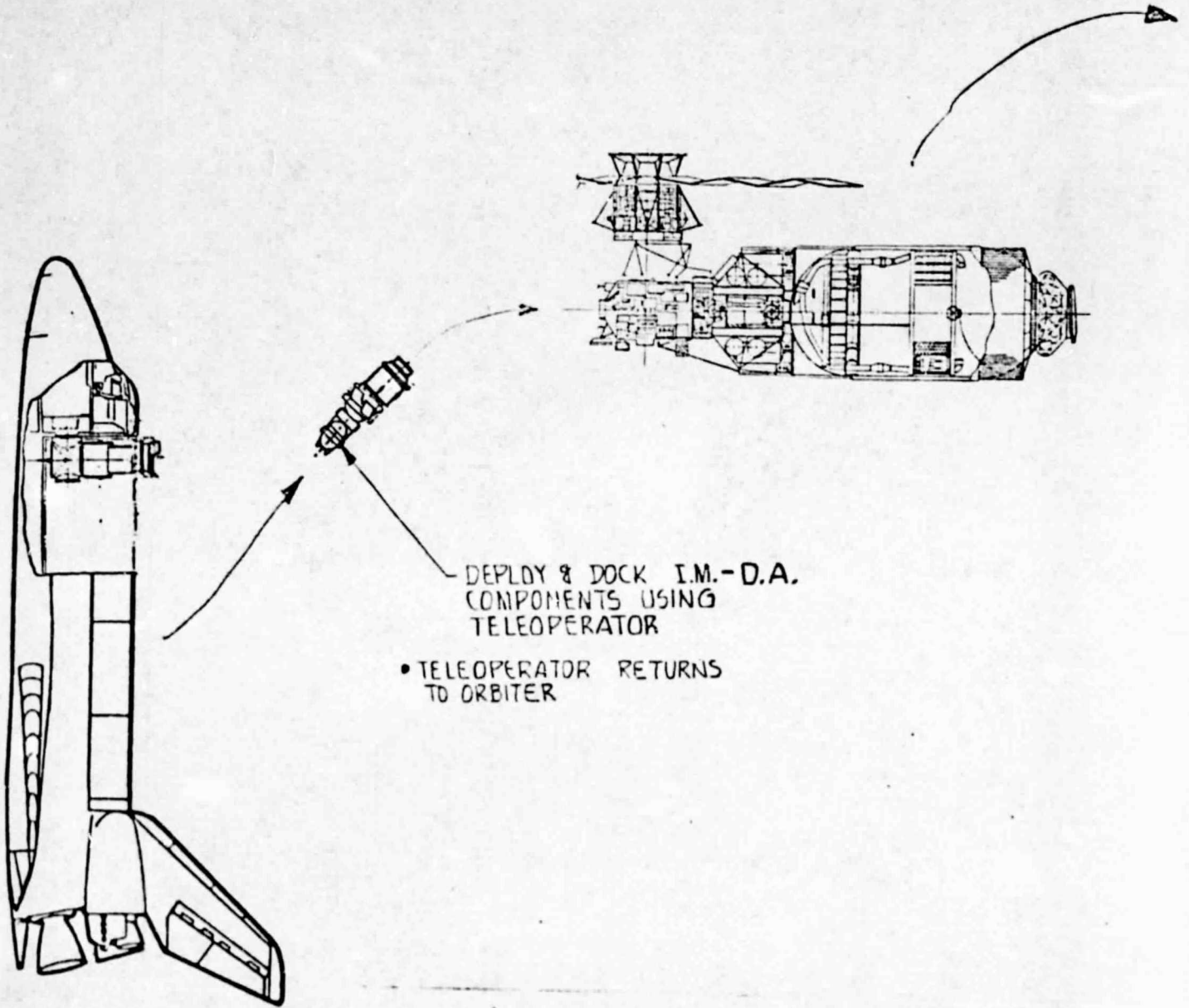
Three different Skylab refurbishment options, Cases I, II and III were analyzed programmatically at the conclusion of the reuse study. The following summary of the technical rationale, key aspects, costs, and master phasing for each case has been extracted from the detail data developed during the study.

Case I - Baseline Reference

The Baseline Reference Case utilizes two Shuttle launches for refurbishment. The first, an inspection visit includes Kit A refurbishment. TACS is resupplied, but this case assumes that (1) ATM-CMGs performance will continue to be acceptable and (2) passive thermal control of OWS is acceptable until Phase III IOC. Thus, refurb. Kit-B, not including CMGs which are to be provided by the Power Module, is shuttled up together with Kit-C on the second visit.

Figure 2.4.3-1 depicts Case I reactivation of Skylab. On the first visit, Orbiter brings up the DA, Figure 2.4.3-2 a two-piece assembly made from the end sections of the IFM to be flown up on the second visit. The Teleoperator docks the DA to Skylab's axial docking port and returns to the Orbiter bay. The Orbiter is then docked to Skylab and the crew proceeds to activate Skylab, perform the tasks assigned to the first visit, and to incorporate refurbishment Kit-A. After completing the activities for the first visit, the crew deactivates Skylab and re-installs the docking probe and drogue at the

FIRST VISIT

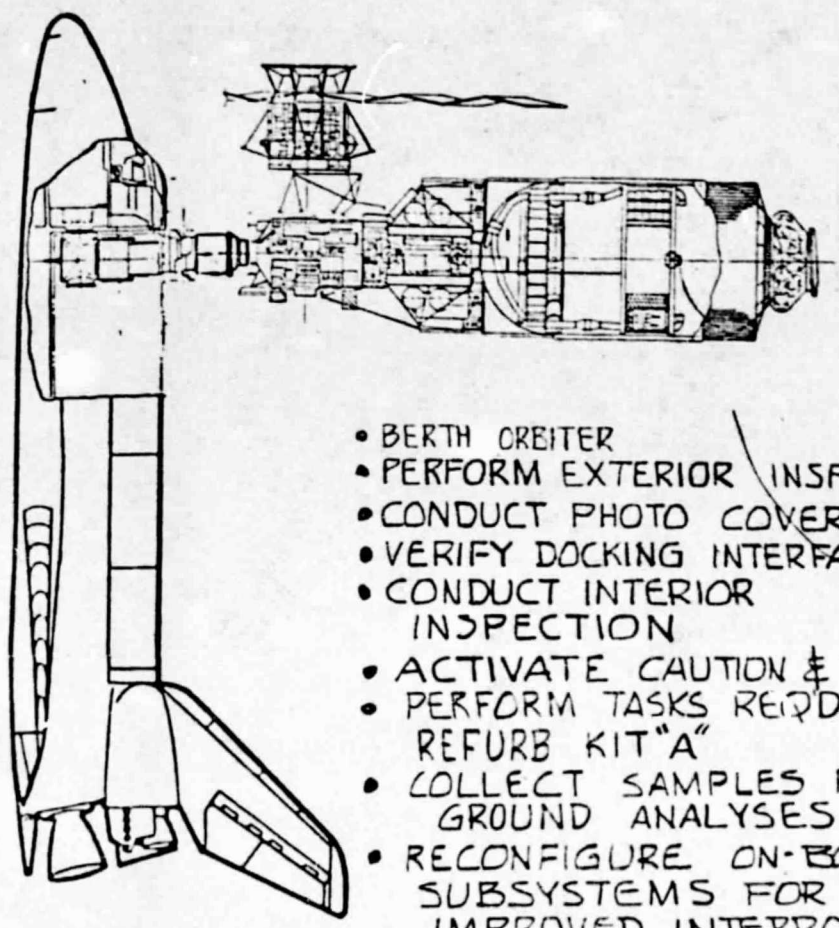


DEPLOY & DOCK I.M.-D.A.
COMPONENTS USING
TELEOPERATOR

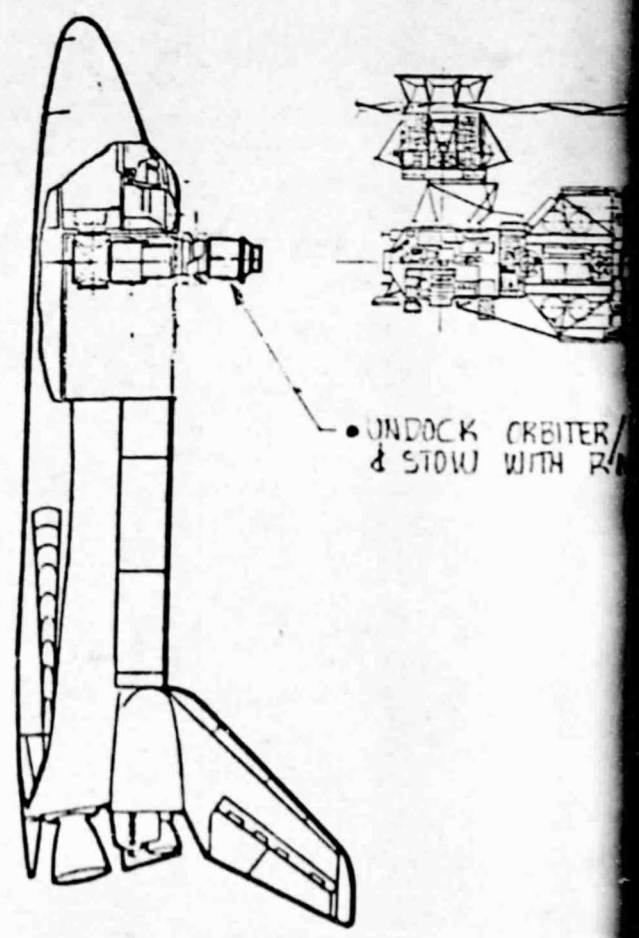
- TELEOPERATOR RETURNS
TO ORBITER

ORBITER DELIVER
INTERFACE MODULE DOCKING ADAPTER
COMPONENTS

FOLDBOUT FRAME



- BERTH ORBITER
- PERFORM EXTERIOR INSPECTION
- CONDUCT PHOTO COVERAGE
- VERIFY DOCKING INTERFACE
- CONDUCT INTERIOR INSPECTION
- ACTIVATE CAUTION & WARNING
- PERFORM TASKS REQ'D BY REFURB KIT "A"
- COLLECT SAMPLES FOR GROUND ANALYSES
- RECONFIGURE ON-BOARD SUBSYSTEMS FOR IMPROVED INTERROGATION



• UNDOCK ORBITER & STOW WITH R

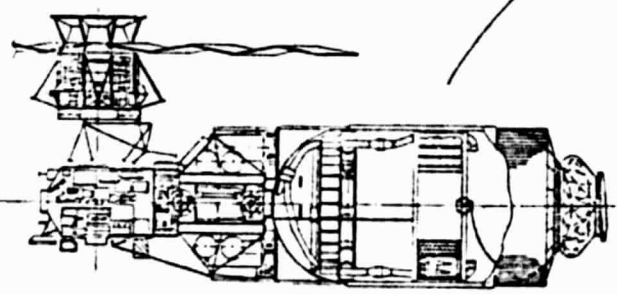
ORBITER RETURNS WITH INTERFACE MODULE COMPONE



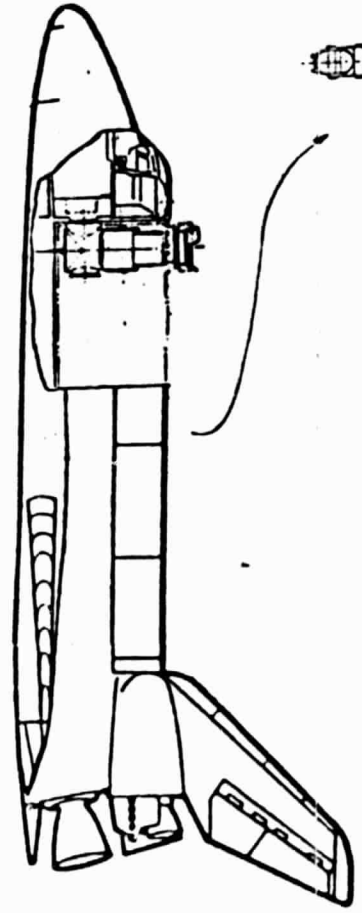
2

FOLDOUT FRAME

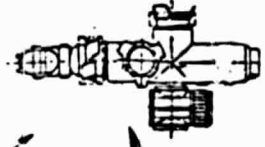
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• UNDOCK ORBITER/IM COMPONENTS
& STOW WITH RIMS.



ORBITER DELIVERS INTERFACE
MODULE ON
2ND LAUNCH

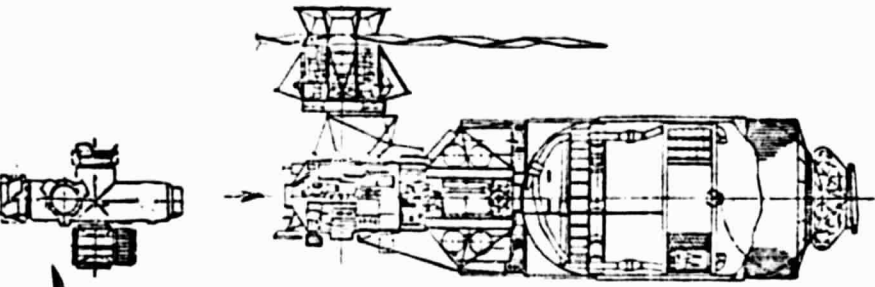


• DEPLOY & DO
TELEOPERAT

ORBITER RETURNS WITH IM-DA
INTERFACE MODULE COMPONENTS



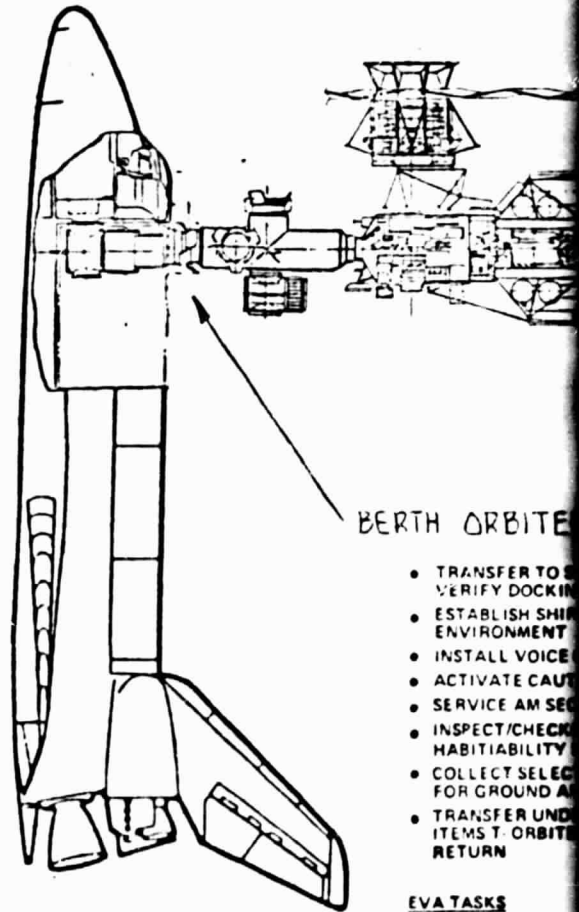
SECOND VISIT



• DEPLOY & DOCK IM USING TELEOPERATOR

3 HOLDOUT PERIOD

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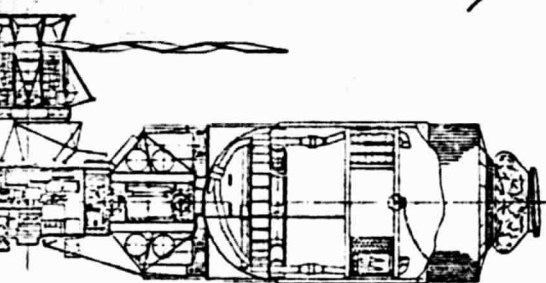


BERTH ORBITER

- TRANSFER TO & VERIFY DOCKING
- ESTABLISH SHIP ENVIRONMENT
- INSTALL VOICE
- ACTIVATE CAUTION
- SERVICE AM SERVICES
- INSPECT/CHECK HABITABILITY
- COLLECT SELECTED ITEMS FOR GROUND ANALYSIS
- TRANSFER UNDERWAY ITEMS TO ORBITER RETURN

EVA TASKS

- ASSEMBLE INTERNAL MODULE SUPPLY
- INSTALL OVERHEAT THERMAL PROTECTORS
- REPLENISH THERMAL PROTECTORS
- GN2 SUPPLY



ERTH ORBITER TO I.M.

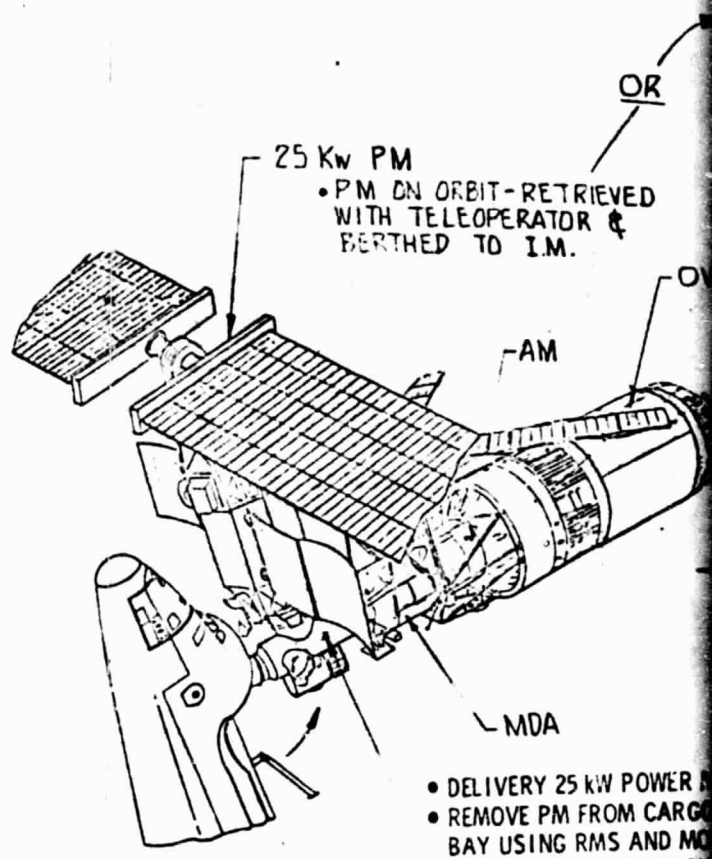
- TRANSFER TO SKYLAB AND VERIFY DOCKING INTERFACE
- ESTABLISH SHIRTSLEEVE ENVIRONMENT
- INSTALL VOICE COM MOD KIT
- ACTIVATE CAUTION AND WARNING
- SERVICE AM SECONDARY COOLING LOOP
- INSPECT/CHECKOUT HABITABILITY SUBSYSTEMS
- COLLECT SELECTED SAMPLES FOR GROUND ANALYSIS
- TRANSFER UNDESIRABLE ITEMS TO ORBITER FOR RETURN

- EVA TASKS**
- ASSEMBLE INTERFACE MODULE SUPPORT STRUTS
 - INSTALL OWS THERMAL PROTECTION
 - REPLENISH TACS GN2 SUPPLY

- PERFORM ALL TASKS REQ'D BY REFURB KITS 'B' & 'C'
- FOLD BACK ATM ARRAYS

FOLDOUT FRAME

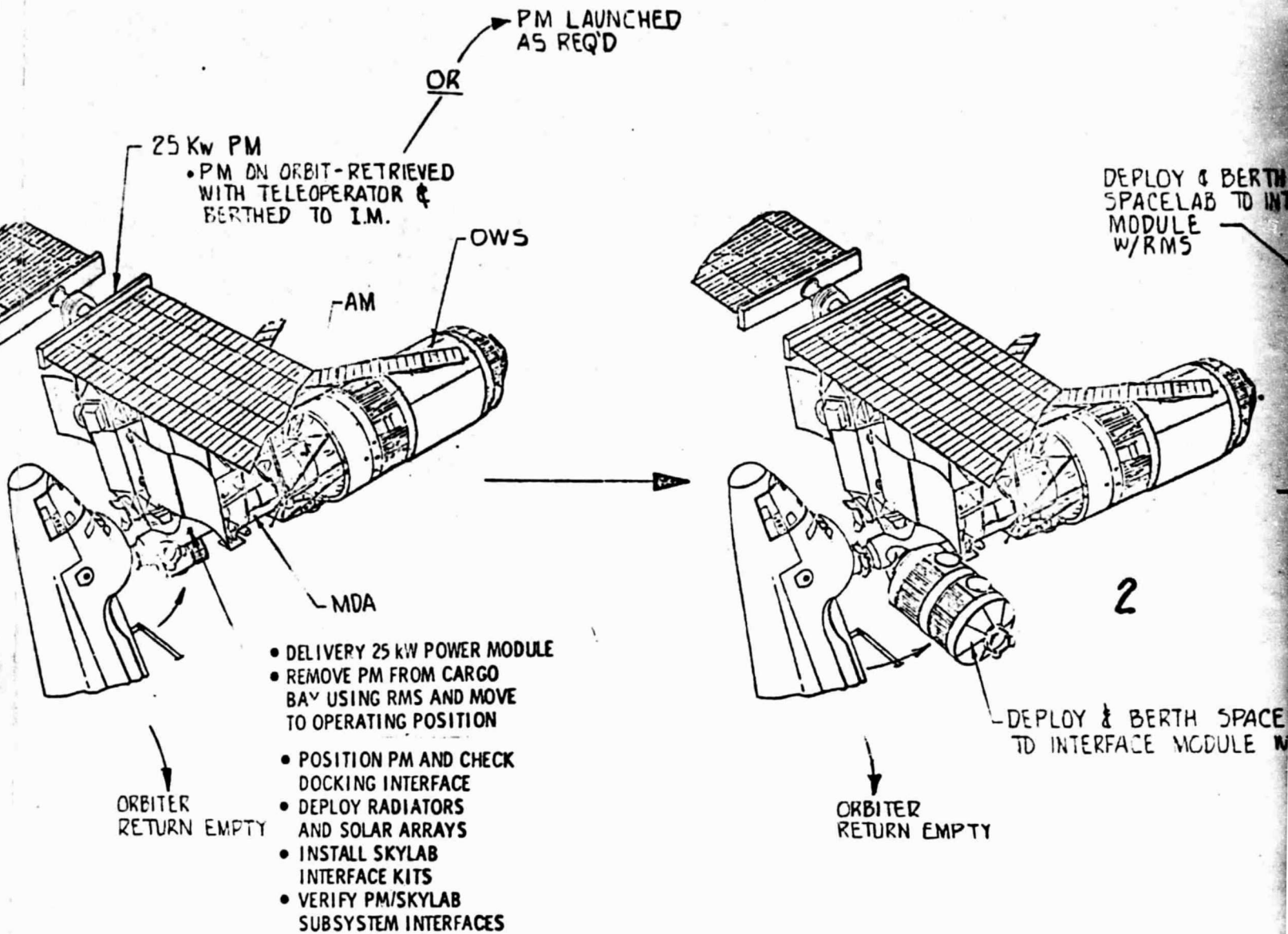
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ORBITER RETURN EMPTY

- DELIVERY 25 kW POWER
- REMOVE PM FROM CARGO BAY USING RMS AND MOVE TO OPERATING POSITION
- POSITION PM AND CHECK DOCKING INTERFACE
- DEPLOY RADIATORS AND SOLAR ARRAYS
- INSTALL SKYLAB INTERFACE KITS
- VERIFY PM/SKYLAB SUBSYSTEM INTERFAC

ASSU

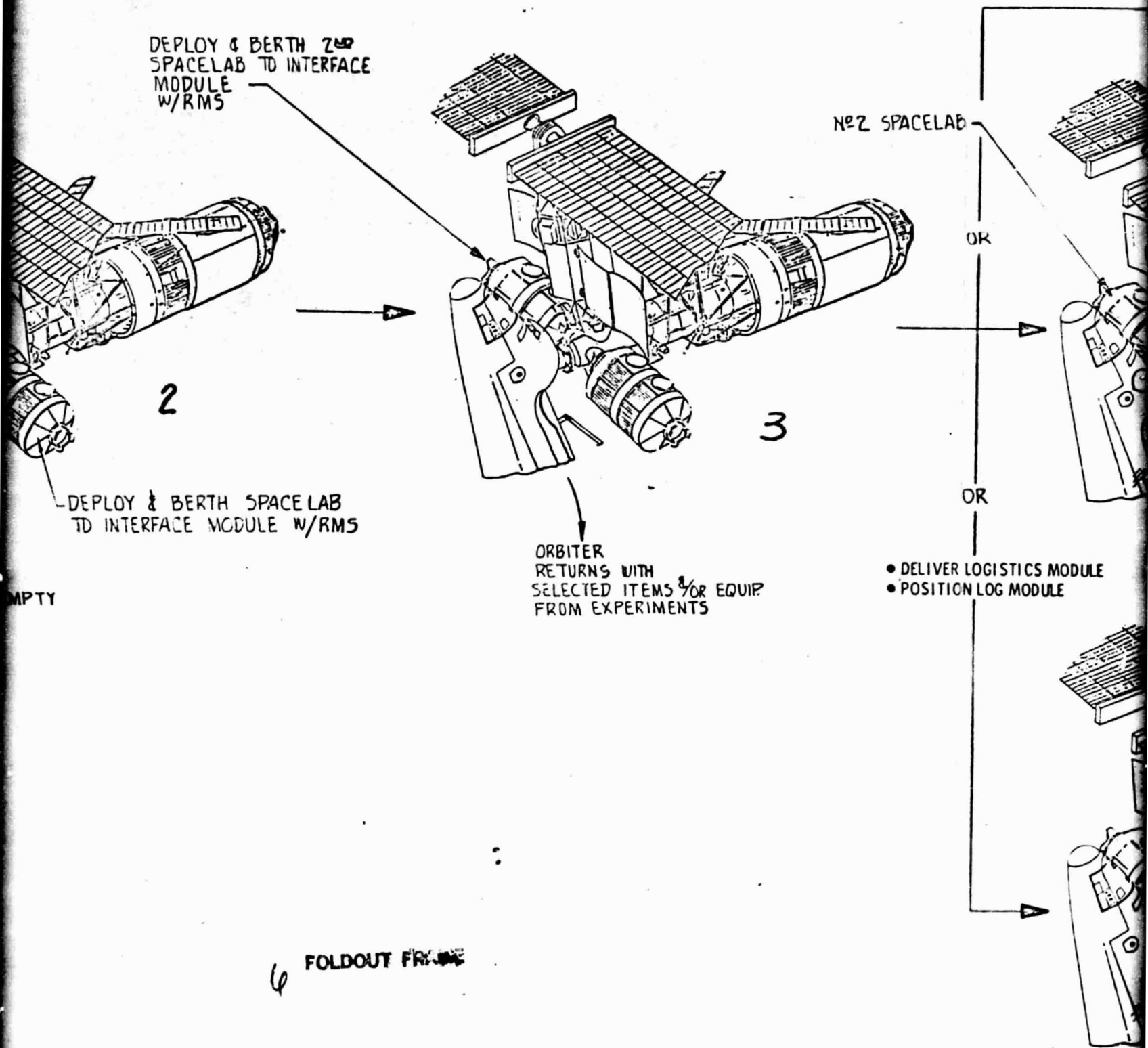


ASSUMPTIONS

- MDA ALTERNATE DOCKING PORT NOT AVAILABLE
- ORBITER EQUIPPED WITH (1) RMS
- 25 KW PM LAUNCHED AS REQ'D
- TELEOPERATOR AVAILABLE

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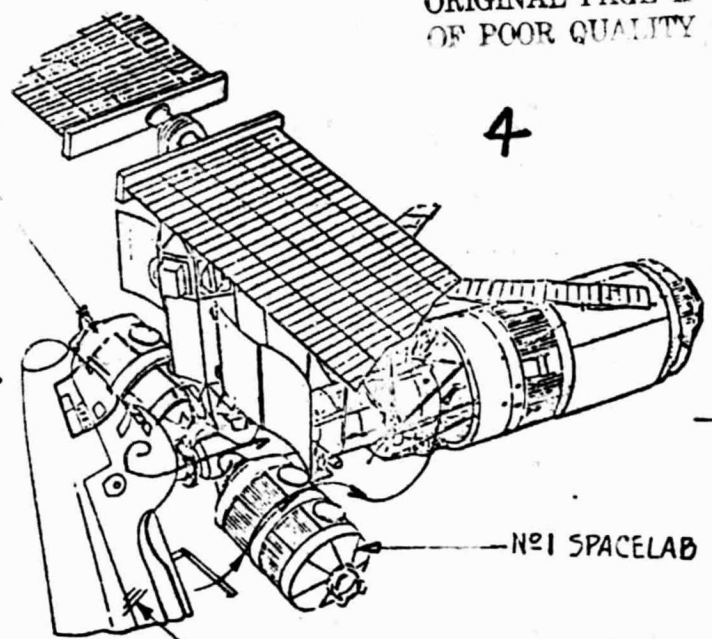


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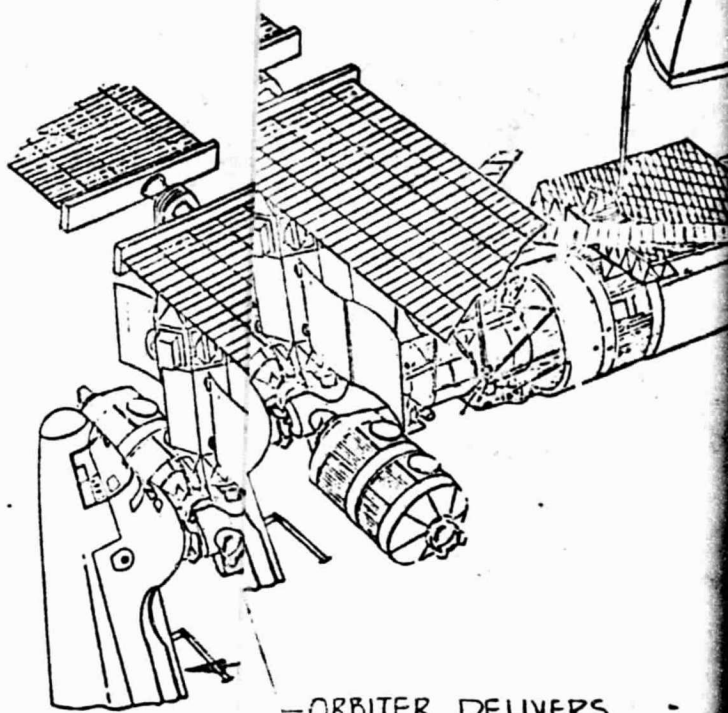
4



NO.1 SPACELAB

ORBITER LOGISTICS FLIGHT
 • CARGO UNLOADED FROM CARGO BAY
 & CREW COMPARTMENT & TRANSFERRED
 INTO SKYLAB - (___ DAY SUPPLY)

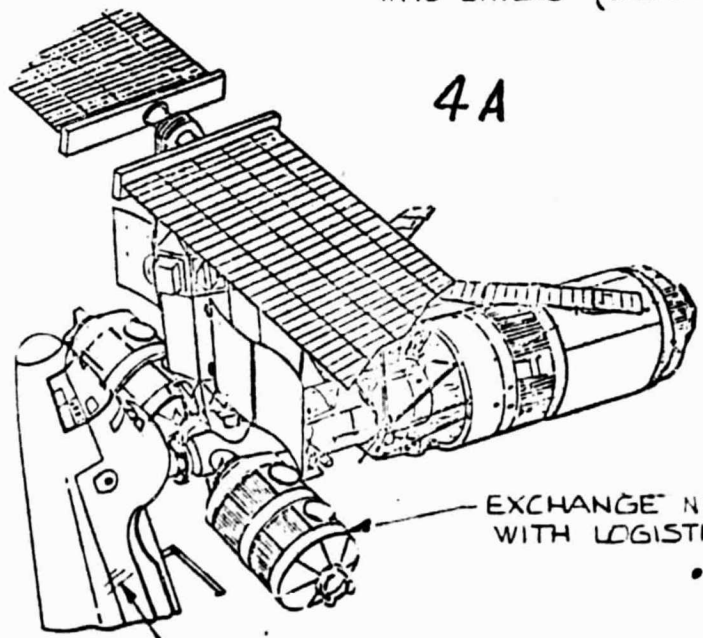
LOGISTICS MODULE



ORBITER DELIVERS LARGE SPACE STRUCTURES

ORBITER RETURNS
 ORBITER WITH N (OR) WITH ORBITER ELAB EI

4A



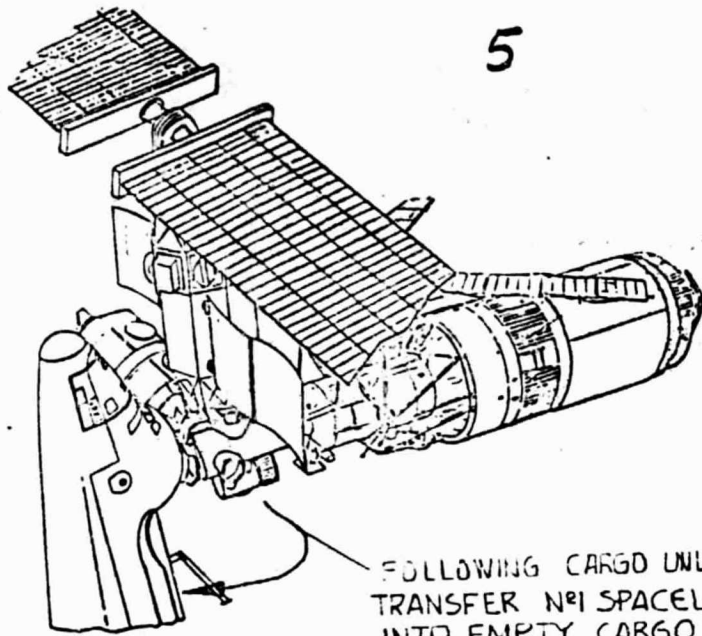
EXCHANGE NO.1 SPACELAB WITH LOGISTICS MODULE

ORBITER DELIVERS LOGISTICS MODULE
 (___ DAYS SUPPLY)

• MODULE EXCHANGE ACCOMPLISHED WITH ONE OF FOLLOWING METHODS:

- Z RMS
- PARKING PORT
- TELEOPERATOR (REMOVAL)
- STACK LOG. MOD. IN R RELOCATE LATER W/
- SIZE MODULES TO ALL (SEE SKETCH)

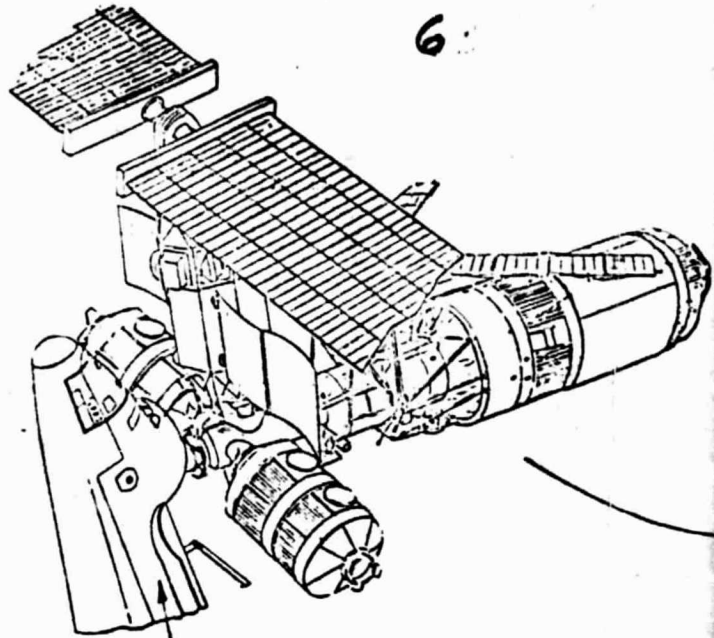
MSFC Baseline Reference Case



5

FOLLOWING CARGO UNLOADING -
TRANSFER N°1 SPACELAB
INTO EMPTY CARGO BAY

ORBITER RETURNS
WITH N°1 SPACELAB
OR
ORBITER RETURNS
EMPTY



6

ORBITER DELIVERS
CARGO & CONSTRUCTION
FACILITY & TOOLING

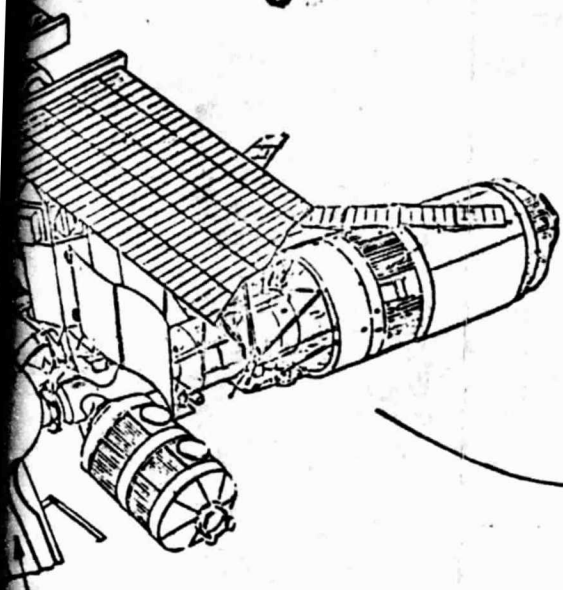
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EXCHANGE
METHOD WITH ONE OF
METHODS:

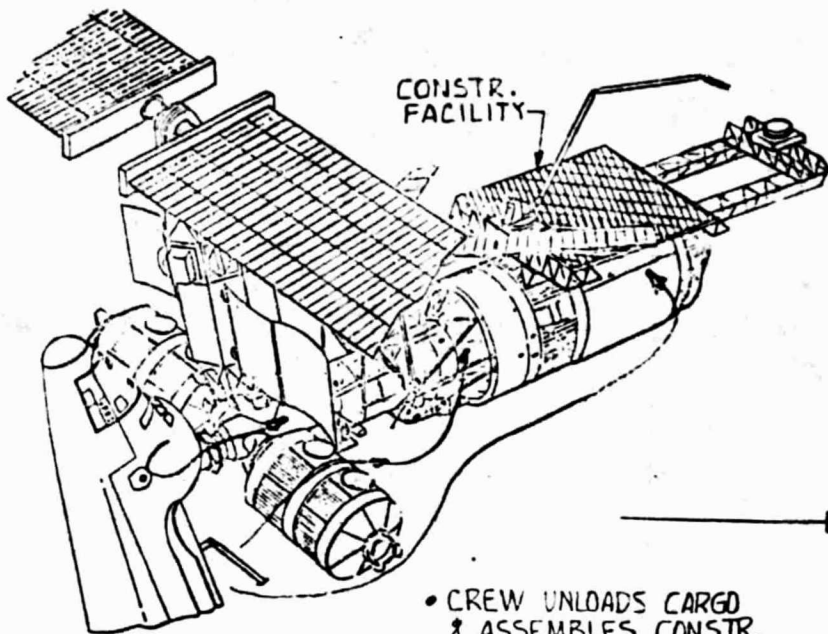
RMS
PORT
OPERATOR (REMOVE BERTHED MODULE & WAIT)
LOAD MOD. ON REMAINING SPACELAB &
LOCATE LATER W/RMS (SEE SKETCH)
MODULES TO ALLOW 2 IN ORBITER BAY
(SEE SKETCH)

6



ORBITER DELIVERS
CARGO & CONSTRUCTION
FACILITY & TOOLING

6A



CONSTR.
FACILITY

CREW UNLOADS CARGO
& ASSEMBLES CONSTR.
FACILITY

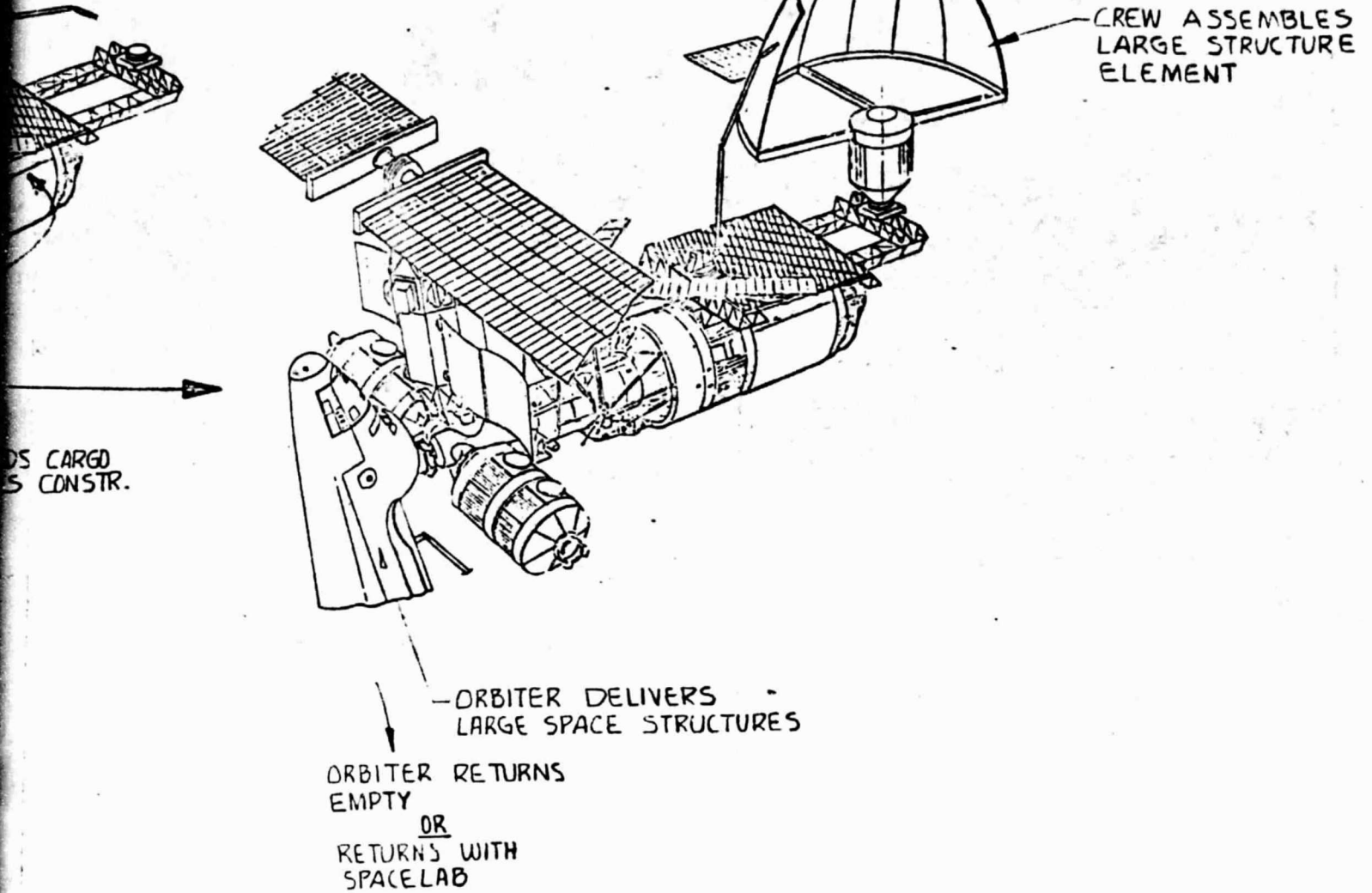
ORBITER RETURNS
EMPTY
OR
RETURNS WITH
SPACE LAB

9 FOLLOUT ETC

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Figure 2.

6B



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Figure 2.4.3-1. IISFC Baseline Reference Case I - Skylab Reactivation Option

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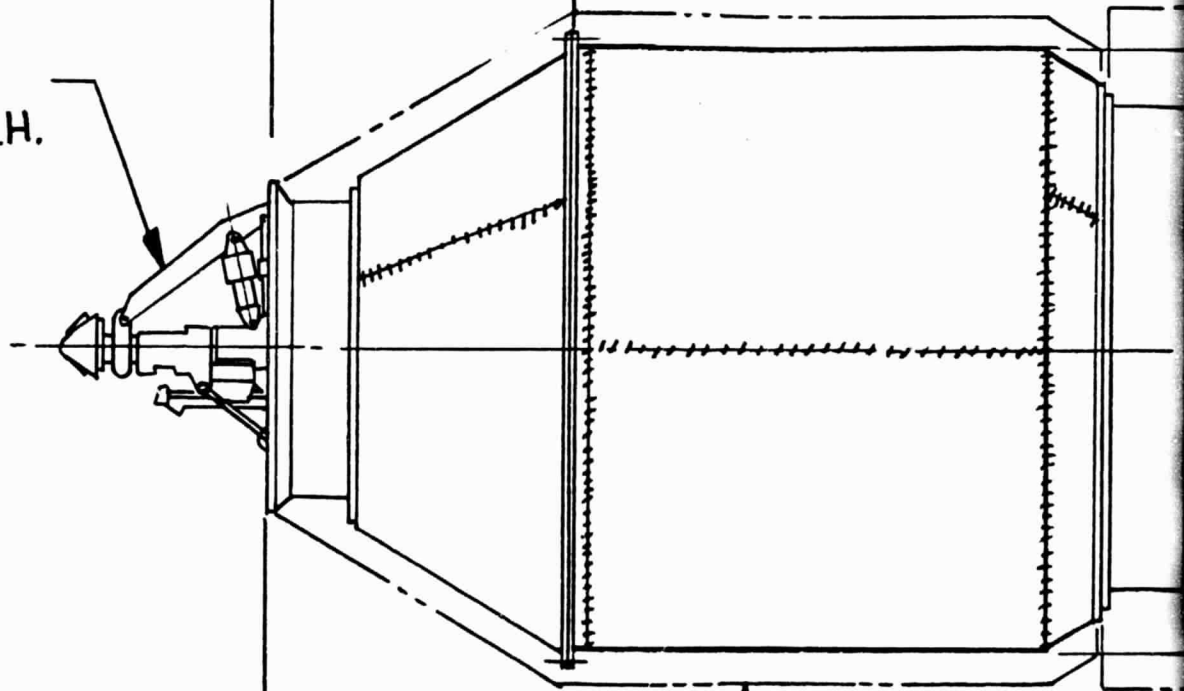
I.M. SKYLAB INTERFACE
SECTION

0.838 M
(33.0)
(REF.)

IM. ORBITER INTERFACE
SECTION

1.87 M
(74.0)
(REF.)

APOLLO TYPE
DOCKING MECH.
(REF)



INSULATION

SKYLAB
INTERFACE

2.71 M
(107.0)

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PRECEDING PAGE BLANK NOT FILMED

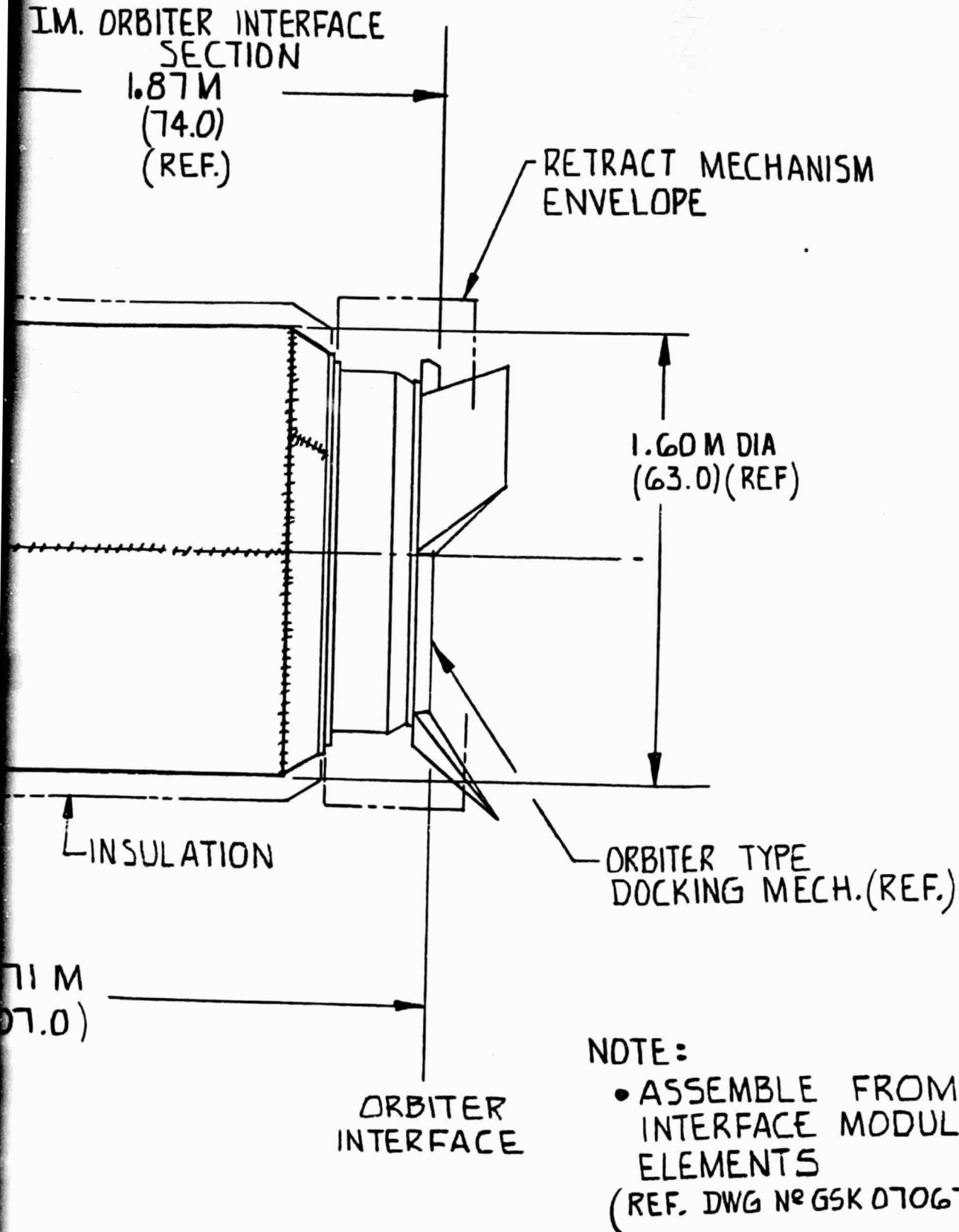


Figure 2.4.3-2. Skylab Reuse Docking Adapter

DA/MDA interface. The Orbiter with the DA is undocked, the DA is stowed in the Orbiter bay, and return to earth completes the first visit mission.

After return to earth, the DA is disassembled at the bolted joint and reassembled with a center section to make up the IFM, Figure 2.4.3-3. The IFM is outfitted and provisioned to fully meet the requirements for IOC of Phases III and IV. On the second visit to Skylab, Orbiter delivers the IFM which is docked to the MDA by the Teleoperator. The Teleoperator is returned to the Orbiter bay and stowed. The Orbiter then docks to the IFM.

Refurb Kits-B and -C are delivered on the second visit to Skylab. Following Orbiter docking and Skylab reactivation, the crew accomplishes the tasks required by these kits. The crew folds back the two ATM solar array panels that extend over the IFM, thus providing the necessary clearance for docking the 25 kW Power Module. At the completion of these tasks, Phase II operations have been completed and Skylab is fully operational.

Figure 2.4.3-4 is the Master Phasing Chart for Case I Skylab reactivation option. Table 2.4.3-1 is the funding summary for Case I showing costs by item, by program phase and by year.

Case I - Baseline Reference (Alternate First Visit)

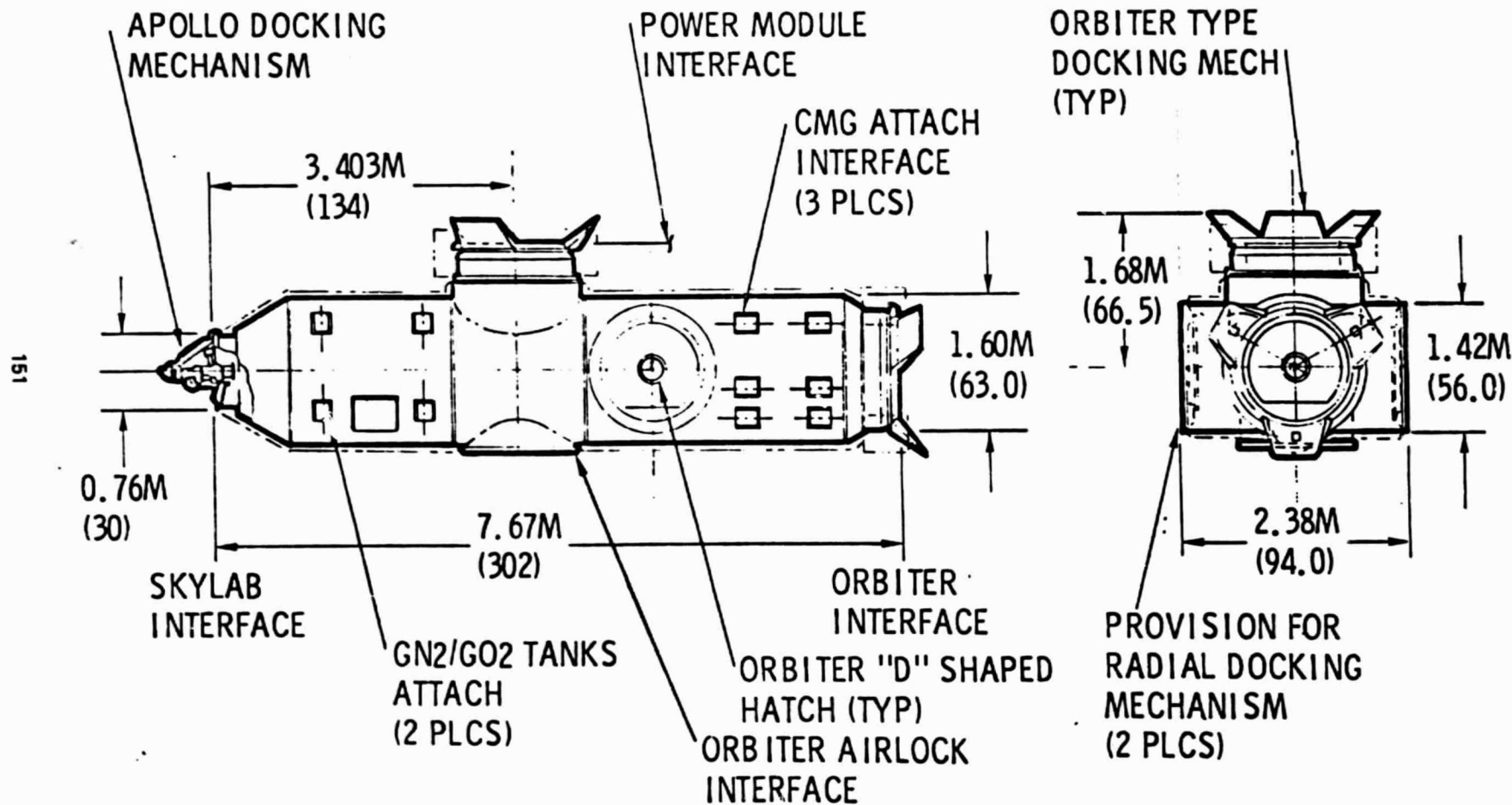
The Case I refurbishment option for Skylab used a DA made from the forward and aft sections of the IFM. This assembly was returned at the completion of the first visit and reassembled into the IFM flown-up on the second visit. An attractive alternate to this scheme is the plan depicted in Figure 2.4.3-5. Here, a simple structural coupling as a Docking Adapter, Figure 2.4.3-6, is shuttled to Skylab for the first visit docking. After the activities for the first mission are completed, Orbiter returns without the DA. In this alternate approach to the reuse build-up, the DA is relocated by Teleoperator to the MDA radial docking port. This would become the permanent location for the DA which would be used as a parking station for various modules; e.g., a docking location for a Logistics Module as discussed in Section 2.4.5, Operations and Logistics Plan.

With the fly-up of the IFM for the second visit to Skylab, the remainder of Case I refurbishment plan is identical to the MSFC Baseline previously discussed.

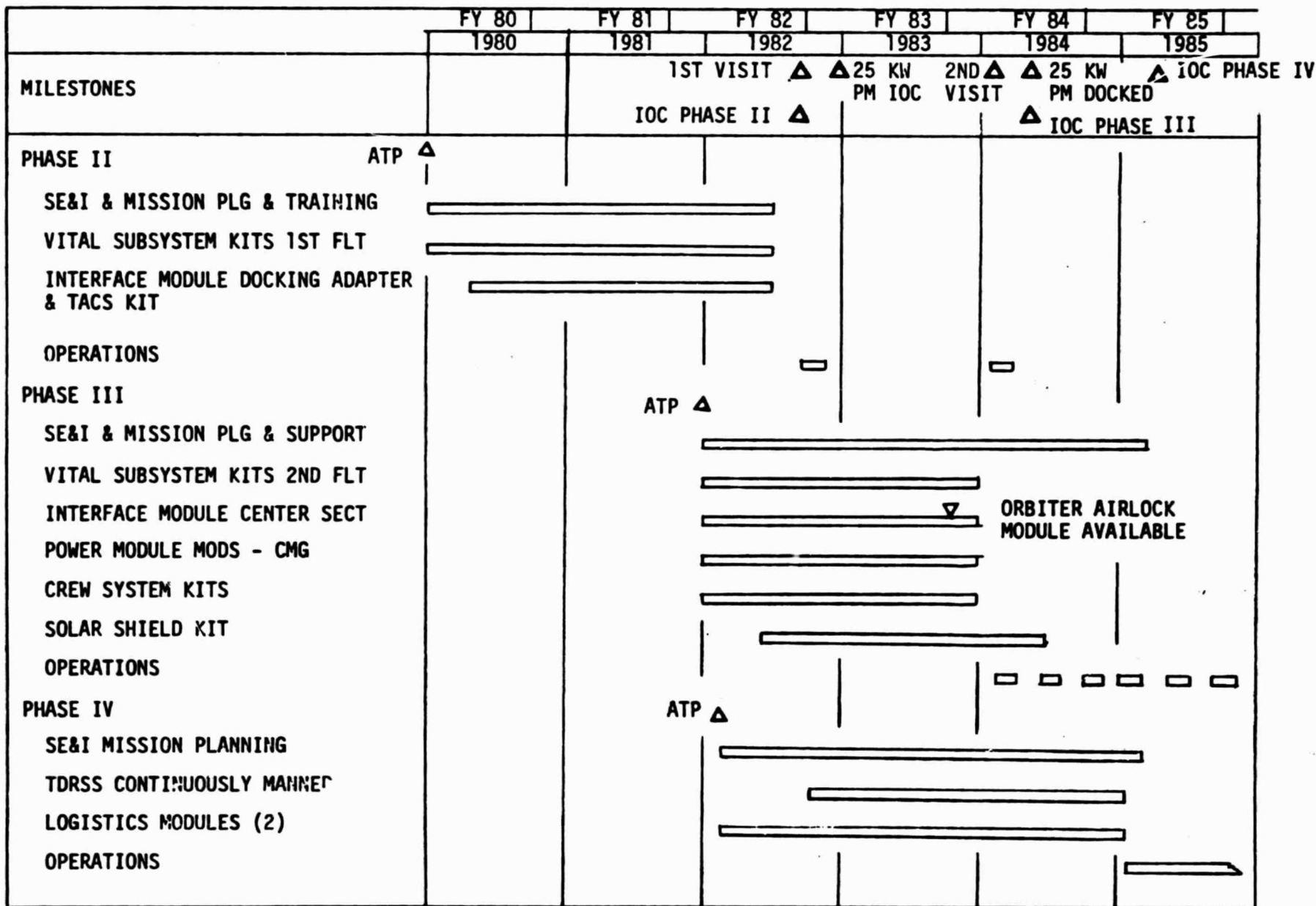
Figure 2.4.3-3

41531

INTERFACE MODULE CONFIGURATION



CASE I - MASTER PHASING CHART



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Figure 2.4.3-4. Case I - MSFC Baseline Reference Skylab Reactivation Option

Table 2.4.3-1 SKYLAB REUSE PROGRAM - CASE I

FUNDING SUMMARY (REAL YEAR DOLLARS IN MILLIONS)

	FY-80	FY-81	FY-82	FY-83	FY-84	FY-85	TOTAL
<u>PHASE II</u>							
SE&I, MISSION PLG. & TRAINING	1.8	3.8	2.0	-	-	-	7.6
VITAL SUBSYSTEM KITS, 1ST FLT.	0.7	2.8	0.7	-	-	-	4.2
INTERFACE MODULE DOCKING ADAPTER	0.2	2.0	0.6	-	-	-	2.8
OPERATIONS - LOGISTICS	-	-	0.8	-	-	-	0.8
SUBTOTAL, PHASE II	2.7	8.6	4.1	-	-	-	15.4
<u>PHASE III</u>							
SE&I, MISSION PLG. & SUPPORT	-	-	2.0	4.3	2.8	0.5	9.6
VITAL SUBSYSTEM KITS, 2ND FLT.	-	-	2.5	6.6	0.2	-	9.3
INTERFACE MODULE CENTER SECTION	-	-	2.7	7.3	0.2	-	10.2
POWER MODULE MODS. - CMG	-	-	0.4	2.1	0.1	-	2.6
CREW SYSTEM KITS	-	-	0.3	0.7	0.1	-	1.1
SOLAR SHIELD	-	-	0.1	0.9	0.4	-	1.4
OPERATIONS - LOGISTICS	-	-	-	0.9	1.7	1.8	4.4
MISSION & OPS SUPPORT	-	-	-	-	-	1.1	1.1
SUBTOTAL, PHASE III	-	-	8.0	22.8	5.5	3.4	39.7
<u>PHASE IV</u>							
SE&I & MISSION PLANNING	-	-	0.2	0.3	1.8	3.0	5.3
TDRSS CONTINUOUSLY MANNED	-	-	-	4.3	7.0	0.2	11.5
LOGISTICS MODULES (2)	-	-	3.9	12.5	6.7	0.3	23.4
OPERATIONS - LOGISTICS	-	-	-	-	5.1	5.4	10.5
MISSION & OPS SUPPORT	-	-	-	-	-	3.2	3.2
SUBTOTAL, PHASE IV	-	-	4.1	17.1	20.6	12.1	53.9
TOTAL CASE I	2.7	8.6	16.2	39.9	26.1	15.5	109.0

The Master Phasing Schedule for Case I would be unchanged.

Case II - Lower Risk Reuse Option

Some degree of risk is associated with revisiting Skylab and not replacing CMG's at the earliest opportunity. This situation may apply to the thermal shield, as well. It is prudent, therefore, to develop a refurbishment option for programmatic analyses and comparison to the Baseline Reference, Case I that would eliminate these risks. The early funding level for this case is somewhat higher than the level for Case I; however, the major program milestones and phasing remains the same.

Figure 2.4.3-7 depicts the Case II plan for the first and second visits to Skylab during Phase II inspection and refurbishment. Following the second Orbiter flight, the Skylab and power module will be docked together in mid 1984. The first visit by Orbiter will shuttle the Interface Module, and refurb Kits-A and -B to Skylab. Kit-A is identical to Kit-A for Case I previously discussed. Kit-B provides the solar shield and CMGs. The Teleoperator is used to dock the IFM including the CMG package to Skylab. After docking the IFM, Teleoperator is returned to the Orbiter bay for stowage. External inspection and photo coverage of Skylab will be conducted and Skylab will be activated. Following activation, internal inspection and the tasks associated with refurb Kit-A will be accomplished.

At some period during the first visit to Skylab, a crew of two will go EVA to install the thermal shield. This task has been approximated to require two crewmen eight hours to accomplish. The task will be timed during Phase B study.

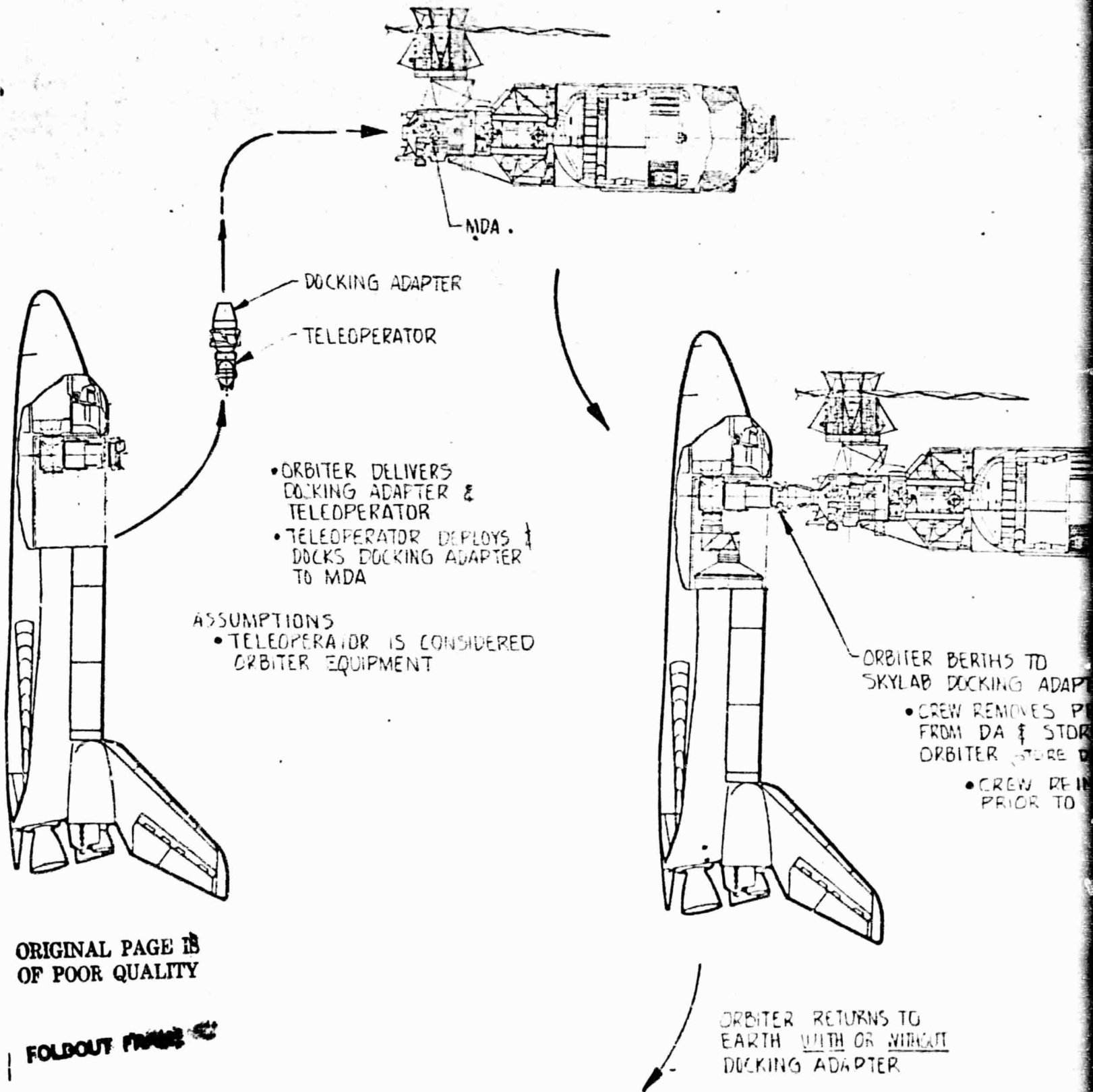
After completion of all first visit activities, Skylab will be placed in the unmanned mode and the crew will return to earth. The Orbiter will be launched for a second visit to shuttle refurb Kit-C to Skylab. As in Case I, with the completion of activities required by Kit-C and tasks shown for the second visit, Skylab will be operational for Phase III/IV reuse.

Case II Master Phasing is shown in Figure 2.4.3-8. Case II funding summary is shown in Table 2.4.3-1.

Case III - Higher Risk Reuse Option

This approach as a reactivation option for Skylab assumes that ground inter-

FIRST VISIT



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ORBITER DELIVERS
INTERFACE MODULE

CREW INSTALLS PROBE FROM
DA (EVA OPERATION)
DOCKING ADAPTER

TELEOPERATOR DISPATCHED
TO RELOCATE DOCKING ADAPTER

TELEOPERATOR REMOVES
DA FROM MDA & RELOCATES
AS SHOWN

MOVES TO
DOCKING ADAPTER
MOVES PROBE & DROGUE
& STORES IN
(STORE DROGUE IN MDA)

CREW REINSTALLS PROBE & DROGUE
PRIOR TO DEPARTURE

OR

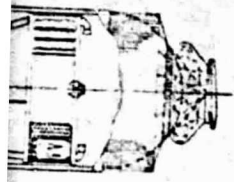
- ORBITER RETURNS TO EARTH WITHOUT DA.
- DA RELOCATED BY TELEOPERATOR PRIOR TO ORBITER DEPARTURE.

2 FOLDOUT FRAME

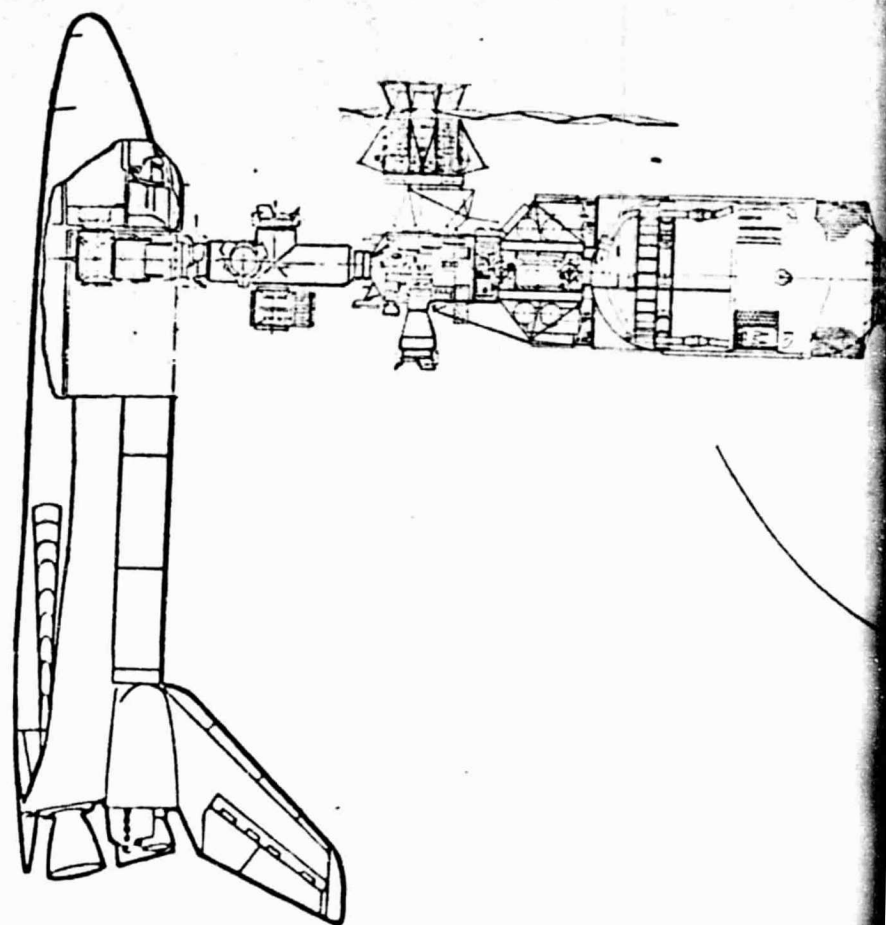
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SECOND VISIT

TELEOP
P.M. F
& DOCK



ORBITER BERTHS
INTERFACE MODULE



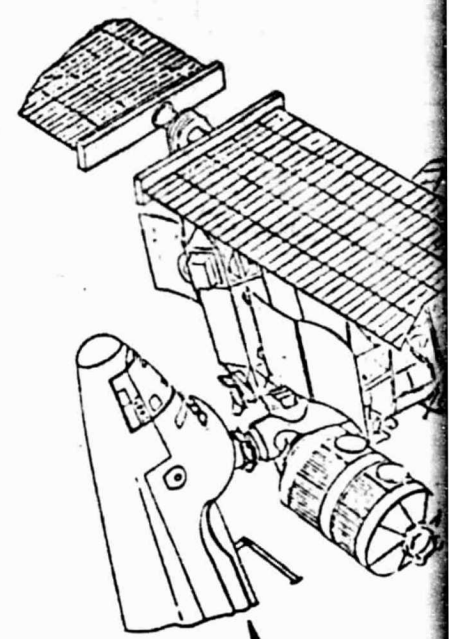
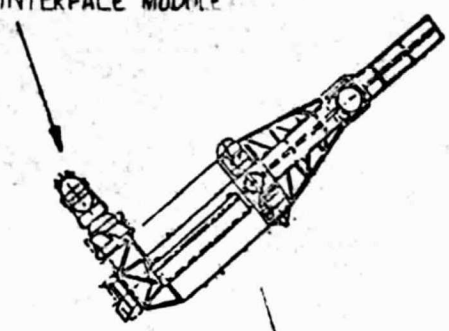
OR
ORBITER RETURNS
TO EARTH

TELEOPERATOR DOCKS
DA TO BACKUP PORT
ON MDA
CREW REMOVES PROBE
VIA EVA & RETURNS IT
TO ORBITER OR INSTALLS
PROBE IN INTER-FACE MODULE,
ALSO EVA OPERATION

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OR
ORB
DEL
POW
/
/

TELEOPERATOR DELIVERS
P.M. FROM ON-ORBIT POSITION
& DOCKS WITH INTERFACE MODULE



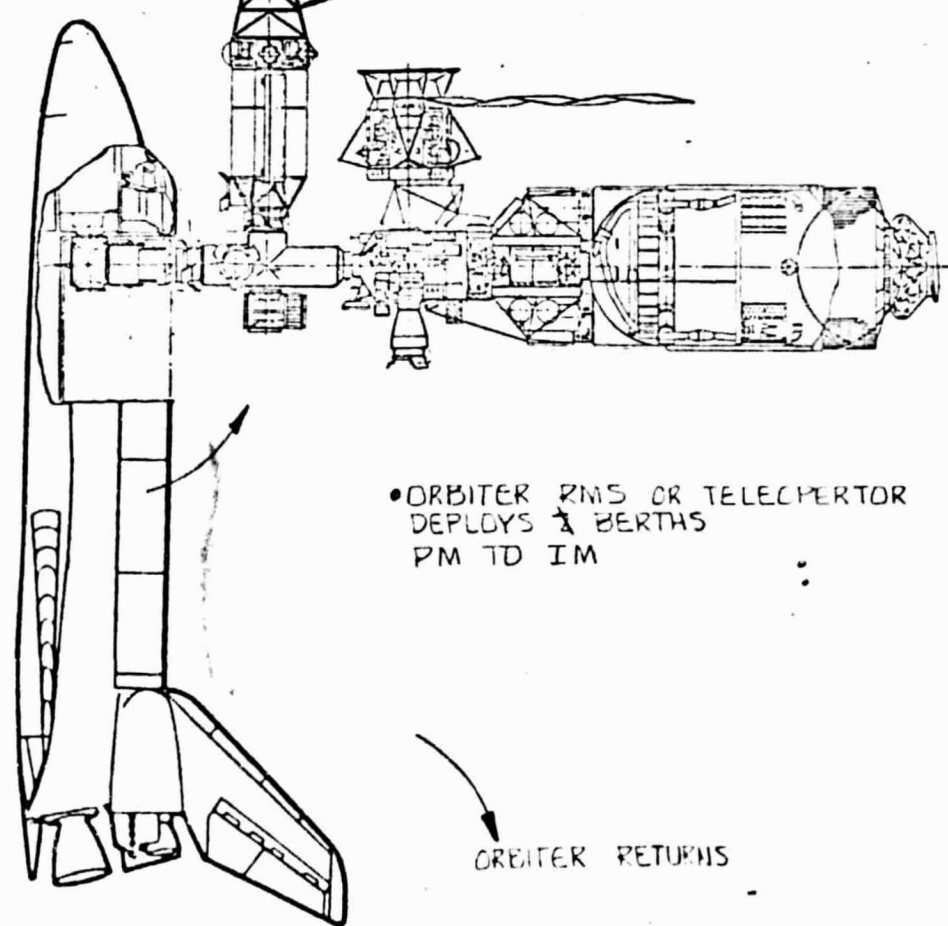
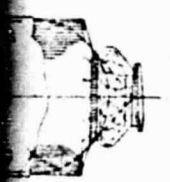
OR

POWER MODULE

ORBITER DELIVERS
SPACELAB #1

OR

ORBITER DELIVERS
LOGISTICS MODULE



• ORBITER RMS OR TELEOPERATOR
DEPLOYS & BERTHS
PM TO IM

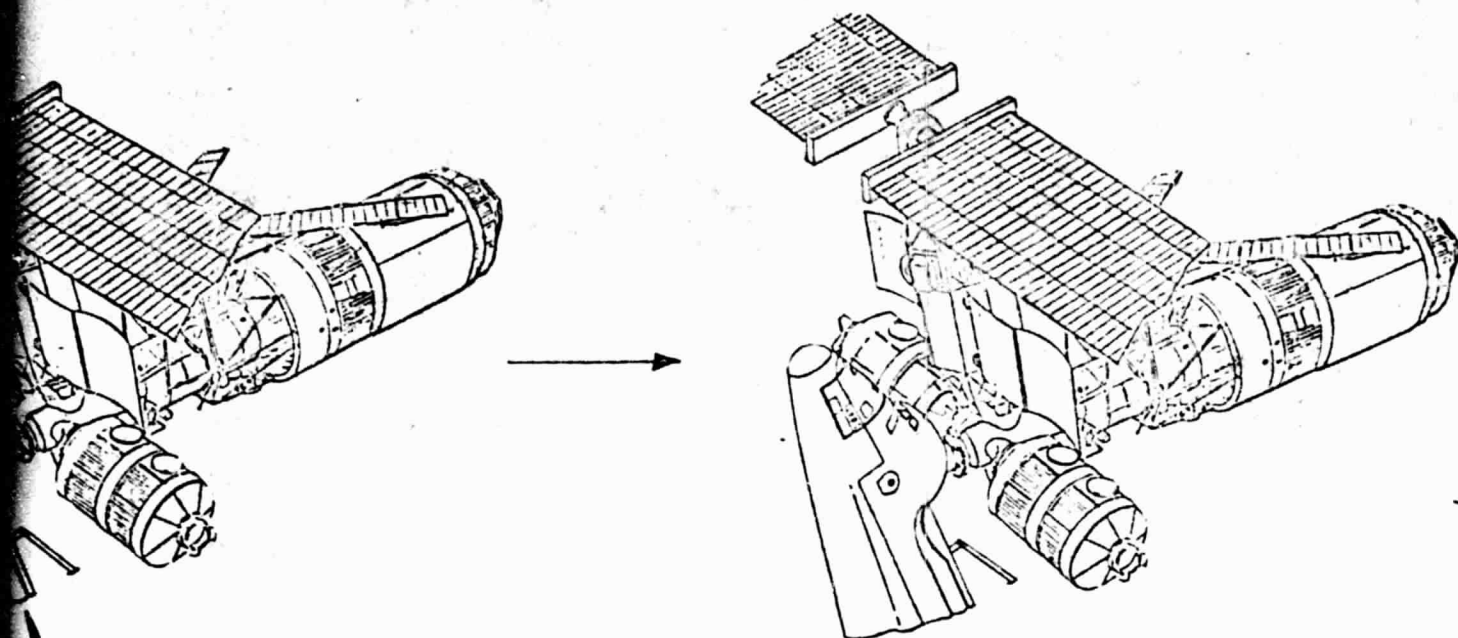
ORBITER RETURNS

ORBITER RETU

OR
ORBITER
DELIVERS
POWER MODULE

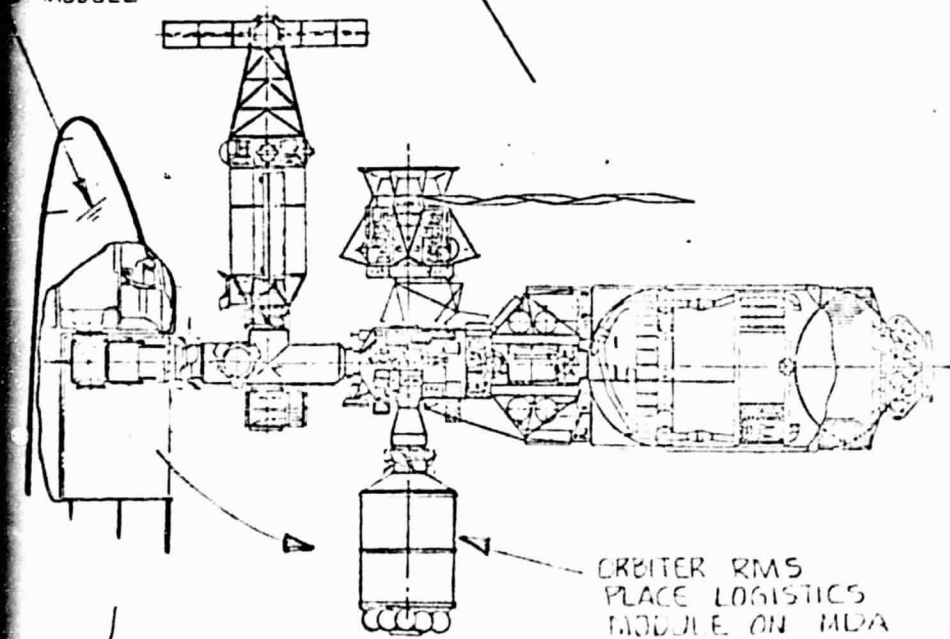
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ORBITER DELIVERS
SPACELAB #1
OR
DELIVERS
MODULE

ORBITER DELIVERS
SPACELAB #2

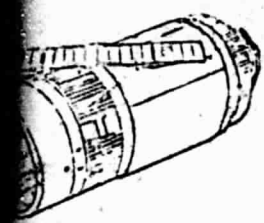


ORBITER RMS
PLACE LOGISTICS
MODULE ON MDA

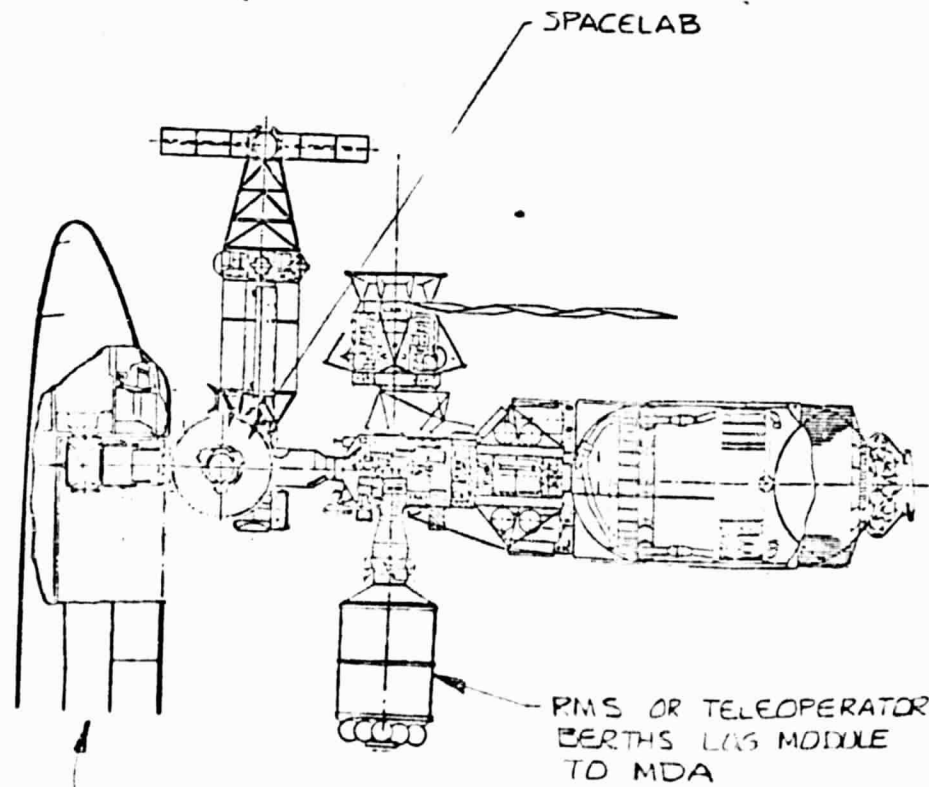
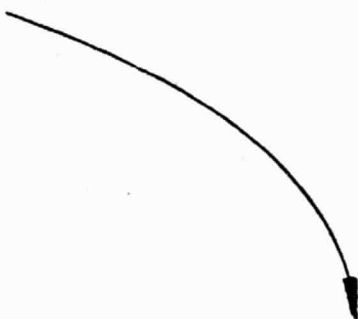
ORBITER RETURNS

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ORBITER DELIVERS LOGISTICS MODULE

RMS OR TELEOPERATOR BERTHS LOGS MODULE TO MDA

Figure 2.4.3-5. MSFC Baseline Reference Case I - (First Visit-Alternate)

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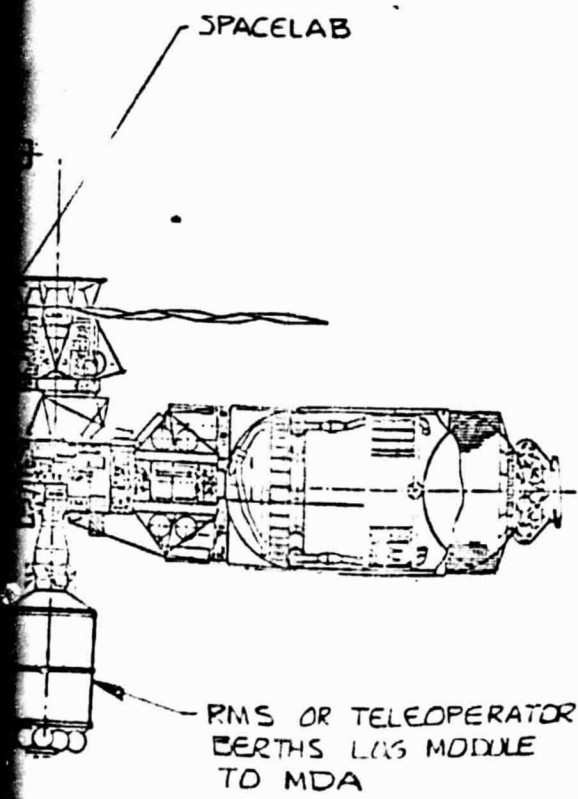


Figure 2.4.3-5. MSFC Baseline Reference Case I - Skylab Reactivation Option (First Visit-Alternate)

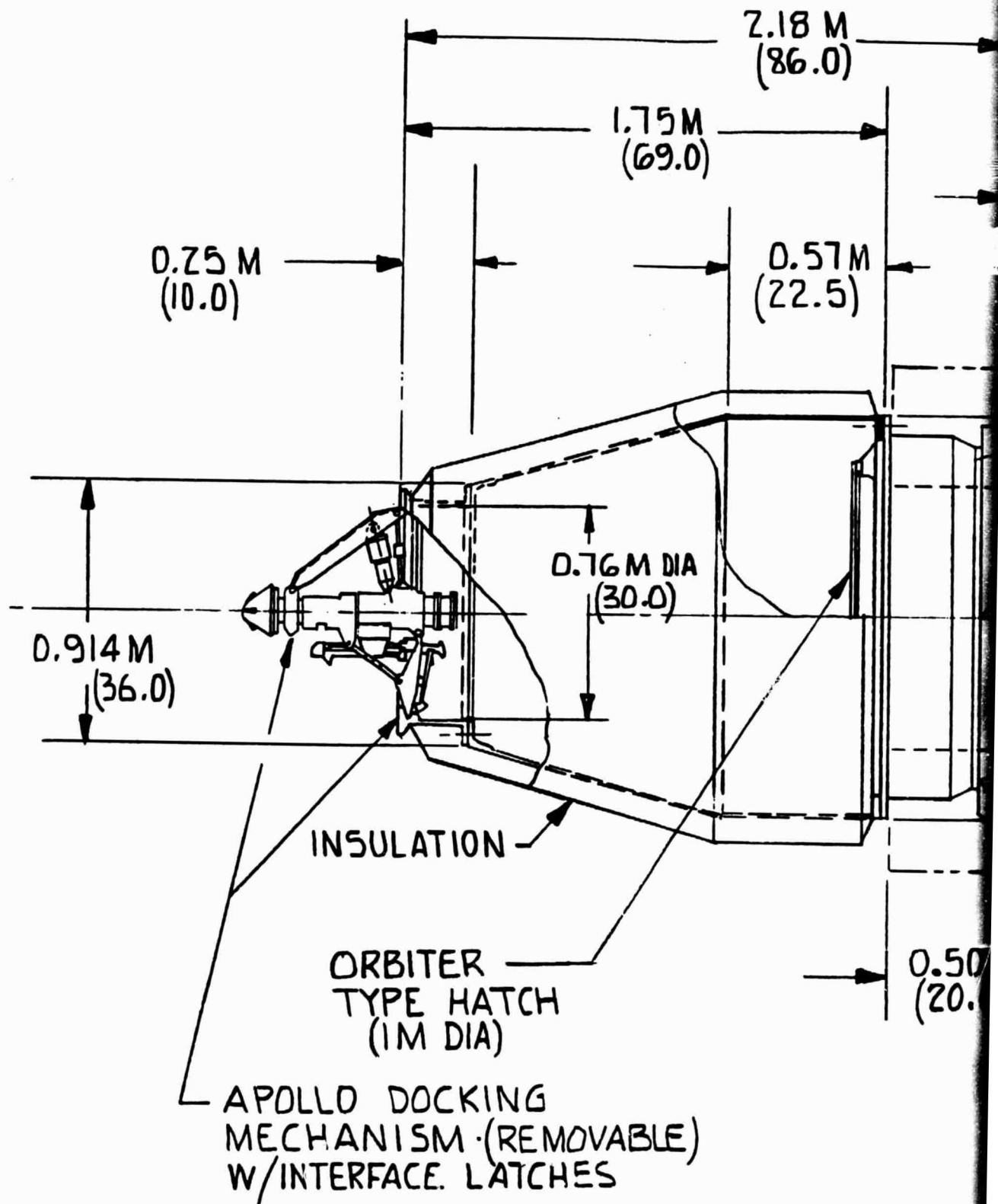
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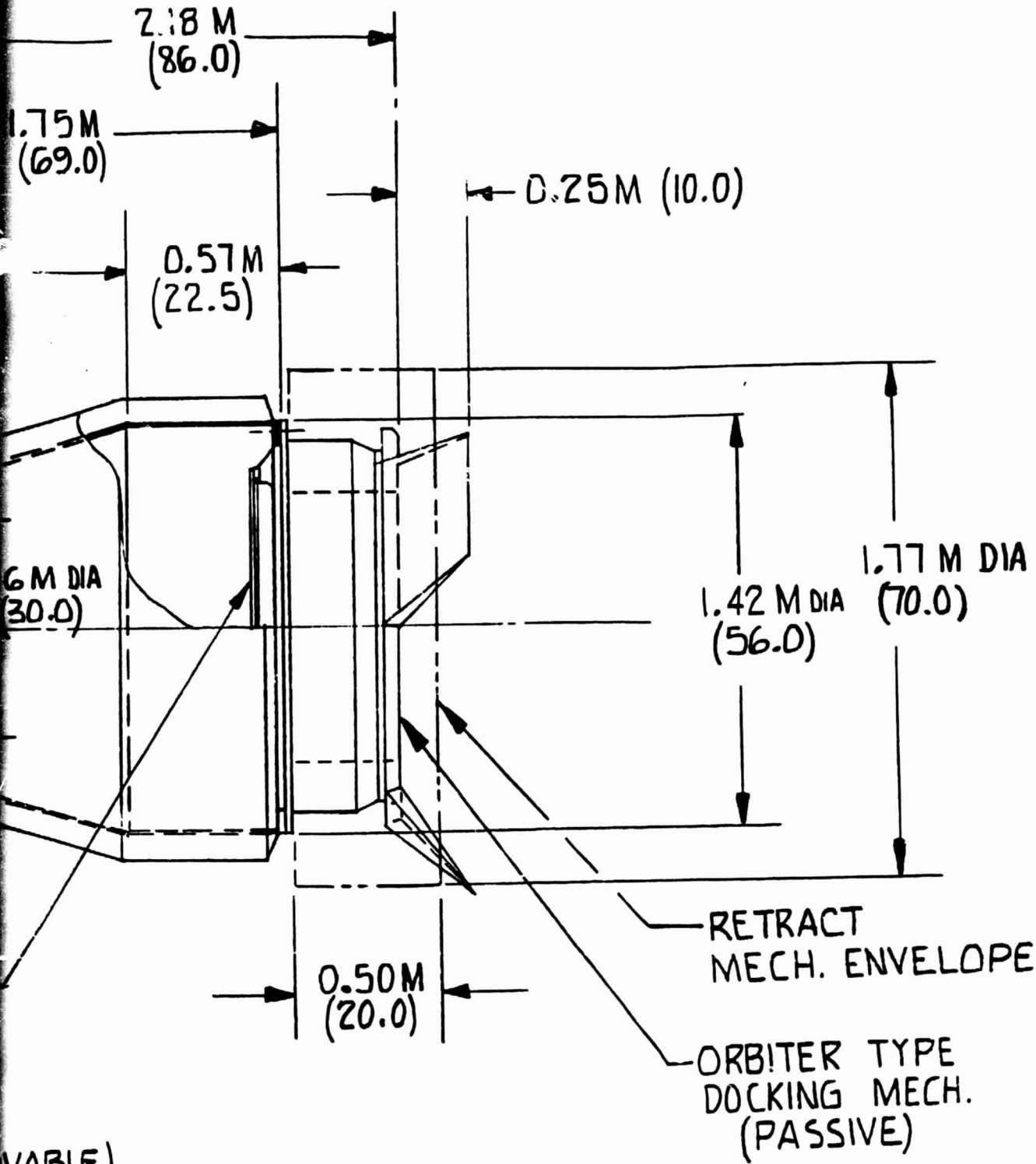
MDA
INTERFACE

ORBITER
INTER



1 EOLDOUTE ERONE

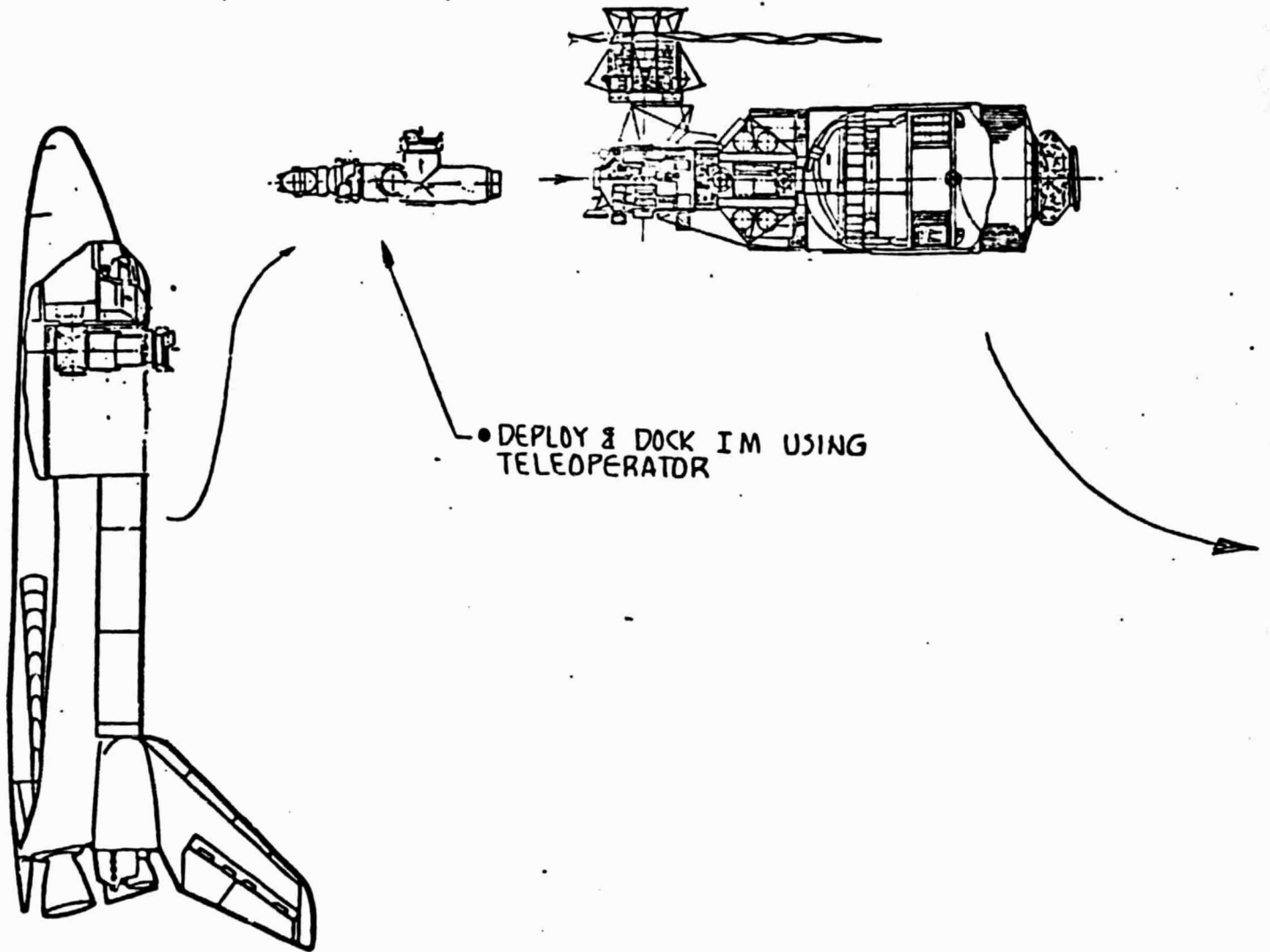
ORBITER PAYLOAD INTERFACE



(VARIABLE)
ES

Figure 2.4.3-6. Skylab Reuse Docking Adapter

FIRST VISIT

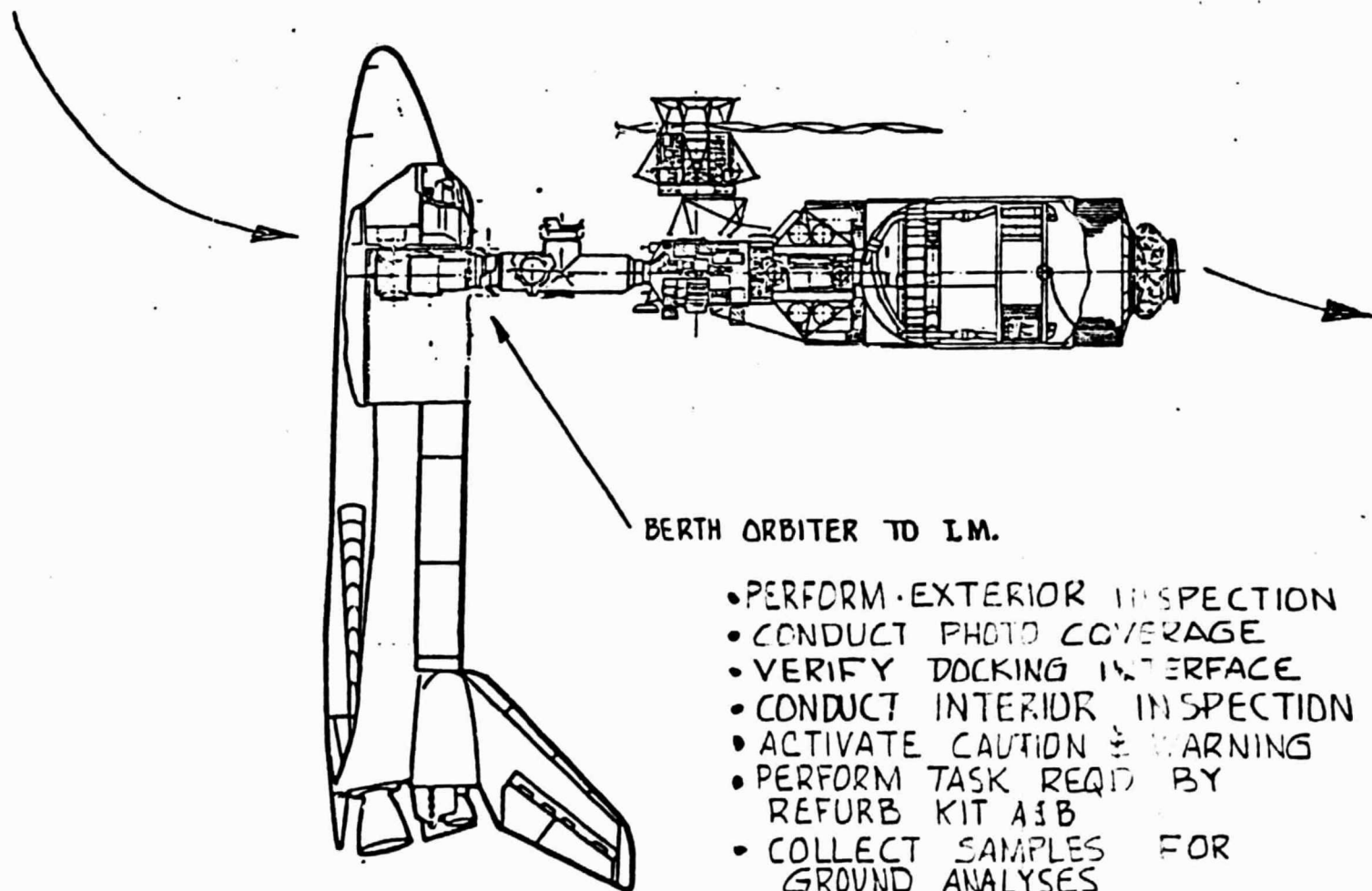
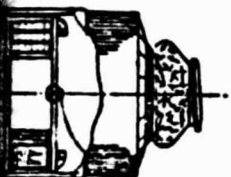


• DEPLOY & DOCK IM USING TELEOPERATOR

ORBITER DELIVERS LIMITED CAPABILITY
INTERFACE MODULE & REFURB
KITS A & B

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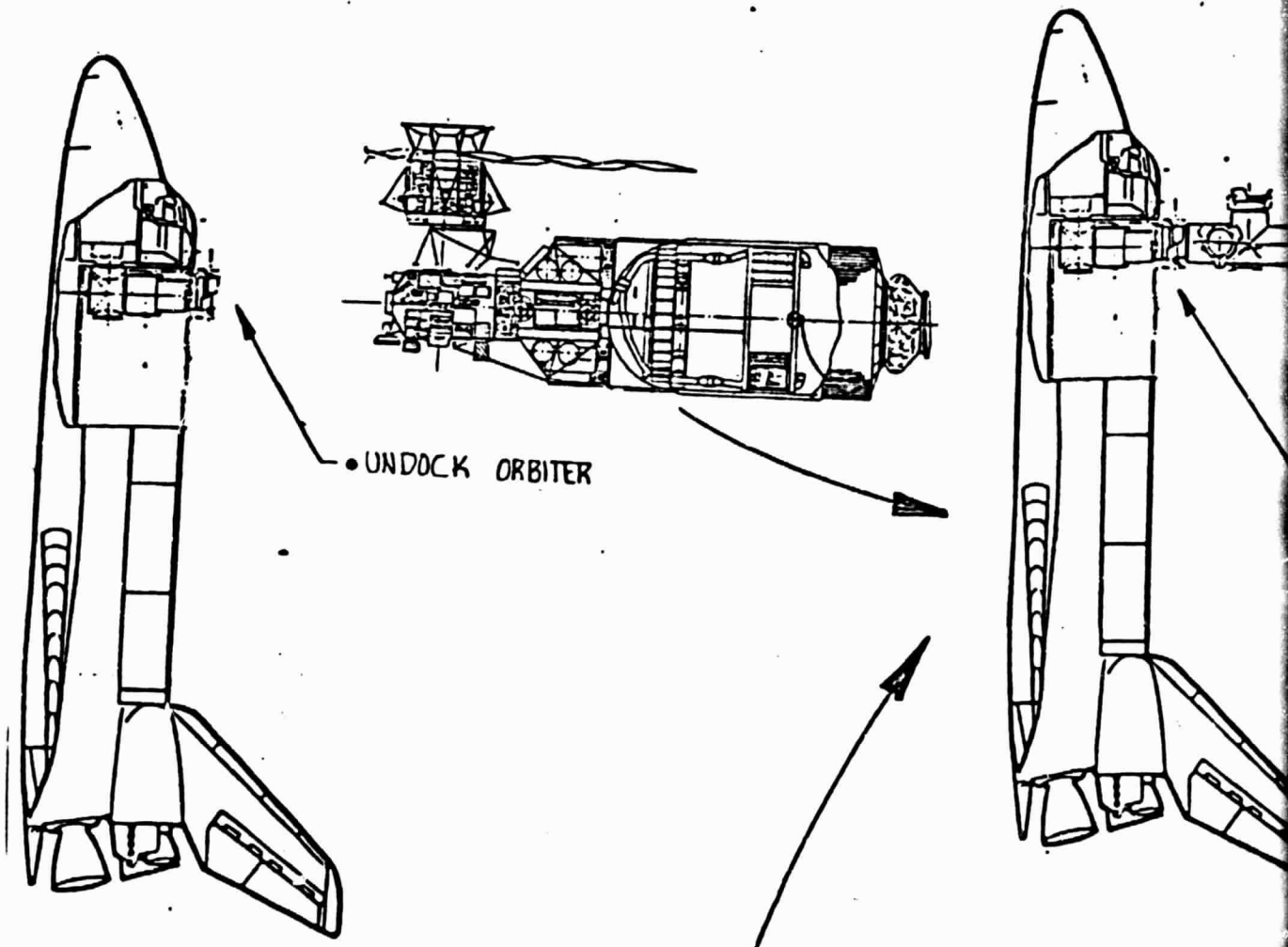
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BERTH ORBITER TO I.M.

- PERFORM EXTERIOR INSPECTION
- CONDUCT PHOTO COVERAGE
- VERIFY DOCKING INTERFACE
- CONDUCT INTERIOR INSPECTION
- ACTIVATE CAUTION & WARNING
- PERFORM TASK REQ'D BY REFURB KIT A3B
- COLLECT SAMPLES FOR GROUND ANALYSES
- RECONFIGURE ON-BOARD SYS. FOR IMPROVED INTERROGATION

INSPECTION
VERAGE
INTERFACE
INSPECTION
WARNING
BY
FOR
BOARD



• UNDOCK ORBITER

ORBITER DELIVERS
REFURB KIT

ORBITER RETURNS

Figure 2.4.3-7. Lower

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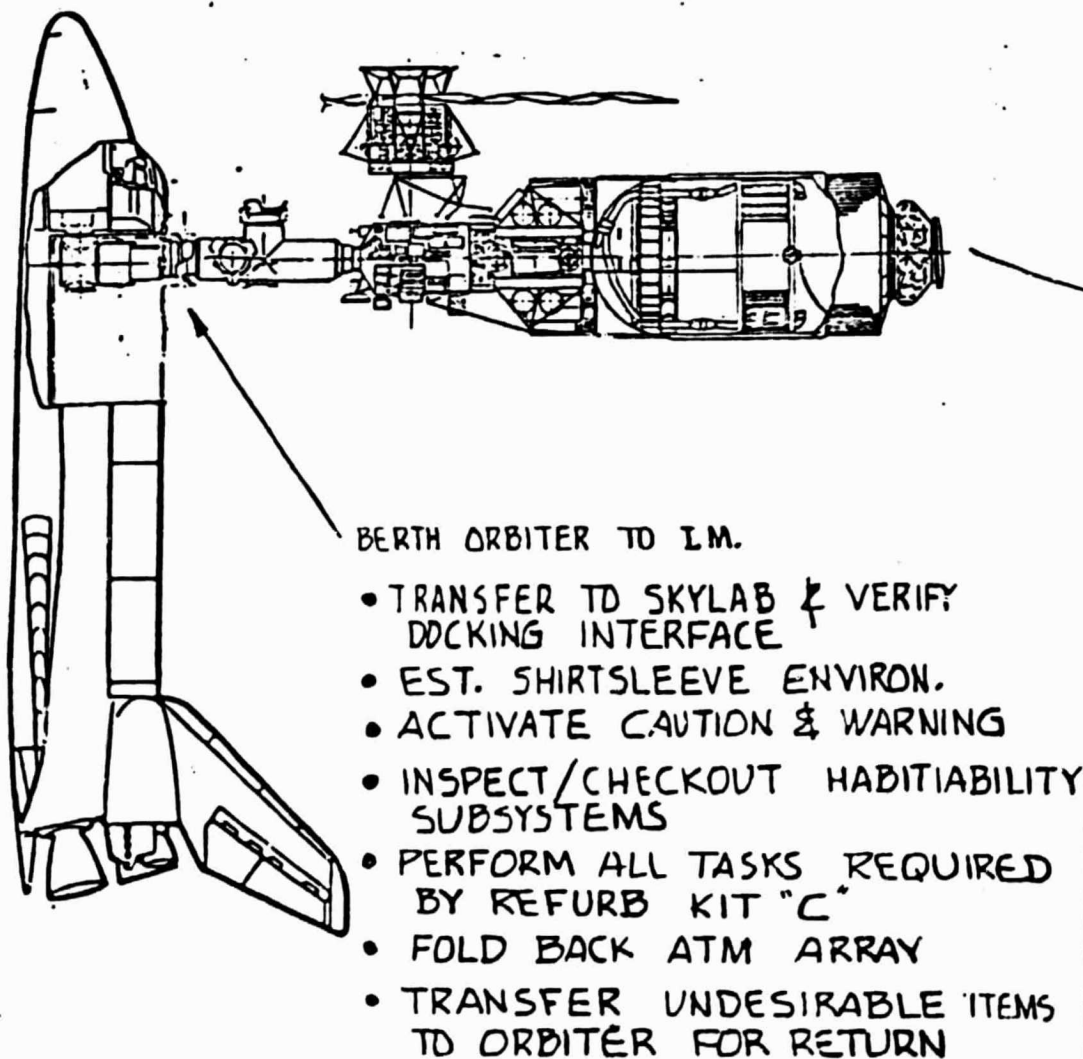
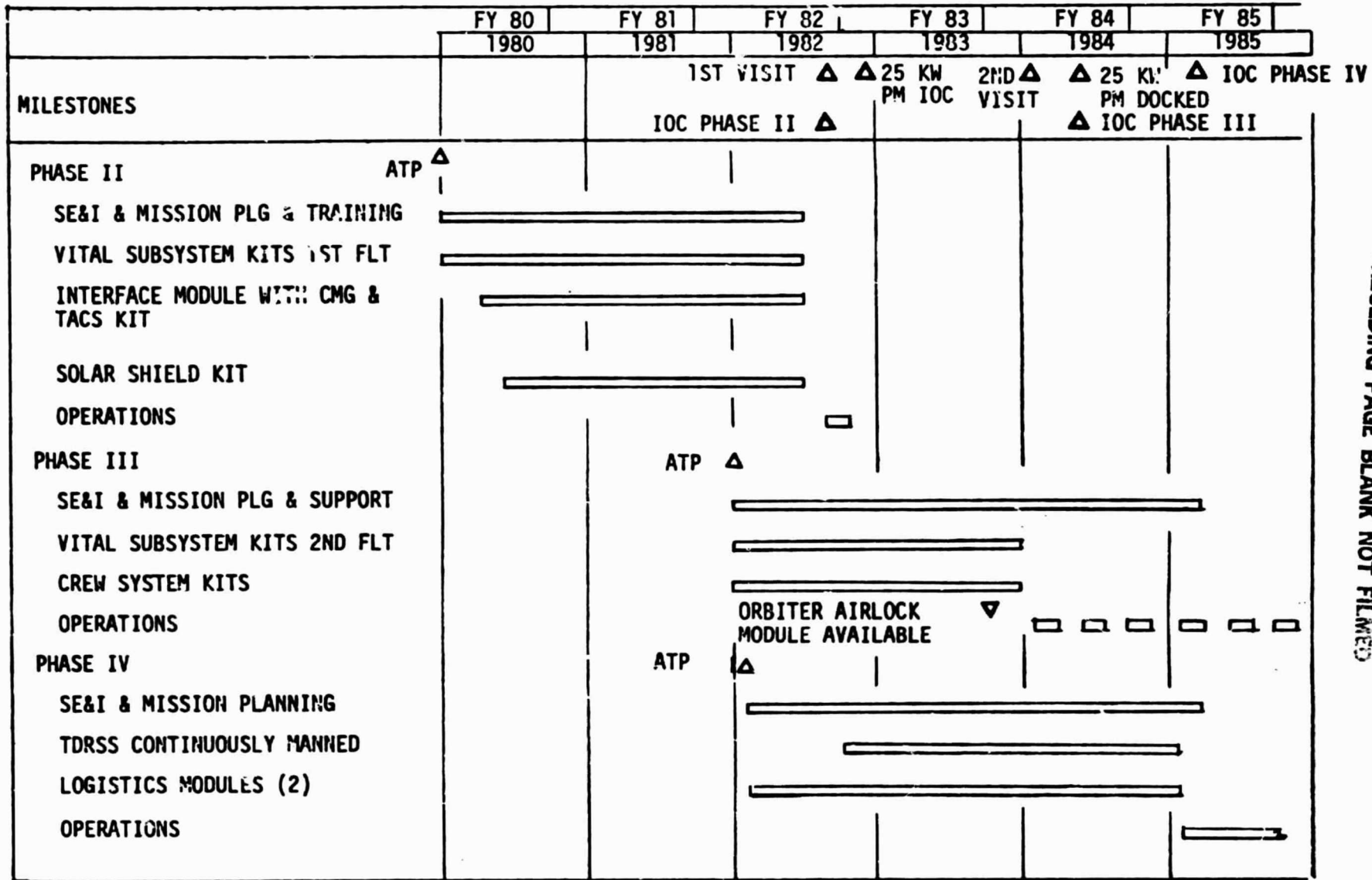


Figure 2.4.3-7. Lower Risk Study Option Case II Skylab Reactivation

CASE II - MASTER PHASING CHART



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Figure 2.4.3-8. Case II - Lower Risk Skylab Reactivation Option

FUNDING SUMMARY (REAL YEAR DOLLARS IN MILLIONS)

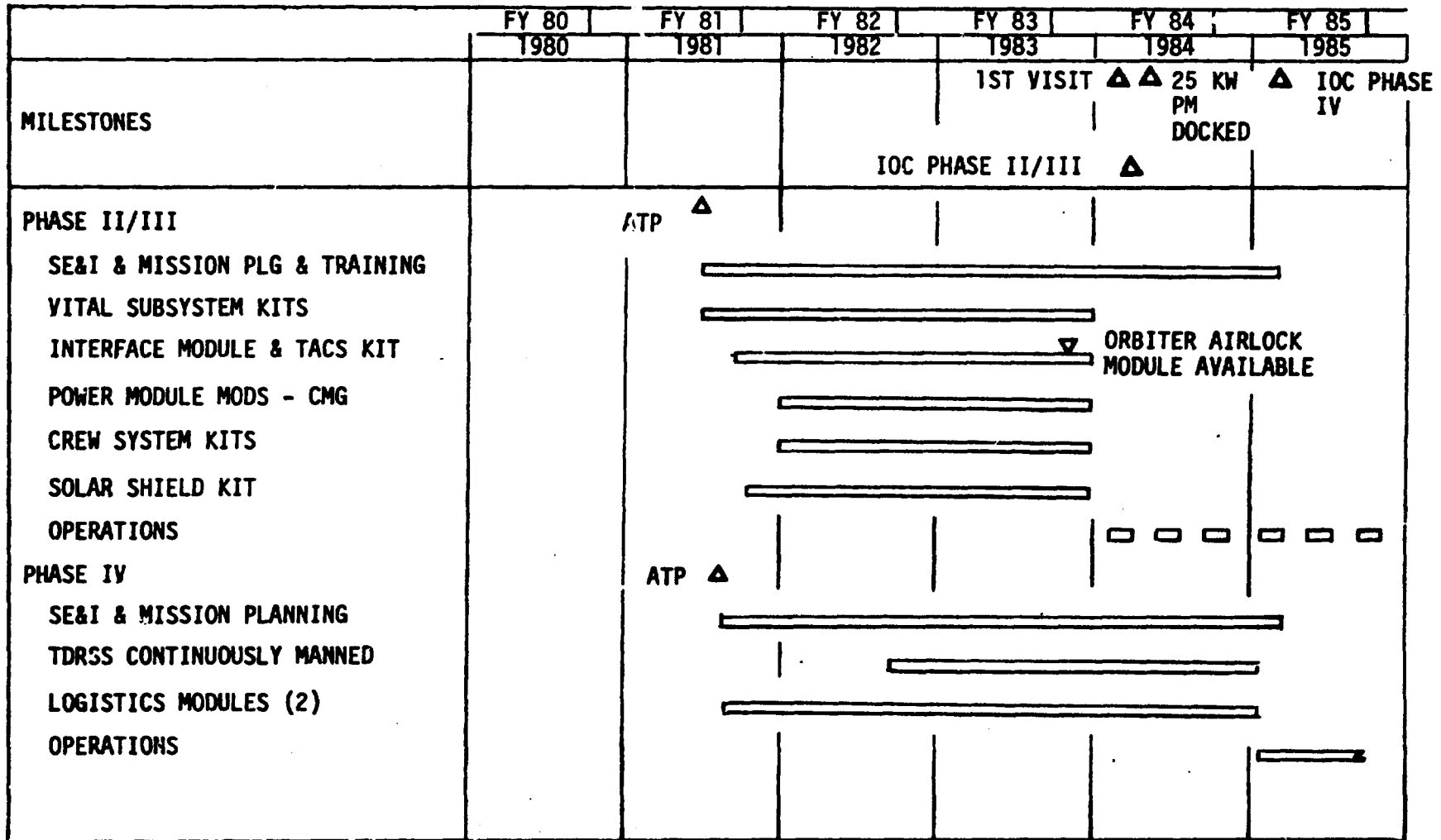
	FY-80	FY-81	FY-82	FY-83	FY-84	FY-85	TOTAL
<u>PHASE II</u>							
SE&I, MISSION PLG. & TRAINING	1.8	3.8	2.0	-	-	-	7.6
VITAL SUBSYSTEM KITS, 1ST FLT.	0.7	2.8	0.7	-	-	-	4.2
INTERFACE MODULE WITH CMG	0.8	10.0	3.5	-	-	-	14.3
SOLAR SHIELD	0.1	0.9	0.4	-	-	-	1.4
OPERATIONS - LOGISTICS	-	-	0.8	-	-	-	0.8
SUBTOTAL, PHASE II	<u>3.4</u>	<u>17.5</u>	<u>7.4</u>	<u>-</u>	<u>-</u>	<u>-</u>	<u>28.3</u>
<u>PHASE III</u>							
SE&I, MISSION PLG. & SUPPORT	-	-	2.0	4.3	2.8	0.5	9.6
VITAL SUBSYSTEM KITS, 2ND FLT.	-	-	2.5	6.6	0.2	-	9.3
CREW SYSTEM KITS	-	-	0.3	0.7	0.1	-	1.1
OPERATIONS - LOGISTICS	-	-	-	0.9	1.7	1.8	4.4
MISSION & OPS SUPPORT	-	-	-	-	-	1.1	1.1
SUBTOTAL, PHASE III	<u>-</u>	<u>-</u>	<u>4.8</u>	<u>12.5</u>	<u>4.8</u>	<u>3.4</u>	<u>25.5</u>
<u>PHASE IV</u>							
SE&I & MISSION PLANNING	-	-	0.2	0.3	1.8	3.0	5.3
TDRSS CONTINUOUSLY MANNED	-	-	-	4.3	7.0	0.2	11.5
LOGISTICS MODULES (2)	-	-	3.9	12.5	6.7	0.3	23.4
OPERATIONS - LOGISTICS	-	-	-	-	5.1	5.4	10.5
MISSION & OPS SUPPORT	-	-	-	-	-	3.2	3.2
SUBTOTAL, PHASE IV	<u>-</u>	<u>-</u>	<u>4.1</u>	<u>17.1</u>	<u>20.6</u>	<u>12.1</u>	<u>53.9</u>
TOTAL CASE II	<u>3.4</u>	<u>17.5</u>	<u>16.3</u>	<u>29.6</u>	<u>25.4</u>	<u>15.5</u>	<u>107.7</u>

rogation and engineering analyses fully identify the refurbishment requirements and that no inspection visit is needed. Further, to assume that no refurb will be required before 1984 and that total refurbishment/resupply to make Skylab fully operational can be accomplished on one visit, combine to yield the higher risk option, Case III. The cost of Skylab reactivation with the Case III plan is the lowest. Thus, the three cases examined provide the bounds for cost and schedule to reactivate Skylab. As such, they present sufficient data for the decision making process.

Case III reactivation option shuttles up refurb Kits-A, -B, and -C together with all new hardware required on one Orbiter flight. Following this mission, the Skylab will dock to the 25 kW power module in mid-1984. The tasks to be accomplished for Skylab reactivation are the same as the other cases and have all been identified in the cases previously discussed.

Figure 2.4.3-9 shows the master phasing for Case III, Skylab Reactivation Option. Table 2.4.3-2 shows the funding summary for Case III showing costs by item, by program phase and by year.

CASE III - MASTER PHASING CHART



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Figure 2.4.3-9. Case III - Higher Risk Skylab Reactivation Option

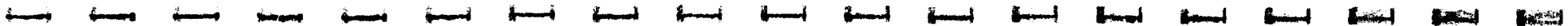


Table 2.4.3-2 SKYLAB REUSE PROGRAM CASE III

FUNDING SUMMARY (REAL YEAR DOLLARS IN MILLIONS)

	FY-80	FY-81	FY-82	FY-83	FY-84	FY-85	TOTAL
<u>PHASE II/III</u>							
SE&I & MISSION PLG. & TRAINING	-	0.2	3.8	5.6	2.1	0.5	12.2
VITAL SUBSYSTEM KITS	-	0.1	4.7	8.9	0.3	-	14.0
INTERFACE MODULE & TACS KIT	-	-	3.9	9.2	0.2	-	13.3
POWER MODULE MODS - CMG	-	-	0.4	2.1	0.1	-	2.6
CREW SYSTEM KITS	-	-	0.3	0.7	0.1	-	1.1
SOLAR SHIELD KIT	-	-	0.4	1.1	-	-	1.5
OPERATIONS - LOGISTICS	-	-	-	1.7	1.7	1.8	5.2
MISSION & OPS SUPPORT	-	-	-	-	-	1.1	1.1
SUBTOTAL, PHASE II/III	-	0.3	13.5	29.3	4.5	3.4	51.0
<u>PHASE IV</u>							
SE&I & MISSION PLANNING	-	-	0.2	0.3	1.8	3.0	5.3
TDRSS CONTINUOUSLY MANNED	-	-	-	4.3	7.0	0.2	11.5
LOGISTICS MODULES (2)	-	-	3.9	12.5	6.7	0.3	23.4
OPERATIONS - LOGISTICS	-	-	-	-	5.1	5.4	10.5
MISSION & OPS SUPPORT	-	-	-	-	-	3.2	3.2
SUBTOTAL, PHASE IV	-	0.3	4.1	17.1	20.6	12.1	53.9
TOTAL CASE III	-	0.3	17.6	46.4	25.1	15.5	104.9

2.4.4 Operations and Logistics Plan

The orbital operation of the Skylab is representative of manned space activities and support for any Shuttle-tended or continuously-manned space facility. In contrast to the initial Skylab operational procedure of prelaunch stowage of consumables and expendables, Skylab reuse missions will depend upon logistics resupply. Thus, the operations plans primary elements include: (1) initial/repetitive crew transfer, (2) crew activities, (3) logistics resupply, and (4) crew safety. In order to address these elements in a cogent manner, they have been divided into the specific approach consistent with the chronological sequence currently being planned for Skylab reuse. The four phases (as shown in Figure 1.0-1) are:

- o Phase I - Ground Interrogation and Reactivation
- o Phase II - Shuttle-tended Inspection and Refurbishment
- o Phase III - Shuttle-tended Operations
- o Phase IV - Continuously-manned Operations

The operational conditions are different for each phase, therefore, the operational plan elements have been divided into appropriate sub-elements.

2.4.4.1 Crew Transfer - Cabin Pressure Levels

Skylab A was conceived as an extension of the basic Apollo program and was therefore, committed to certain key design and operational characteristics. One of the most significant carry-over features was the 5.0 psi cabin pressure of the Apollo Command Module. As the command module was to serve as the crews' transportation system and therefore must dock to the Skylab, simplicity of crew transfer, safety, and potential cost of additional transfer airlock hardware dictated a 5.0 psi Skylab cabin pressure. As these operational decisions preceded the Orbiter definition, there was no reason to incorporate growth potential into the Skylab subsystems. Therefore, in the Orbiter era, a salient consideration of shirtsleeve crew transfer procedures is that the crew will be moving from a higher Orbiter pressure to the lower Skylab pressure. There are two basic approaches: (1) prebreathing for up to three hours depending upon the cabin pressure's ratio and (2) eliminate the prebreathing constraint by narrowing the pressure differential between the two operating volumes. The key points covering the practical requirements of pressure regulation and relief are outlined in Table 2.4.4.1-1.

Table 2.4.4.1-1

CREW TRANSFER EFFECTS OF CHANGING PRESSURE SCHEDULES

ORBITER AND SPACELAB (DECREASE CABIN PRESSURE TO 12.4 PSIA)

- FLAMMABILITY WITHIN LIMITS (25% OXYGEN)
- AVIONICS COOLING WITHIN LIMITS
- CABIN COOLING WITHIN LIMITS
- MODIFY N₂ TOTAL PRESSURE CONTROL SYSTEM FOR 2-SCHEDULE OPERATION

SKYLAB (INCREASE CABIN PRESSURE TO 6.2 PSIA)

- MODIFY ONBOARD EQUIPMENT (PRESSURE REGULATOR)
TO CAUSE THE EXISTING SYSTEM TO REGULATE CABIN PRESSURE AT A HIGHER
LEVEL AUTOMATICALLY
- ISOLATE ECS RELIEF VALVES, INSTALL NEW RELIEF VALVE KITS AT EXISTING
MDA/OWS PORTS, AND ACCEPT OPERATIONAL PROC CONSTRAINT

To stay within the Orbiter flammability operating upper limit of 25% oxygen, the Orbiter cabin pressure may be reduced to 12.4 psia minimum (12.6 psia nominal) and still maintain the sea level partial pressure of oxygen at approximately 3.1 psia which is desirable for biomedical reasons. At this lower pressure, it appears that the Orbiter avionics and cabin cooling requirements will be maintained within the necessary temperature limits. At lower pressure levels system modifications including increased air circulation would be required to maintain the Orbiter within the temperature design limits and both flammability and crew physiological limits would not be met. A modification to the Orbiter pressure control system would be required to maintain the 12.6 psia. Modification to a two-schedule N₂ total pressure control system would allow the Orbiter to operate at either 12.6 psia or 14.7 psia (nominal).

With the Orbiter at 12.4 psia, the prebreathing constraint can be eliminated (based on a 1% risk) by increasing Skylab pressure to 6.2 psia minimum which, coincidentally, happens to be the design limit pressure for the AM/MDA. To increase Skylab pressure to 6.6 psia nominal, the cabin pressure regulator and cabin pressure relief system would require modification. New relief valve modules could be installed at existing vent ports within the OWS and MDA. The initial relief system which included three independent vent systems in the AM Forward, AM Lock and AM Aft sections would be shut off using existing manual valves. Should future operations require the crew to be isolated in one of these volumes, the shutoff valve could be opened for over-pressure protection necessitating operation at the lower cabin pressure (approximately 5.7 psia).

In order to evaluate the cabin pressure ratios between the Orbiter and Skylab, it is necessary to account for the operating tolerance of control components and the cumulative effect of the tolerances on the maximum operating pressure. Further, it is assumed that the scheduled pressure ratio will be assured within the minimum/maximum tolerance envelope of the pressure regulators and vent/relief valves. Included in the total equation is the structural factor of safety as measured between valve relief pressure and the proof pressure of the structure together with the pressure ratio of O₂ to N₂ in the Orbiter cabin. This ratio is low since the atmosphere cannot exceed 25 percent O₂ as a flammability limitation. This requirement establishes the low-end pressure of the Orbiter at 12.4 psia.

To assure an Orbiter to Skylab pressure ratio of two or less to eliminate prebreathing, it is necessary to use the highest Orbiter regulator setting of 12.8 psia and a Skylab regulator setting of 6.4 psia for extended operating periods. Thus, the pressure exposure ratio for the crew during transfer will not exceed two. However, the resultant margin of safety of 8.7 psia proof pressure for the ATM/MDA over the pressure relief valve setting of 7.6 psia maximum is reduced to 14 percent. This suggests that serious consideration should be given to a crew prebreathing period with O₂ masks for two hours prior to transfer while holding the Orbiter and Skylab at their current design pressures. An attempt to achieve a pressure ratio of two for crew transfer by holding the Orbiter design pressure of 14.7 psia and increasing the Skylab pressure to 7.35 - 7.5 psia, requires additional analysis since the condition yields a margin of safety of zero for the 8.7 psia proof pressure test. This is shown in Figure 2.4.4.1-1 by a Factor of Safety, F.S. equal to 1.0 for the AM.

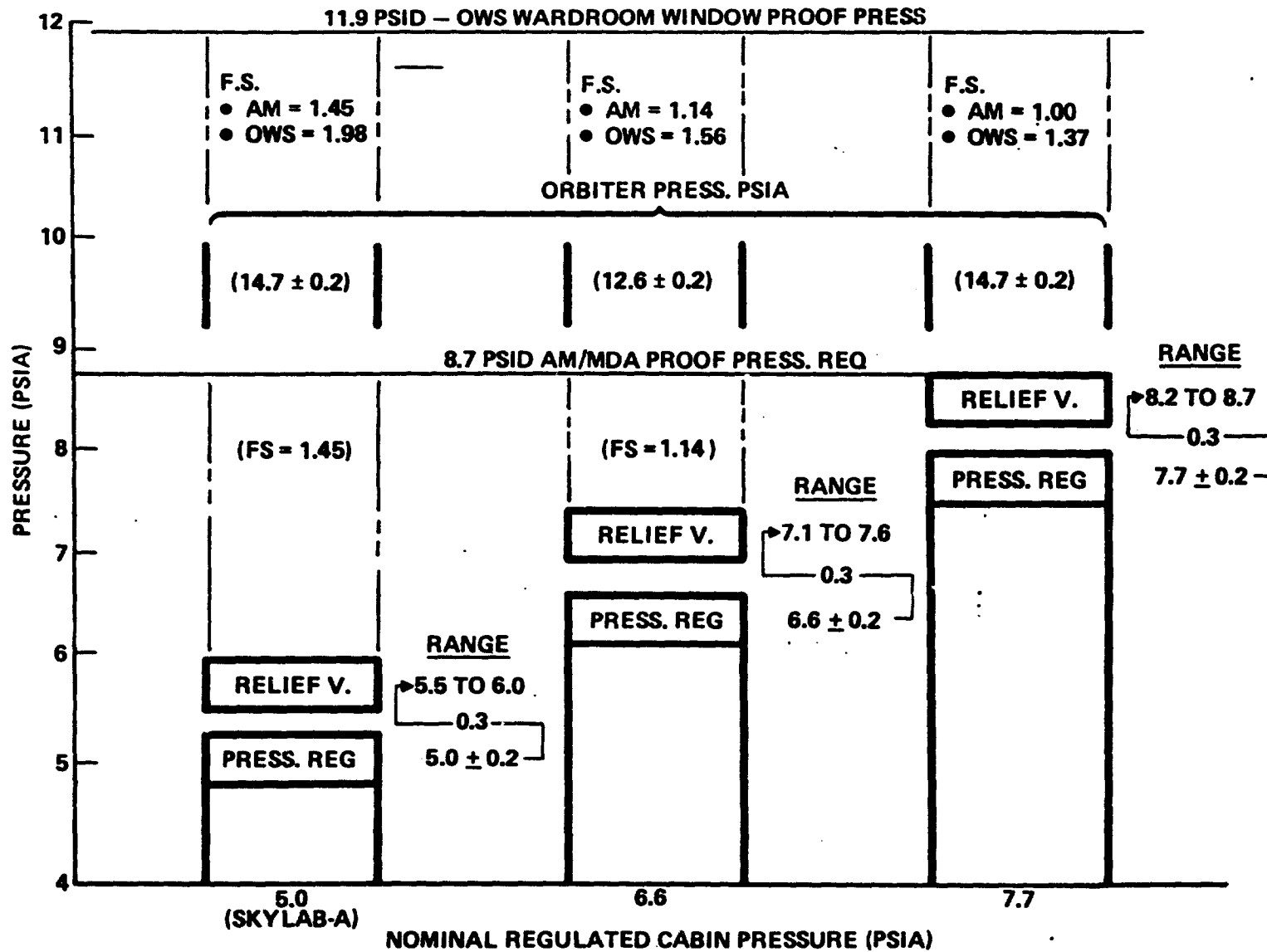
To provide an appreciation of the cabin pressure ratio-prebreathing issue, the physiological effect of dysbarism (i.e., bends) is described. Dysbarism is a term normally used to describe the condition in which gas bubbles are formed in body tissues because of a reduction in the pressure to which the body is exposed. A brief introductory summary is included in the following text, however, a full analytical treatise has been included as Appendix B. Although current testing of dysbarism efforts and time requirements may produce empirical results which will change the theoretical values, the theory and analytical procedures will provide a sound basis for future assessments. The production of bubbles depends upon the pressure reduction being of sufficient magnitude and occurring over a sufficiently short duration. Dysbarism symptoms can vary from a mild itching of the skin to coma and death but are most commonly manifested as pains in the elbow or knee joints. The nature and severity of the symptoms appear to be related to the size of the bubbles and the site of their formation.

The risk of dysbarism can be reduced by decreasing the pressure of the gases dissolved in the tissues prior to exposure to a decreased environmental pressure. The pressures of the metabolic bases are fixed by metabolic characteristics and cannot be significantly changed; the amount of dissolved

Figure 2.4.4.1-1

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PRESSURE CONTROL TOLERANCE BUILDUP



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nitrogen can, however, be reduced. The amount and, consequently, the pressure of nitrogen can be reduced by causing the subject to breathe a gas mixture containing a lower nitrogen pressure than the tissue nitrogen pressure. This can be accomplished by prebreathing 100% oxygen or by operating in a lower N_2 partial pressure environment for a period of time.

Figure 2.4.4.1-2 defines prebreathing and/or residence time requirements at various Orbiter/Skylab pressure ratios before transferring to Skylab or conducting EVA from the Orbiter or Skylab. Although the most efficient crew operations approach is to adjust the cabin pressures to a ratio which precludes prebreathing, the practical aspects of component pressure control tolerances and structural factors of safety which were identified in Figure 2.4.4.1-1 must be considered. However, while the prebreathing concept is acceptable for the early visits, there is definite interest in eliminating that requirement in future operational missions. This possibility was evaluated in this reuse study and it can be concluded that increasing Skylab habitation pressure to 7.5 psi is feasible and represents a finite option. However, before approving the increase an in-depth review of all Skylab stress analyses and test data should be accomplished to ensure there are no potential hazards relative to the crews' safety resulting from structural problems. Further, the long term effects (i.e., approximately 12 years) of the low earth orbital environment should be examined to assure that there are no adverse effects on the structural integrity of susceptible components. A third option would be to remain with the 5.0 psi Skylab cabin pressure, minimizing the length of the Shuttle-tended operations and accepting the periodic (i.e., at crew transfer) prebreathing requirement.

Tables 2.4.4.1-2 and -3 provide the design factors of safety for increasing Skylab habitation pressure to 7.5 psi nominal. The structural components listed in the tables are considered to be the most susceptible to an increase in pressure. The noted proof pressures represent the pressure to which the components were subjected. In most cases, these components have been proof tested to pressures higher than 7.5 psi.

Figure 2.4.4.1-1 has been included in order to show the original factors of safety which were applied to the Skylab design. In a preliminary comparison of these values to those associated with the 7.5 psi pressure it is

PRESSURE RATIO		PREBREATHING TIME WITH 1% RISK (HRS)		
ORBITER PRESSURE (PSIA)	SKYLAB PRESSURE (PSIA)	ORB TO SL	ORB TO EVA	SL TO EVA
		14.7	5.0	2.0
14.7	7.5	0	4.9	0 AFTER 11.6 HRS
12.4	6.2	0 AFTER 24 HRS	3.5 AFTER 24 HRS	0 AFTER 3.4 HRS
10.3	5.0	0 AFTER 24 HRS	2.0 AFTER 24 HRS	0 AFTER 2.4 HRS

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Figure 2.4.4.1-2 Crew Transfer - Pressure and Time Relationships

Table 2.4.4.1-2 (Page 1 of 3)

STRUCTURAL ASSESSMENT FOR 7.5 PSIA HABITATION PRESSURE

<u>OWS</u>	<u>PROOF PRESSURE (PSID)</u>	<u>PROOF FACTOR OVER 7.5 PSIA</u>	<u>BURST PRESSURE (PSID)</u>	<u>BURST FACTOR OVER 7.5 PSI</u>
o TRASH AIRLOCK	- 9.3	1.24	- 26	3.47
o COMMON BULKHEAD	-	-	- 20.5	2.73
o PORTABLE WATER BOTTLE	- 8.56	1.14	- 12	1.6
o WARDROOM WINDOW				
o INNER GLAZING	11.9	1.59	62*	8.27
o OUTER GLAZING	14.7	1.96	62*	8.27
o SCIENTIFIC AIRLOCK				
o OUTER DOOR	23.0**	3.06	32	4.27
o WINDOW	19.0**	2.53	52.9	7.05
o REFRIGERATION PUMP ENCLOSURE	-12.5	1.66	26.0	3.47

* INDIVIDUAL GLAZING BURST TEST

**DESIGN LIMIT PRESSURE DURING LAUNCH AND ASCENT

NEGATIVE PRESSURE IS EXTERNAL (COLLAPSE) TO THE COMPONENT

Table 2.4.4.1-2 (Page 2 of 3)

STRUCTURAL ASSESSMENT FOR 7.5 PSIA HABITATION PRESSURE

<u>AM</u>	<u>PROOF PRESSURE (PSID)</u>	<u>PROOF FACTOR OVER 7.5 PSIA</u>	<u>BURST PRESSURE (PSID)</u>	<u>BURST FACTOR OVER 7.5 PSI</u>
o SHELL STRUCTURE	8.7	1.16	12.4	1.65
o INTERNAL (END) HATCHES	-8.7	1.16	-12.4	1.65
o EVA HATCH	8.7	1.16	12.4	1.65
o WINDOWS				
o STS VIEWING PORT	8.7	1.16	12.4	1.65
o EVA HATCH	8.7	1.16	12.4	1.65
o CONDENSATE TANK	-8.7	1.16	-10.9	1.45
o FLEXIBLE BELLOWS	8.7	1.16	12.4	1.65
o WATER SEPARATOR PLATES*	-8.7	1.16	-12.4	1.65

*INCREASED LEAKAGE WHICH MAY EXCEED SPECIFICATION

NEGATIVE PRESSURE IS EXTERNAL (COLLAPSE) TO THE COMPONENT

Table 2.4.4.1-2 (Page 3 of 3)

STRUCTURAL ASSESSMENT FOR 7.5 PSIA HABITATION PRESSURE

<u>MDA</u>	<u>PROOF PRESSURE (PSID)</u>	<u>PROOF FACTOR OVER 7.5 PSIA</u>	<u>BURST PRESSURE (PSID)</u>	<u>BURST FACTOR OVER 7.5 PSI</u>
o SHELL STRUCTURE	9.3	1.24**	12.4	1.65**
o EXTERNAL PRESSURE HATCHES (2) (COMMAND MODULE)	9.3	1.24**	12.4	1.65**
o S-190 WINDOW	14.7	1.96	32*	4.27
o S-191 WINDOW	33.6	4.48	50.4*	6.72
o S-192 WINDOW	12.4	1.65	18.6*	2.48

* INDIVIDUAL GLAZING BURST TEST

**EVALUATION OF THE 12.4 PSID BURST PRESSURE TEST RESULTS OF THE MDA STRUCTURE INDICATED THAT THE ACTUAL BURST FACTOR OVER 7.5 PSIA WOULD BE 2.33 AND THE PROOF FACTOR OVER 7.5 PSIA WOULD EXCEED 1.5.

Table 2.4.4.1-3
MDA/AM/OWS ORIGINAL DESIGN FACTORS OF SAFETY

GENERAL STRUCTURE (MANNED VEHICLE)

- o YIELD - 1.10
- o ULTIMATE - 1.40

HABITATION AREA AND WASTE TANK (ON-ORBIT)

- o PROOF PRESSURE = 1.50 TIMES LIMIT PRESSURE
- o YIELD PRESSURE = 1.10 TIMES PROOF PRESSURE
- o BURST PRESSURE = 2.00 TIMES LIMIT PRESSURE

WINDOW GLAZING (NOT IN ASSEMBLY)

- o PROOF PRESSURE = 2.0 TIMES LIMIT PRESSURE
 - o BURST PRESSURE = 3.0 TIMES LIMIT PRESSURE
-

immediately evident that the OWS primary and secondary structures meet the basic proof pressure factor of safety (i.e., 1.50). The exception being the portable water, which is not a critical item and can be reproof-tested to the higher pressure by means of an available backup unit or returning the flight units to earth via the Orbiter. In the final analysis the current bottles could be discarded and new higher pressure bottles provided. The second item with lower proof safety factor (i.e., FS = 1.24), the trash airlock, has a very substantial burst factor (i.e., 3.47 vs 2.00 spec) and would probably be acceptable. To establish a final approved position, it will be necessary to undertake a thorough detail review in a follow-on study. This task would include review and evaluation of test data, test configurations/procedure design analyses, design details, and potential effects of long-duration orbital storage (i.e., 11 to 12 years) exposure to the space environment.

In contrast to the OWS which benefitted from the higher proof pressures of its Saturn S-IVB heritage, the Airlock Module and Multiple Docking Adapter were designed for 5.0 psia cabin pressure, as a result, the 7.5 psia proof factors developed from the official proof tests range from 1.16 to 1.24 (vs 1.50) and the burst factors from 1.45 to 1.65 (vs 2.0). The exceptions to those values were the Multiple Docking Adapters windows.

A mitigating factor that was introduced into the evaluation, was the 12.4 psia burst test that was conducted at MSFC on the combined AM/MDA. As this test was successful, it served as a form of proof test. However, application of the same factors that were noted on the portable water bottle (i.e., test results, test configurations/procedure, etc.) must be made in order to arrive at a final decision.

In summary, at this point in the assessment of the orbiting Skylab's capability to operate at a 7.5 psia nominal, it appears feasible. However, before making a final decision that has direct ramifications to crew safety, it is recommended that a full detailed investigation be undertaken as a follow-on task.

2.4.4.2 Crew Operations - Phase III - Shuttle-tended

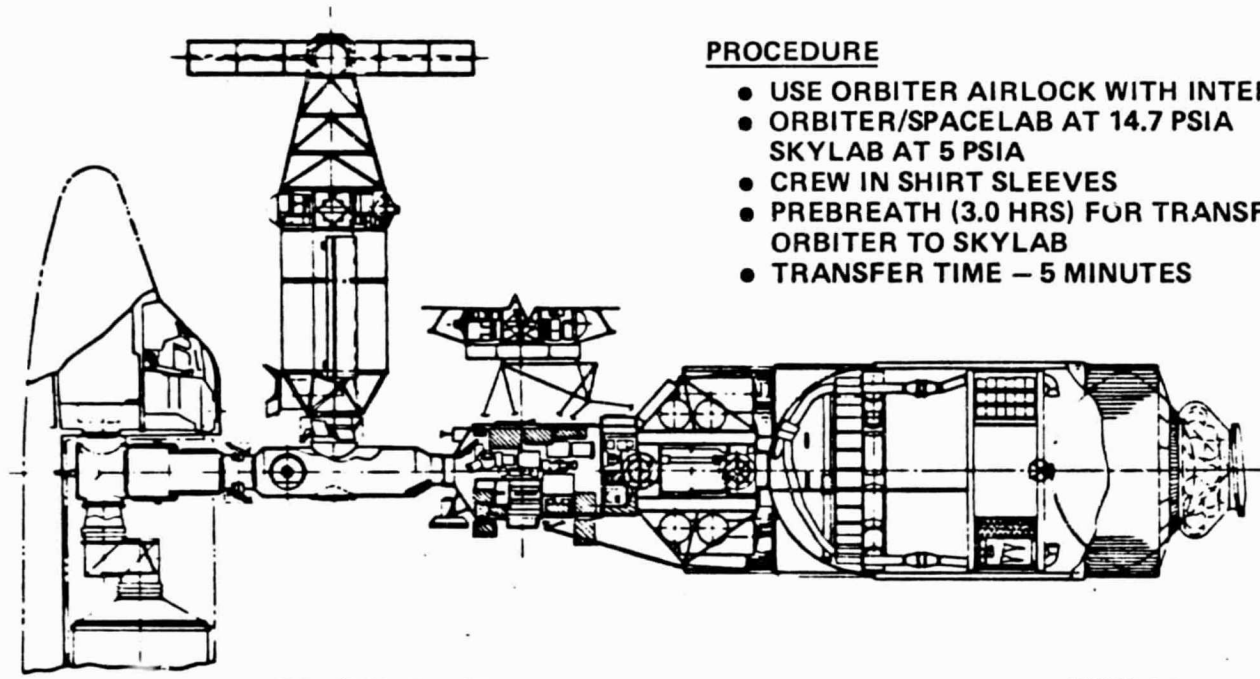
The Shuttle-tended operational mode is a logical follow-on to the initial sortie missions. Its initial purpose and benefit is the availability of crew support areas as an adjunct to the Orbiter which are larger than the basic Orbiter and possess the inherent privacy, functional separation, and improved effectiveness attendant with increased volume. These accommodations would benefit the flight crew as the mission durations approach 30 days. Orbiter sleeping accommodations, for example, are 0.85 m^3 (30 ft^3)/man while the Skylab or free-flying Spacelab would be approximately double that volume in the crew quarters, while providing 85 to 115 m^3 ($3,000$ to $4,000 \text{ ft}^3$) of free space and compartmentalized galley and waste management areas.

In the Shuttle-tended mode, the Orbiter remains docked to the Skylab during the entire manned mission. Thus, the docked Orbiter with a cargo bay Spacelab can be dedicated to payload operations, while the Skylab space habitat provides the crew support and accommodations.

A key candidate application for an early Skylab reuse objective is to provide crew habitation support during Orbiter sortie payload operations. In this orbital flight mode, payload activities would be conducted in the Orbiter/Spacelab or from payload pallets in the cargo bay. This latter case would be the most demanding on the crew during long-duration sortie missions as the Spacelab habitable volume is not available in the cargo bay as a source of additional volume. In this mode, the Skylab would be used during off-working hours to provide facilities for eating, sleeping, exercise, recreation, and personal hygiene. This Skylab support configuration would require minimum hardware modifications. For a crew of three, refurbishment would be the only requirement. As illustrated in Figure 2.4.4.2-1, for this concept, the Orbiter and Skylab working pressures would remain at their initial design levels requiring crew members to don oxygen masks for two to three hours of pre-breathing prior to the end of each payload operations work period. This mode of operation would normally require crew transfer to the Skylab of one trip per day. Lunch and personal hygiene requirements during the working day would be provided by Orbiter facilities. A crew timeline for a typical work-day is also illustrated in the noted figure.

Figure 2.4.4.2-1

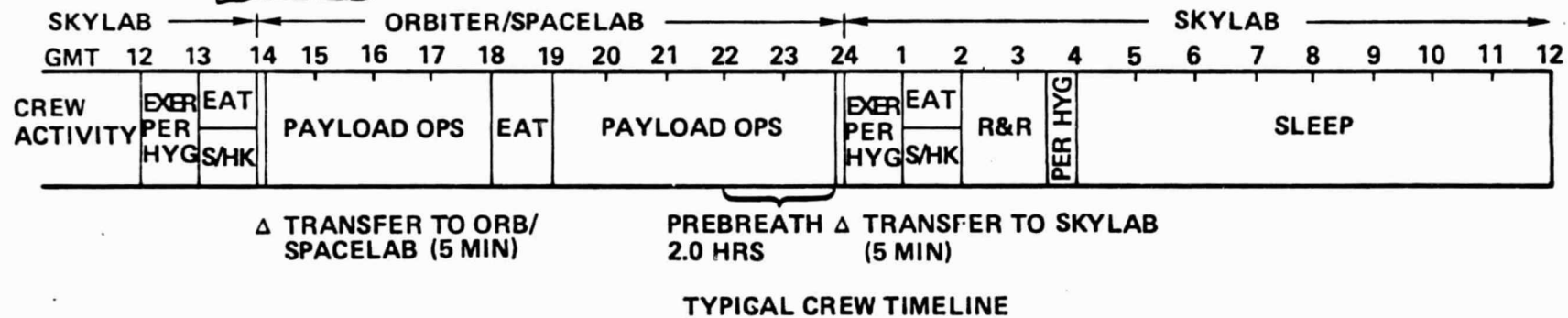
SHUTTLE-TENDED OPERATIONS SKYLAB HABITABILITY SUPPORT



PROCEDURE

- USE ORBITER AIRLOCK WITH INTERFACE MODULE
- ORBITER/SPACELAB AT 14.7 PSIA
SKYLAB AT 5 PSIA
- CREW IN SHIRT SLEEVES
- PREBREATH (3.0 HRS) FOR TRANSFER FROM ORBITER TO SKYLAB
- TRANSFER TIME - 5 MINUTES

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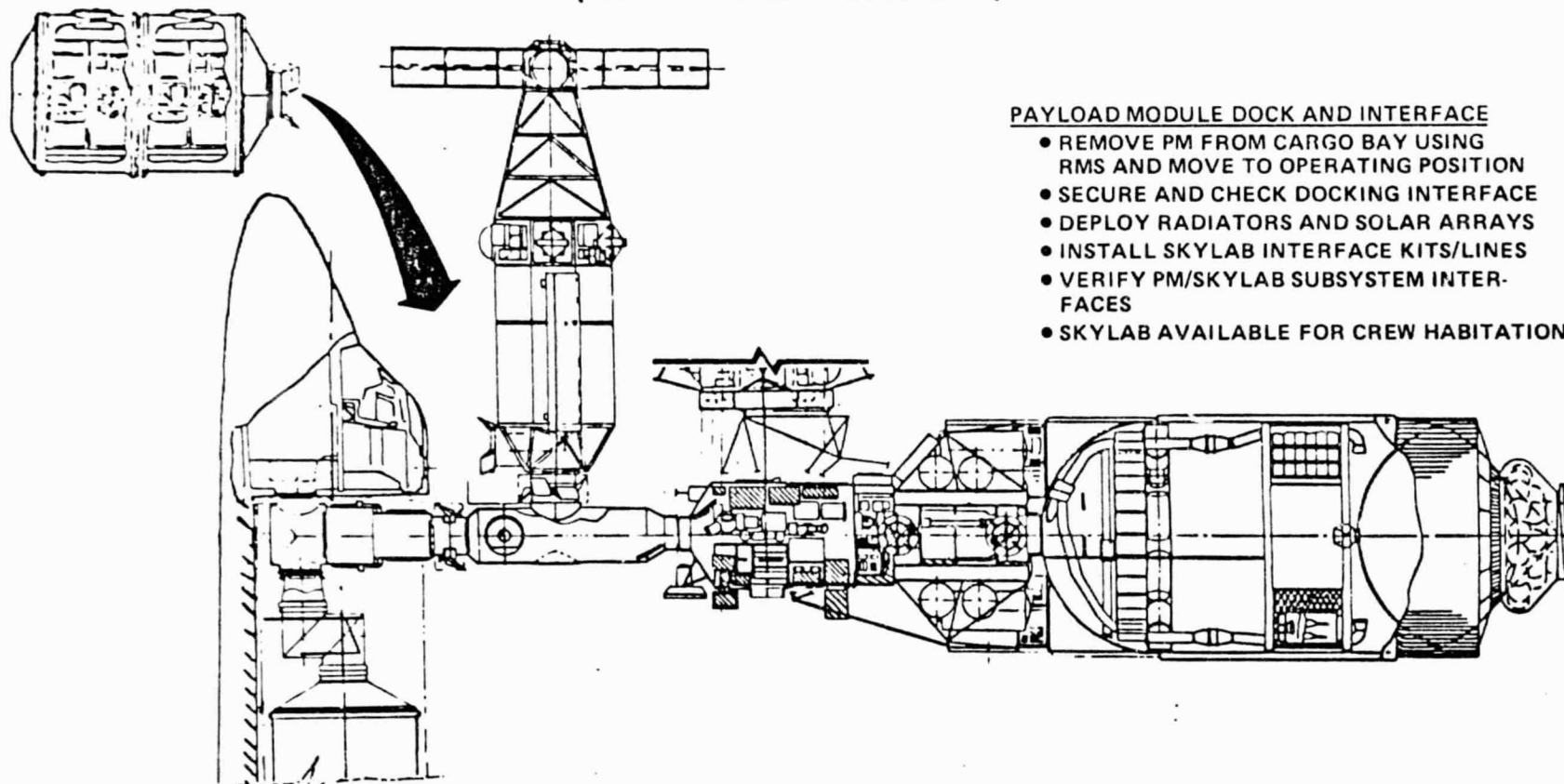
Operating under this timeline event sequence, the crew would be able to maximize the operational/habitability benefits of both the Orbiter and the Skylab. An alternate approach which would eliminate the crew prebreathing requirement is to retrofit the necessary subsystem hardware modification kits for a higher internal operating pressure, e.g., 7.5 psi. This concept is described in Section 2.4.4-1.

As shown in the figure, the Skylab cluster must include the 25 kW power module in order to support the payload and the vital subsystems. At this point in the Skylab's operational life, the original power subsystem would not be utilized except perhaps as an emergency backup. The major refurbishment requirement is the cooling loop in the AM which thermally controls the battery chargers. It is estimated 25 to 50 percent (i.e., two to four of the chargers will be operating in the reuse period. This would provide one to two kW backup power. Figure 2.4.4.2-2 further defines the orbital cluster elements.

Crew Operations - Phase IV - Continuously Manned

The final step in the initial Skylab Reuse Program would be the achievement of continuously-manned operations. In contrast to the Shuttle-tended operations based on periodic manning, the continuously-manned mode is based upon regular crew rotation (e.g., 60 to 120 days). The Orbiter supporting the crew exchange would be docked only for several days during the crew rotation and logistics resupply. Table 2.4.4.2-1 summarizes the salient advantage of the Skylab accommodations vis-a-vis the long duration mission. Figure 2.4.4.2-3 shows a typical orbital configuration and lists key characteristics. In this mode, the crew would follow the activity sequence and gross timeline developed on the Skylab-A missions. Skylab is the first manned spacecraft developed to fully accommodate man's capacity to do useful work in space for long periods of time. It was developed to provide habitability accommodations similar to those in his home and at work. The 12,000 ft³ Skylab volume is five or more times commodious than space crews lived and worked in on flights previous to Skylab. Further, in addition to uncongested work areas, private and comfortable sleep quarters are included. A lavatory for collection, processing and disposition of human waste is provided. In the wardroom a fully equipped "kitchen with pantry and dining area" are made available. A wide variety of frozen,

CREW OPERATIONS — PHASE III PM DOCK AND INITIAL OPERATIONS (SHUTTLE TENDED)



PAYLOAD MODULE DOCK AND INTERFACE

- REMOVE PM FROM CARGO BAY USING RMS AND MOVE TO OPERATING POSITION
- SECURE AND CHECK DOCKING INTERFACE
- DEPLOY RADIATORS AND SOLAR ARRAYS
- INSTALL SKYLAB INTERFACE KITS/LINES
- VERIFY PM/SKYLAB SUBSYSTEM INTERFACES
- SKYLAB AVAILABLE FOR CREW HABITATION

OPTION A OPERATIONS
(HABITABILITY ONLY)

- ALL PAYLOAD OPERATIONS CONDUCTED FROM ORBITER/SPACELAB

OPTION B OPERATIONS
(SELECTED SL EXPERIMENTS)

- PAYLOAD OPS CONDUCTED FROM ORBITER/SPACELAB PLUS SELECTED SKYLAB EXPERIMENTS (OSW/MDA/ATM)

OPTION C OPERATIONS
(NEW EXPERIMENTS)

- PAYLOAD OPS CONDUCTED PER OPTIC. J B PLUS NEW SKYLAB DOCKED/BERTHED EXPERIMENTS

(ALL OPTIONS: SKYLAB PROVIDES HABITABILITY SUPPORT FOR CREW WITH CONSUMABLES BEING RESUPPLIED)

Table 2.4.4.2-1

SKYLAB REUSE-LONG DURATION MISSION CREW SUPPORT

SKYLAB OFFERS LARGE HABITABLE QUARTERS & CREW ACCOMMODATIONS

- PRIVATE SLEEPING AREAS
- EFFECTIVE WASTE DISPOSITION
- PLEASANT GALLEY
- AMPLE ROOM FOR WORK AND EXERCISE
- SPACE FOR SICK BAY
- FREE VOLUME FOR CREW RELAXATION

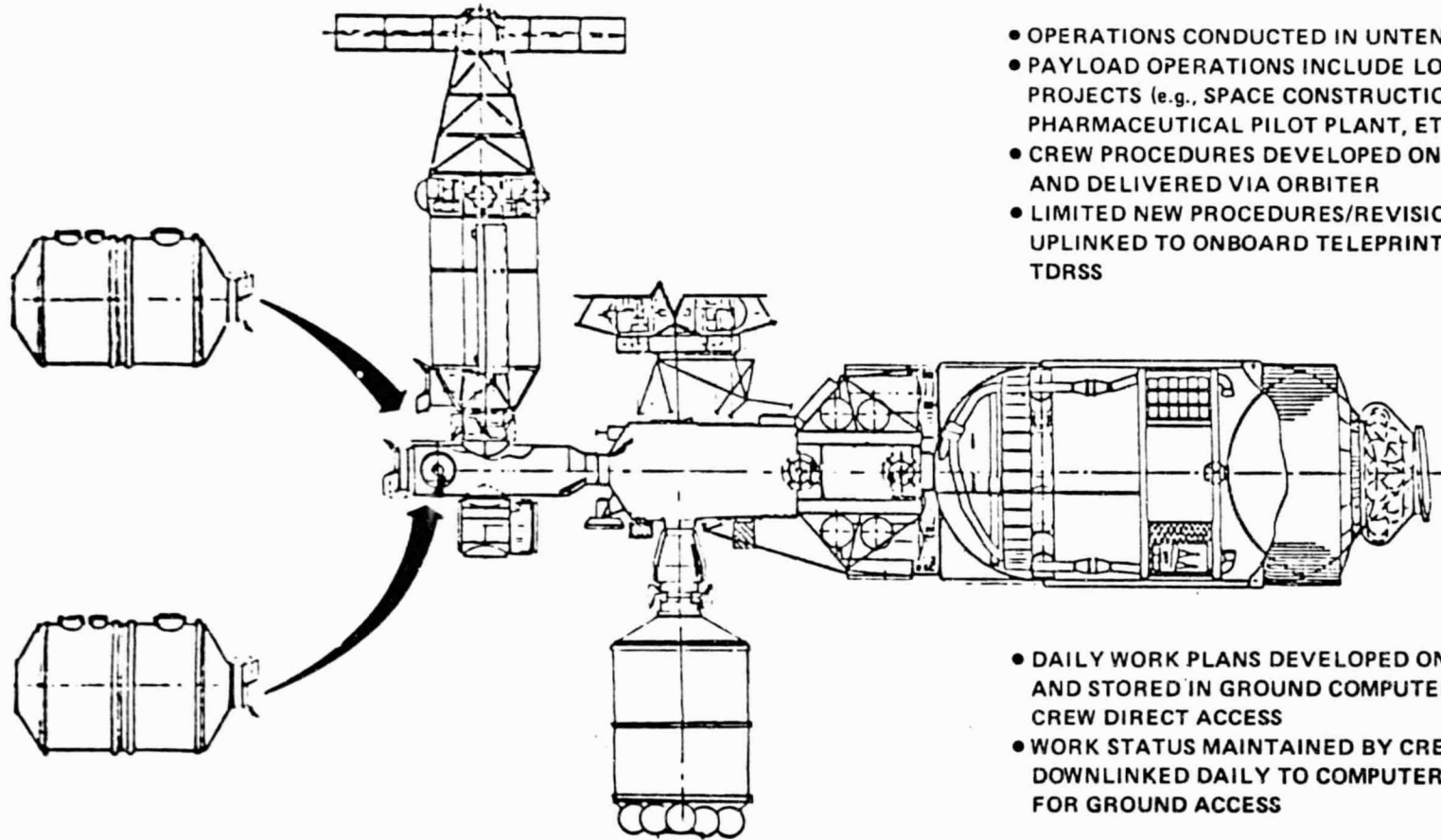
SKYLAB EXERCISE ACCOMMODATIONS ARE EXTENSIVE

- SPACE FOR CALISTHENICS
- EXERCISORS
- BICYCLE ERGOMETER
- JOGGING TRACK
- FREE VOLUME FOR SPONTANEOUS ACTIVITY

SKYLAB CLUSTERED WITH ORBITER/SPACELAB PROVIDES HABITABILITY ACCOMMODATIONS

- ORBITER/SPACELAB VOLUME CAN BE TOTALLY DEDICATED TO PAYLOADS AND LOGISTICS

CREW OPERATIONS PHASE IV GROWTH/CONTINUOUSLY-MANNED OPERATIONS



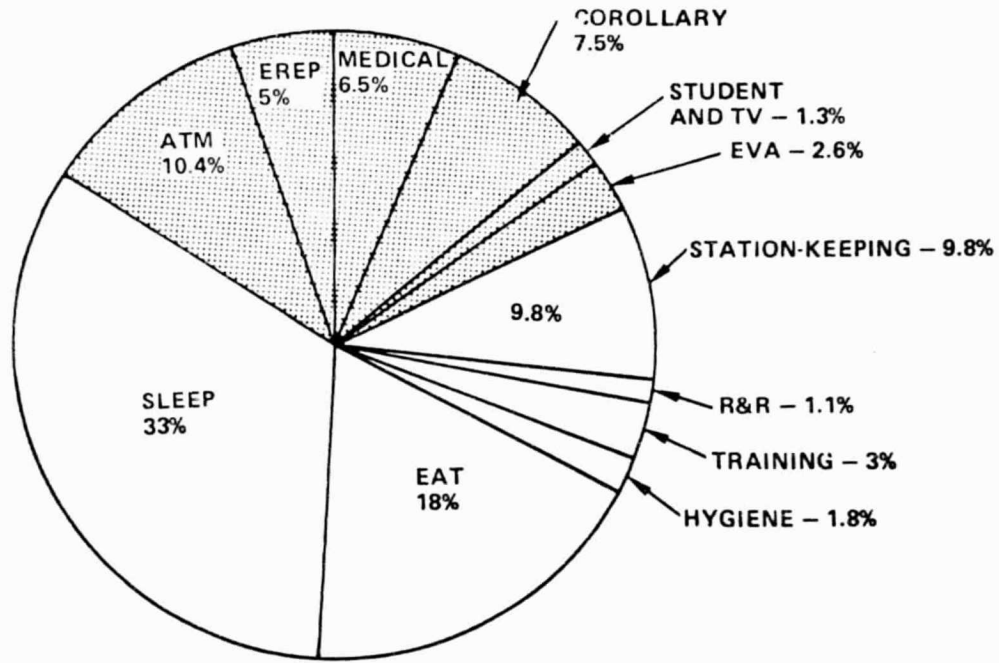
- OPERATIONS CONDUCTED IN UNTENDED MODE
- PAYLOAD OPERATIONS INCLUDE LONG TERM PROJECTS (e.g., SPACE CONSTRUCTION, PHARMACEUTICAL PILOT PLANT, ETC)
- CREW PROCEDURES DEVELOPED ON GROUND AND DELIVERED VIA ORBITER
- LIMITED NEW PROCEDURES/REVISIONS UPLINKED TO ONBOARD TELEPRINTER VIA TDRSS

- DAILY WORK PLANS DEVELOPED ON GROUND AND STORED IN GROUND COMPUTER FOR CREW DIRECT ACCESS
- WORK STATUS MAINTAINED BY CREW AND DOWNLINKED DAILY TO COMPUTER STORAGE FOR GROUND ACCESS

refrigerated, and dry foods can be stored. Skylab offers ample exercise area for physical conditioning and recreation. All these benefits are readily available for Skylab reuse by a crew of three over long-duration STS missions. Crews of up to seven can be accommodated through the addition of crew quarters in the forward area.

During the Skylab missions, the above habitability benefits were evaluated by three different flight crews as part of the experiments on Habitability/Crew Quarters (M487) and Crew Activities/Maintenance (M516). The Principal Investigator for M487 was Cadwell C. Johnson, Jr. of the Manned Spacecraft Center. Marshall Space Flight Center was the development and integration center and the contractor was McDonnell Douglas Astronautics Company, Huntington Beach, California. The Principal Investigator for M516 was R. L. Bond of the Manned Spacecraft Center. MSC was the development and integration center and the contractor was Martin-Marietta Corporation, Denver Division. Some of the more significant conclusions drawn from these experiments are (1) Skylab's living and working environments were quite acceptable to all three crews; their performance of duties was not compromised by the lack of habitability accommodations; (2) crew opinions and evaluations concurred in that privacy during "free-time," exercise, recreation, and diversion from day-to-day routines is necessary; (3) personal hygiene accommodations, including a shower facility, are very important; (4) good meals at regularly scheduled meal periods very beneficial as are shared meal periods. Figure 2.4.4.2-4 summarizes a typical orbital period (e.g., seven days) and displays the division of time allocated to the necessary activities. In this phase, as the crew would be living and working in Skylab, maximum efficiency can be achieved. This permits the assignment of an eight- to ten-hour workday and benefits from increased efficiency which can be derived in those tasks and experiments which inherently involve some degree of repetitive tasks. This advantageous situation is displayed on the lower area of the figure. These empirical results from Skylab-A are particularly applicable to the longer duration, continuously-manned missions. The Skylab experience and supporting medical evidence has established the fact that man is qualified for mission durations of 90 days. The presence of man can enhance the probability of mission success through his command and control functions and by repairing and restoring critical functions of components and systems.

CREW PERFORMANCE IMPROVEMENT



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EXPERIENCE DURING EXTENDED DURATION SKYLAB MISSION

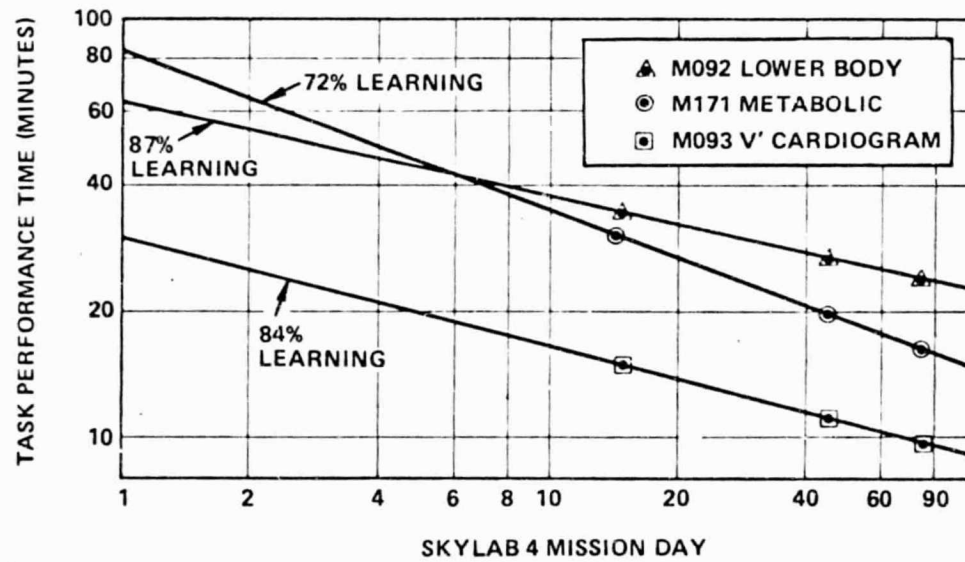


Figure 2.4.4.2-4. Crew Activities Allocation and Mission Duration Benefit

The noted empirical data of Figure 2.4.4.2-4 shows two important results derived from detailed analysis of crew activities experienced during the Skylab missions: (1) distribution of crew time, and (2) efficiency of repeated tasks as a function of mission duration. It was observed that, on the average, about eight hours of a 24-hour period to be available for payload work, the remainder being required for personal activities and station-keeping tasks. Under certain conditions (e.g., emergencies, special long-duration tests, etc.) this workday can be readily extended. The second observation was a marked improvement in task efficiency as measured by the time required to perform specific experiment related tasks as the mission progresses. The data shown describes "learning curve" averages between 72 percent (very good) and 87 percent (good) for three major biomedical experiments. For example, at the outset of Skylab-4, the M171 metabolic activity medical experiment required an aggregate of 82 minutes to perform; at the end of the mission, the same experiment required a mere 18 minutes to complete or a savings of about one hour of crew time which was an improvement of approximately 80 percent in task efficiency.

General conclusions that can be drawn from the Skylab crew experience are: (1) on the average, about eight hours per day are available for payload useful work, (2) a daily recreation period is desirable, (3) a periodic day of rest is required, and (4) with adequate provisions for crew accommodations considerable improvement in task efficiency can be experienced on longer missions. This means that given Skylab class accommodations, the same workload can be accomplished on one 60-day mission by a crew of three that otherwise could be derived from seven or more 7-day missions with larger crews.

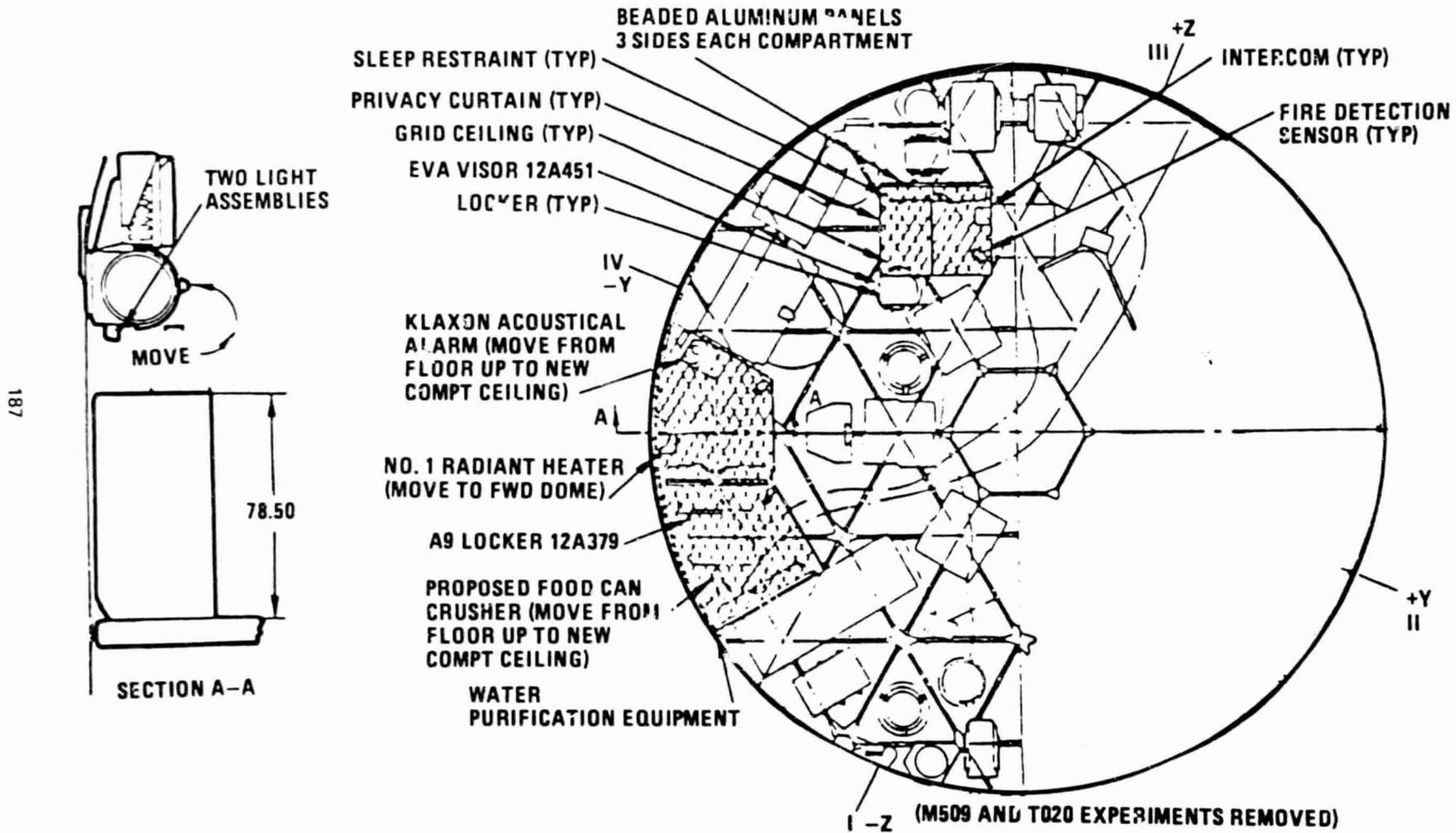
Initial crew size has been studied for three to five members, depending upon the types of payload and related crew support. A baseline mission of five crew members was established for purposes of defining the logistics support system as described in Section 2.4.4.4. In order to support the additional crew, crew quarters would be installed in the forward deck area. A typical candidate installation is shown in Figure 2.4.4.2-5.

A further consideration in long-duration missions and crew physical conditioning are the exercise facilities offered by the Skylab. In order to maintain

Figure 2.4.4.2-5

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SKYLAB AUGMENTED SLEEP PROVISIONS (LOCATED WITHIN EXISTING EQUIPMENT)



condition and strength in a zero-gravity environment, a muscle must be exercised at or near to its customary level of effort.

As shown in the upper chart of Figure 2.4.4.2-6, in Skylab-2 and Skylab-3, the bicycle ergometer (SL2) and the MK-1 exerciser plus a spring device (SL3) were not adequate to maintain the leg extensor muscles at an acceptable condition level. Only after the treadmill was added on Skylab-4 did the extensor muscles in the legs maintain their strength. This was due to the compression load placed on the legs by the tension harness around the shoulders. This device was designed to simulate the normal one-g leg load.

The lower chart illustrates strength loss in the arm flexor muscles when only the bicycle ergometer is used. The addition of the MK-1 and spring device resulted in negligible loss on Skylab-3 and even some improvement on Skylab-4.

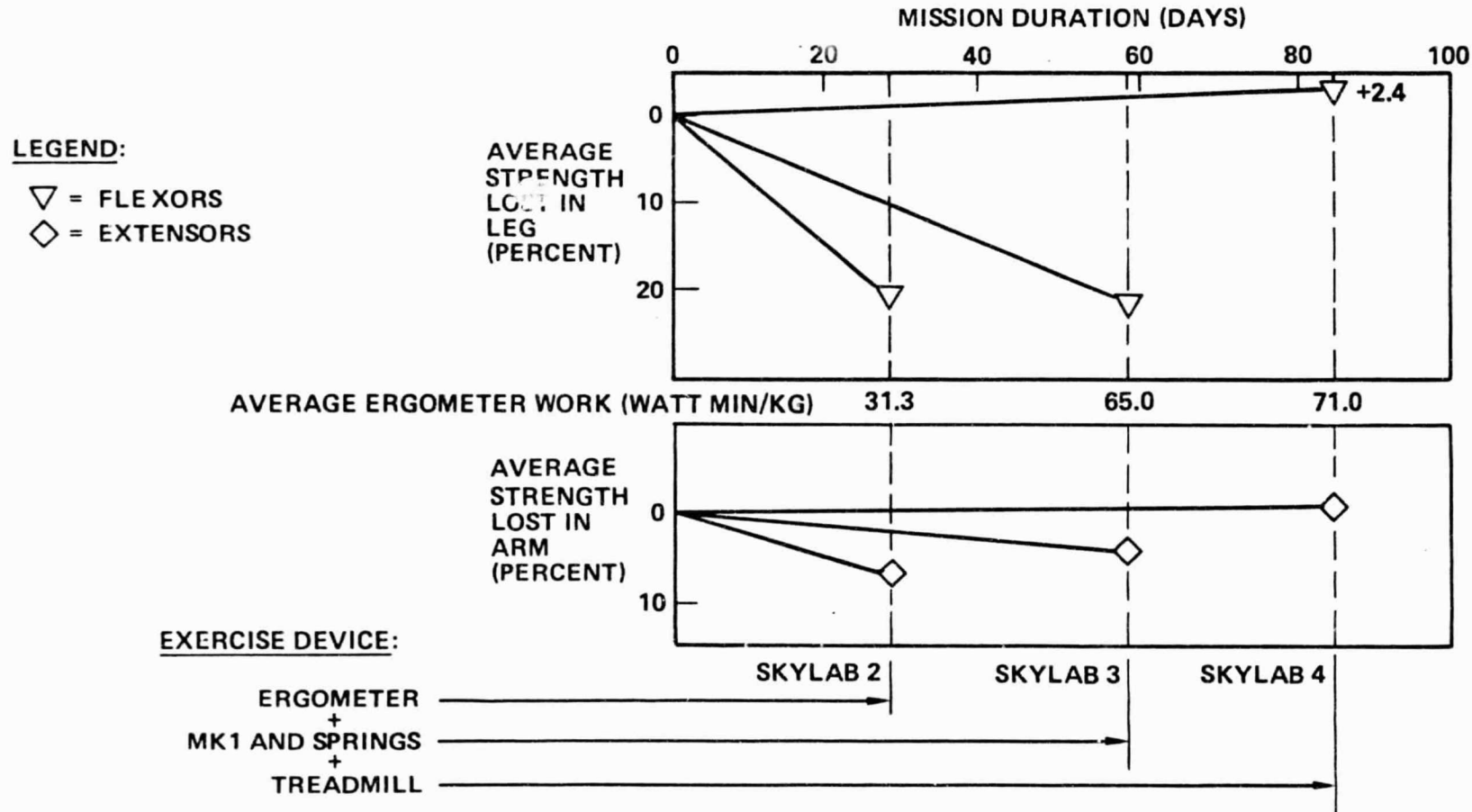
This empirical data illustrates very graphically the importance of a continuing crew exercise program of physiological conditioning. As described in Figure 2.4.4.2-7, the Skylab provides both the exercise equipment and sufficient free volume for an uninterrupted, non-interfering exercise program for three to seven crew members. On long-duration missions, it has been proven to be vital that all crew members be provided the opportunity for both an exercise regimen and recreational physical activities. This will contribute to the maintenance of mental and emotional well being which is as essential for successful mission completion as the maintenance of physical health. Skylab offers the free volume needed for "workout" space. The jogging track, handball court, and free exercise gym serve to provide both physical exercise and a means for emotional relaxation. An interesting characteristic of the jogging track (ring lockers) is that a crew member running at 10 km/hr generates 1/3 g level (average).

The treadmill, exercisers, and the ergometer are all three essential for maintaining muscular and cardiovascular strength and tone. The available shower is an added element which becomes more important to the crew members as the missions become longer.

Figure 2.4.4.2-6

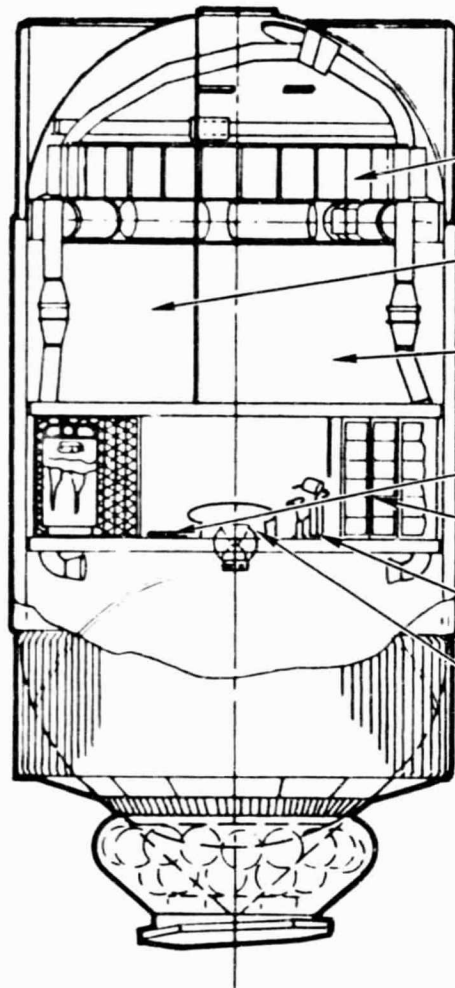
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BIOMEDICAL EVIDENCE OF NEED FOR VIGOROUS EXERCISE



SOURCE: MUSCULAR DECONDITIONING AND ITS PREVENTION IN SPACE FLIGHT
W. E. THORNTON AND J. A. RUMMEL, CHAPTER 12, BIOMEDICAL RESULTS FROM SKYLAB,
NASA SP-377, 1977

SKYLAB CREW CONDITIONING FACILITIES



FACILITIES

BENEFITS

JOGGING TRACK -- MAINTAINS LEG STRENGTH

HANDBALL COURT -- IMPROVES MENTAL ATTITUDE

FREE EXERCISE GYM -- RELAXATION

TREADMILL -- MAINTAINS LEG STRENGTH

MK I AND II EXERCISORS -- MAINTAINS ARM STRENGTH

BICYCLE ERGOMETER -- CARDIOVASCULAR TONE

SHOWER -- PERSONAL HYGIENE AND RELAXATION

2.4.4.3 Spares Provisioning

A preliminary task was accomplished which developed a spares plan for Skylab reuse missions. The spares provisioning concept for the operations program was based on how and why to reclaim Skylab and integrate it into the STS program, to determine what is required to refurbish/resupply Skylab and restore its operational capability. This task outlined a potential spares plan including a candidate spares list. Phase B studies must re-examine it in the fully detailed development of the Skylab reuse spares program. For example, Skylab backup is on display at Smithsonian with components and equipment that could be reclaimed for Skylab reuse. This hardware should be inventoried and examined for that purpose.

Following is a brief summary of a potential spares program for both Phases III and IV of Skylab reuse and the logic behind the concept identification.

Background: The orbital flight spares program for OWS-1 and OWS-2 was developed in 1972 and documented in the Orbital Flight Candidate Spares Parts List Orbital Workshop under Contract NAS9-6555, Schedule II, MSFC-DRL-171A, Line Item E04, dated 1 August 1972. Table 2.4.4.3-1 is copied from this document. The spares usage on OWS-1 for the three manned missions totaling 171 days (513 man-days) was virtually nil. No major hardware components experienced failure; however, some expendables such as filters and dry cell batteries were used. Note from Table 2.4.4.3-1 that expendable items had multiple onboard spares. The noted table also indicates that a full complement of spares for OWS-2 exists in NASA stores today.

Assumptions: The following assumptions pertaining to spares provided for Skylab should be verified during Phase B studies and during the first revisit to Skylab.

- o The background on spares for the ATM, MDA, and AM is similar to the OWS spares background.
- o Remaining onboard spares for Skylab are in good condition and usable.
- o Skylab-2 spares were impounded by NASA and can be reclaimed for Skylab's reactivation and reuse.

Groundrules: The following groundrules were established for the development of a spares provisioning plan.

Table 2.4.4.3-1 (Page 1 of 5)
 ORBITAL FLIGHT CANDIDATE SPARE PARTS LIST
 ORBITAL WORKSHOP

Page No.	Part Number	Nomenclature	OWS-1			OWS-2			Procurement Leadtime (In Weeks)	Estimated Unit Cost	
			Recom Spares Qty		Approval Authority	Recom Spares Qty		Approval Authority			
			Onboard	Ground Backup		Onboard	Ground Backup				
1	1B74832-501	Sealing Device, Habitation Area Vent Outlet	1	0	C/O 400	1	0	SA-594	26	\$ 7,263.00	R
3	1B69364-501 (Was 1B69364-1)	Floodlight, General Illumination	6	6	C/O 252	6	6	SA-594	56	\$ 7,910.00	E
5	61A850003-319 (Was 61A850003-315)	Intercommunication Box	2	0	C/O 252	2	0	SA-594	--	GFP	R
7	1B77902-501 (Was 1B77902-1)	Heater Assembly, Thermal Control	1	1	C/O 252	1	1	SA-594	56	\$ 15,121.00	R
9	20M42270-3 (Was 20M42371)	Post Landing Ventilation Fan (GFP)	8	1	C/O 252 C/O 569	8	1	SA-594	--	GFP	R
11	1B77645-1	Probe Assembly - Heated	1	1	C/O 252	1	1	SA-594	45	\$ 4,569.00	R
13	1B75334-505	O-Ring	4	0	C/O 252 C/O 400	4	0	SA-594	14	\$ 50.00	E
15	1B83241-1 (Was 115D406002)	Power Module, Collection	1	0	C/O 252	1	0	SA-594	50	\$193,510.00	R
17	1B78850-501 (Was 1B93496-1)	Valve Assembly, Water Dispenser	1	0	C/O 252	1	0	SA-594	51	\$ 7,679.00	R
19	1B223 (Was 1B335)	Plug, O-Ring Subassembly	1	0	C/O 252	1	0	SA-594	55	\$ 200.00	E
21	1B80661-1	Cartridge, Filter and Charcoal	5	0	C/O 252	5	0	SA-594	56	\$ 75.00	E
23	1B78612-1 (Was 1B93498-1)	Dispenser Assembly, Drinking Water	1	0	C/O 252	1	0	SA-594	59	\$ 17,078.00	R
25	1B81445-1	Valve Assembly, Dispenser	1	0	C/O 252	1	0	SA-594	51	\$ 175.00	E

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E - Expendable R - Refurbishment

Table 2.4.4.3-1 (Page 2 of 5)
 ORBITAL FLIGHT CANDIDATE SPARE PARTS LIST
 ORBITAL WORKSHOP

Page No.	Part Number	Nomenclature	OWS-1			OWS-2			Procurement Leadtime (In Weeks)	Estimated Unit Cost
			Recom Spares Qty		Approval Authority	Recom Spares Qty		Approval Authority		
			Onboard	Ground Backup		Onboard	Ground Backup			
27	AA5452-A (Was AA5417-1)	Seal, Inboard Hatch, Trash Disposal Airlock	3	0	C/O 252	3	0	SA-594	22	\$ 100.00
29	Q4266	Quad-X Seal	3	0	C/O 252 C/O 400	3	0	SA-594	28	\$ 50.00
31	115C402100-3 (Was 115C402100)	Odor Control Filter	5	0	C/O 252	5	0	SA-594	50	\$ 8,855.00
33	115D403009-63 (Was 115D403009-11)	Panel Assembly, Processor Control	1	0	C/O 252	1	0	SA-594	66	\$28,251.00
35	1B86553-1	Filter, Upstream	3	0	C/O 252	3	0	SA-594	50	\$ 336.00
37	1B86553-501 (Was 1B86554-1)	Filter, Upstream	20	0	C/O 252	20	0	SA-594	50	\$ 311.00
39	61A830301-25 (Was 61A830301-21)	Fire Sensor Assembly	6	0	C/O 400	6	0	SA-594		GFP
41	61A800026-11 (Was 61A800026-9)	Fire Sensor Control Panel	2	0	C/O 400 C/O 658	2	0	SA-594 CO 658		GFP
43	52-79718-73 (Was GE304)	Lens and Lamp Assembly	8	0	C/O 400	8	0	SA-594		GFP
45	1B87469-1	Dosimeter Mounting Assembly	1	0	C/O 179	1	0	C/O 179	28	\$ 936.00
46	1B90672-1 (Was 1B83884-1)	Gage, Pressure, Absolute	1	0	C/O 400	1	0	SA-594	24	\$ 3,172.00
48	1B86899-1	Packing, O-Ring, Dynamic	4	0	C/O 400	4	0	SA-594	14	\$ 45.00
50	1B86899-501	Packing, O-Ring, Dynamic	2	0	C/O 400	2	0	SA-594	19	\$ 35.00

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Table 2.4.4.3-1 (Page 3 of 5)
 ORBITAL FLIGHT CANDIDATE SPARE PARTS LIST
 ORBITAL WORKSHOP

Page No.	Part Number	Nomenclature	OWS-1			OWS-2			Procurement Leadtime (In Weeks)	Estimated Unit Cost	
			Recom Spares Qty		Approval Authority	Recom Spares Qty		Approval Authority			
			Onboard	Ground Backup		Onboard	Ground Backup				
52	1B86899-509	Packing, O-Ring Dynamic	2	0	C/O 400	2	0	SA-594	14	\$ 160.00	E
54	1B86899-511	Packing, O-Ring, Dynamic	2	0	C/O 400	2	0	SA-594	19	\$ 160.00	E
56	305A-232 (Was 2005-232)	Bal-Seal	1	0	C/O 400	1	0	SA-594	5	\$ 45.00	E
58	VA3180VL1704-2-6	Flapper Valve	1	0	C/O 400	1	0	SA-594	7	\$ 5.00	E
60	SV722959-11 (Was 1B92341-501)	Separator Assembly, Centrifugal, Urine (Less Motor)	7	0	C/O 400	7	0	SA-594	32	\$70,308.00	R
62	1B88828-1	Hose Assembly, Flexible	1	0	C/O 400	1	0	SA-594	20	\$ 488.00	E
64	1B88940-1	Flush Water, Dispenser	1	0	C/O 400	1	0	SA-594	28	\$11,137.00	R
66	SV723270-1	Motor and Filter, Separator	2	0	C/O 400	2	0	SA-594	27	\$35,563.00	E
68	STSV047J49 (Was STSV047A49)	Packing, Preformed	3	0	C/O 400	3	0	SA-594	26	\$ 40.00	E
70	SV748753-2	Support and Filter	6	0	C/O 400	6	0	SA-594	22	\$ 3,994.00	E
72	24-0100-02 (Was 24-0100)	Food Tray	2	0	C/O 569	2	0	SA-594		GFP	
73	1B79636-631 (Was 1B93501-501)	Coupling, Quick Disconnect	1	0	C/O 400	1	0	SA-594	21	\$ 1,193.00	R
75	1B79636-615 (Was 1B93501-1)	Coupling, Quick Disconnect	1	0	C/O 400	1	0	SA-594	24	\$ 1,046.00	R
77	1B83881-503	Hose, Wardroom	1	0	C/O 400	1	0	SA-594	20	\$ 1,594.00	E

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Table 2.4.4.3-1 (Page 5 of 5)
 ORBITAL FLIGHT CANDIDATE SPARE PARTS LIST
 ORBITAL WORKSHOP

Page No.	Part Number	Nomenclature	OWS-1			OWS-2			Procurement Leadtime (In Weeks)	Estimated Unit Cost
			Recom Spares Qty		Approval Authority	Recom Spares Qty		Approval Authority		
			Onboard	Ground Backup		Onboard	Ground Backup			
105	1B82799-503	Packing, O-Ring	4	0	Pending	4	0	Pending	12	\$ 22.00
107	1B82799-511	Packing, O-Ring	6	0	Pending	6	0	Pending	12	\$ 11.00

E
E

o Sufficient spares exist onboard Skylab or in NASA storage to provision Skylab reactivation/reuse through Phase III operations.

o During the first mission of Phase II selected spares will be retrieved for inspection and examination to determine the effects of long duration orbital storage.

o Refurbishable Skylab-2 spares may be put through checkout and refurbishment for Phase IV operations. Expendable Skylab-2 spares and spares whose shelf life has been exceeded will be replaced.

o Logistics resupply of expendable spares after Phase IV IOC will be based on four missions annually. Each mission will be a 30-day, three-crewman visit. Assume a complement of expendable spares equal to the provisions for OWS-1 will be resupplied annually.

o During Phase IV operations, refurbishable equipment that has been replaced by spares will be returned to ground for refurbishment.

Phase IV Spares Program - Annual Resupply

o Expendable - Denoted by E in Table 2.4.4.3-1.

o Refurbishable - Denoted by R in Table 2.4.4.3-1.

2.4.4.4 Logistics Support System

The original Skylab program and missions were structured around the "all-up" expendables and consumables provisions concept in which all items were stored onboard the Skylab. This approach simplified the mission operations, reduced initial costs to some degree, and established the maximum number of on-orbit crew days. In contrast, Skylab reuse missions must be entirely supported through a logistics resupply system which will provide both replenishment of the existing storage capability and additional on-orbit storage. The following lists the primary items to be resupplied for Skylab reuse and correlates each item with the initial Skylab procedure.

SKYLAB CONSUMABLES/EXPENDABLES PROPOSED RESUPPLY INITIAL MISSION/SKYLAB REUSE -

I. Food - Dehydrated, Intermediate Moisture and Wet Pack

- o Initial - Food packages were loaded into the containers and then the loaded food containers were installed in the OWS.
- o Reuse - Food packages will be transferred from the logistic vehicle to be stored in the existing food containers.

- Frozen

- o Initial - Freezers were installed in the OWS and checked out. Frozen food packages were brought aboard the OWS and placed in the freezers.
- o Reuse - Frozen food packages will be transferred from the logistics vehicle to the existing freezers.

II. Water

- o Initial - Ten water containers were individually charged by a drag-in water line after they had been installed in the OWS.
- o Reuse - As configured, the OWS would accept water from the logistics vehicle either by (1) a drag-in line to connect the logistics vehicle water container(s) to the OWS water dispensing system or (2) portable water bottles. The portable water bottles could be either of a single or multiple use variety and could be utilized directly or connected to the existing OWS water dispensing system.

The recommended approach would eliminate the drag-in line and portable bottles by the installation of a hard line to connect the logistic vehicle water supply tanks (through an external umbilical next to the logistics vehicle docking port) to a water supply port in the OWS. The OWS water fill line would probably come through a hull fitting temporarily mounted in the scientific airlock.

III. Stowage Allocations and Provisions

The storage subsystem provides storage of the necessary mission support supplies, expendables, and loose items as dictated by the following stowables:

- a. Mission equipment
- b. Waste management supplies and equipment
- c. Hygiene supplies
- d. Crew clothing
- e. Personal equipment
- f. Sleep equipment
- g. Maintenance equipment
- h. EVA/IVA support equipment
- i. Food management equipment

Each stowable item was stored in OWS Standard Stowage Lockers, AM Stowage Boxes, MDA Stowage Containers, OWS Ring Containers, or OWS Special Stowage Containers, as applicable.

- OWS Standard Stowage Lockers
 - o Initial - A standard stowage locker consists of an installation of vertically stacked compartments and can accommodate as many as six compartments in a vertical assembly. The interior of each compartment provides for stowable item supply and temporary stowage, with appropriate restraints, for launch and on-orbit environment. These empty standard stowage lockers are installed in the OWS at various locations in the OWS Forward Compartment and in each of the Crew Quarters compartments.

- o Reuse - The standard stowage locker compartments can be reloaded by manual transfer of packaged items from the logistic vehicle.
- AM Stowage Boxes
 - o Initial - Stowage in the AM is provided by stowage boxes located in the AM Aft Compartment, AM Lock Compartment, AM Forward Compartment, and in the Structural Transition Section and each is sized specifically to accommodate a given stowed item. Adjustable restraints are provided in those stowage boxes which store consumable items. Fitted restraints, hard mounting and contour mounting is provided to restrain non-depletion mission equipment. These boxes can either be preloaded and then installed or installed and then loaded with their appropriate cargo.
 - o Reuse - AM Stowage boxes which contain depletable items can be restocked manually from the logistic resupply vehicle.
- MDA Stowage Containers
 - o Initial - These containers can be preloaded and installed or installed empty and then loaded.
 - o Reuse - Depleted containers can be resupplied manually from the logistic vehicle.
- OWS Ring Containers
 - o Initial - These containers which are located above the water bottles were preloaded and then installed.
 - o Reuse - The ring containers can be reloaded by manual transfer of items from the logistic resupply vehicle.
- OWS Special Stowage Containers
 - o Initial - Special stowage containers include the film vaults and peculiar spares containers which were preloaded and installed.
 - o Reuse - Depleted film vaults and spares containers can be resupplied manually from the logistic vehicle.

IV. Thruster Attitude Control System Propellant

- o Initial - GN_2 was loaded into the TACS bottles through an umbilical located on the OWS aft skirt. After loading the umbilical was disconnected and manually capped.
- o Reuse - As presently configured, the TACS could be supplied with GN_2 from the logistic vehicle (docked at the MDA) via a flexible line which would be connected to the umbilical by a crew member during an EVA operation.

With EVA modification, a hard line could be installed to accept an external umbilical connection between the logistic vehicle gas supply and a TACS line at the MDA docking port. If the umbilical disconnect were automated, this would eliminate the need for an EVA operation.

V. AM Life Support GN_2 and GO_2

- o Initial - GN_2 and GO_2 bottles, which are external to the AM tunnel, were loaded by hoses which were dragged in through an access door in the FAS.
- o Reuse - As presently configured, it is not possible to resupply the GN_2 and GO_2 through the FAS access door as it is too small to allow a crew member who has been suited up for an EVA operation to pass through. Therefore, the outer thermal curtains would be removed and either drag-in lines or a hard manifold would be connected to the bottles' pressurization port. A modification that would provide an umbilical at the MDA for either a hard or flex line connection to the logistic vehicle GN_2 and GO_2 tanks is required.

VI. Internal Openings Clearance

In the orbital configuration, the tightest clearance envelope exists at the AM aft internal hatch which is at the bellows connection between the AM and the OWS. The maximum free opening dimension is 0.75m (29.1 in). The length would be a function of the maximum length that could be stowed in the logistic vehicle or by the maximum length that could be turned around intervening corners when transferred from an end-docked Orbiter, or a radially docked logistic vehicle into the MDA.

VII. Non-consumable/Expendable Classified Items

- o Initial - Items such as PCGs (including batteries), TACS control valves, ECS pumps, etc., are designed with built-in redundancy to provide a high level of confidence of meeting the mission life requirements. Replaceable spares were not provided due to the external location of these items and the hazards and complexity associated with an EVA operation.
- o Reuse - These services would be provided by the 25 kW Power Module, however, if mission operations required that the power module be removed (undocked) during unmanned operations then it would be necessary to determine onboard subsystems reliability or replacement concepts.

VIII. Waste/Trash Disposal

For a reuse mission, the remaining screened waste/trash disposal volume in the aft tank would be utilized. The installation of a waste/trash compactor onboard would provide a method of increasing the efficient utilization of the existing trash volume and ultimately the logistics system would return the waste/trash to earth.

Logistics Systems Options

A variety of system configurations must be considered before a final selection of the optimum systems for Skylab can be selected. Programmatic and technical characteristics which must be evaluated include: crew safety, transfer efficiency, orbital timelines, available hardware, operational flexibility, traffic model, EVA limitations, cost tradeoff, etc. In this current study, an initial evaluation was conducted and preliminary recommendation has been made.

The characteristics and requirements analyzed are described in the following data. The ultimate optimization is recommended as a major task for the next phase of study.

In order to size the basic system, a trade matrix was prepared to bound the basic system.

The following limiting physical constraints which define the size of a logistic system, (1) crew size, (2) mission duration, (3) dedicated consumables

volume, and (4) EVA support, were plotted for comparison of several logistics concepts as shown in Figure 2.4.4.4-1. Dedicated volume is defined as that volume allocated for stowage and access of consumables. Normally, the packaging of dedicated volumes requires a factor ranging from 2.5 to 1 up to 5 to 1 more volume to permit both manned access and ground removal/refurbishment than the actual volume of the consumables.

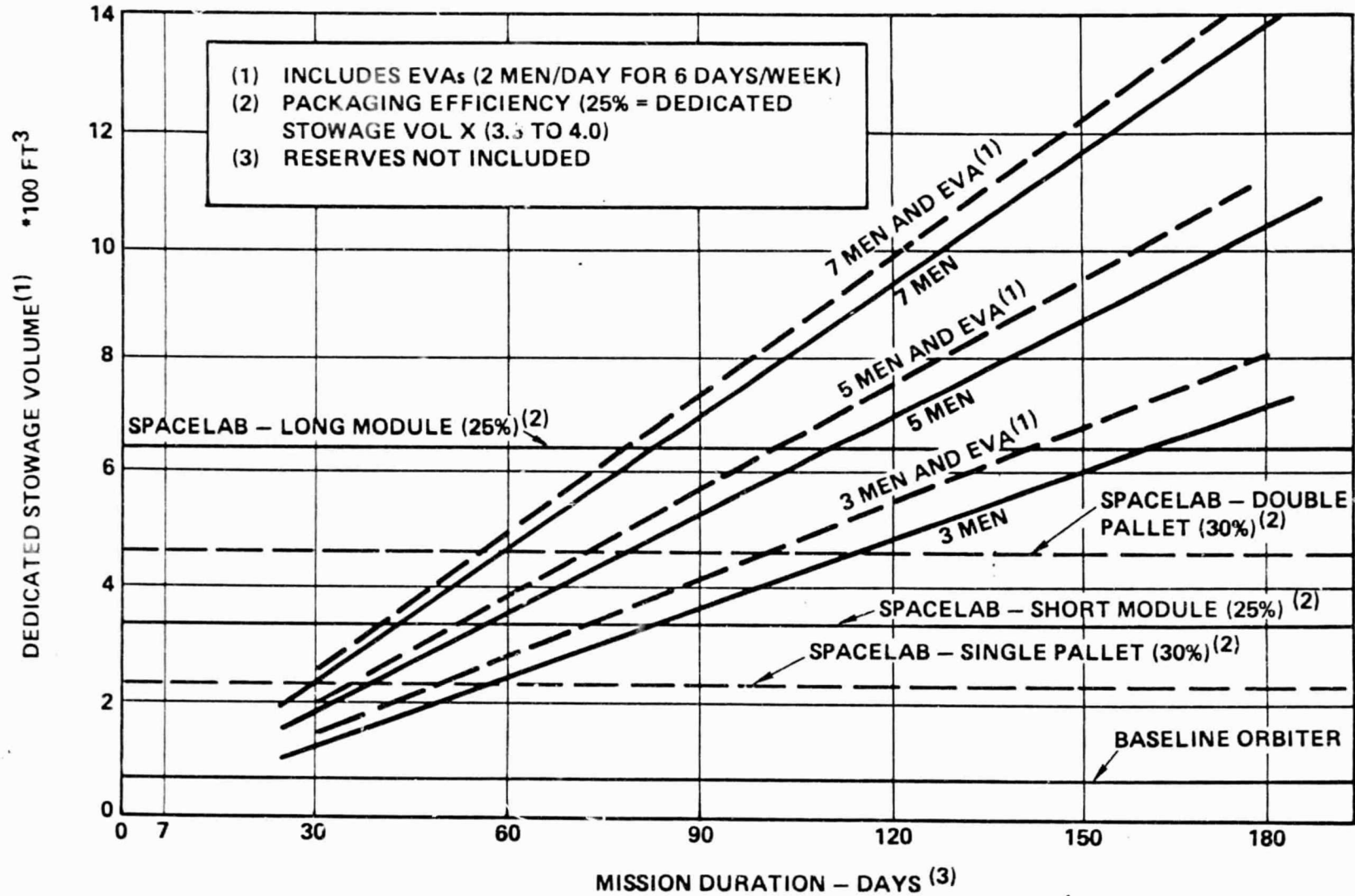
As a basis for sizing and comparison, both single and double Spacelab pallets plus short and long-module Spacelab logistic schemes were evaluated. Using a packaging factor of 4 to 1 (25%), a long-module Spacelab with five men has a logistics capacity of 120 days. A three-man crew can be supported for 160 days. The basic Orbiter, without augmented logistic capability, would have approximately 30 days capability using only cabin volume.

Figure 2.4.4.4-2 depicts a typical long logistics module capable of providing the support shown in the preceding figure. Figure 2.4.4.4-3 similarly depicts a basic Spacelab pallet which has been modified for logistics support.

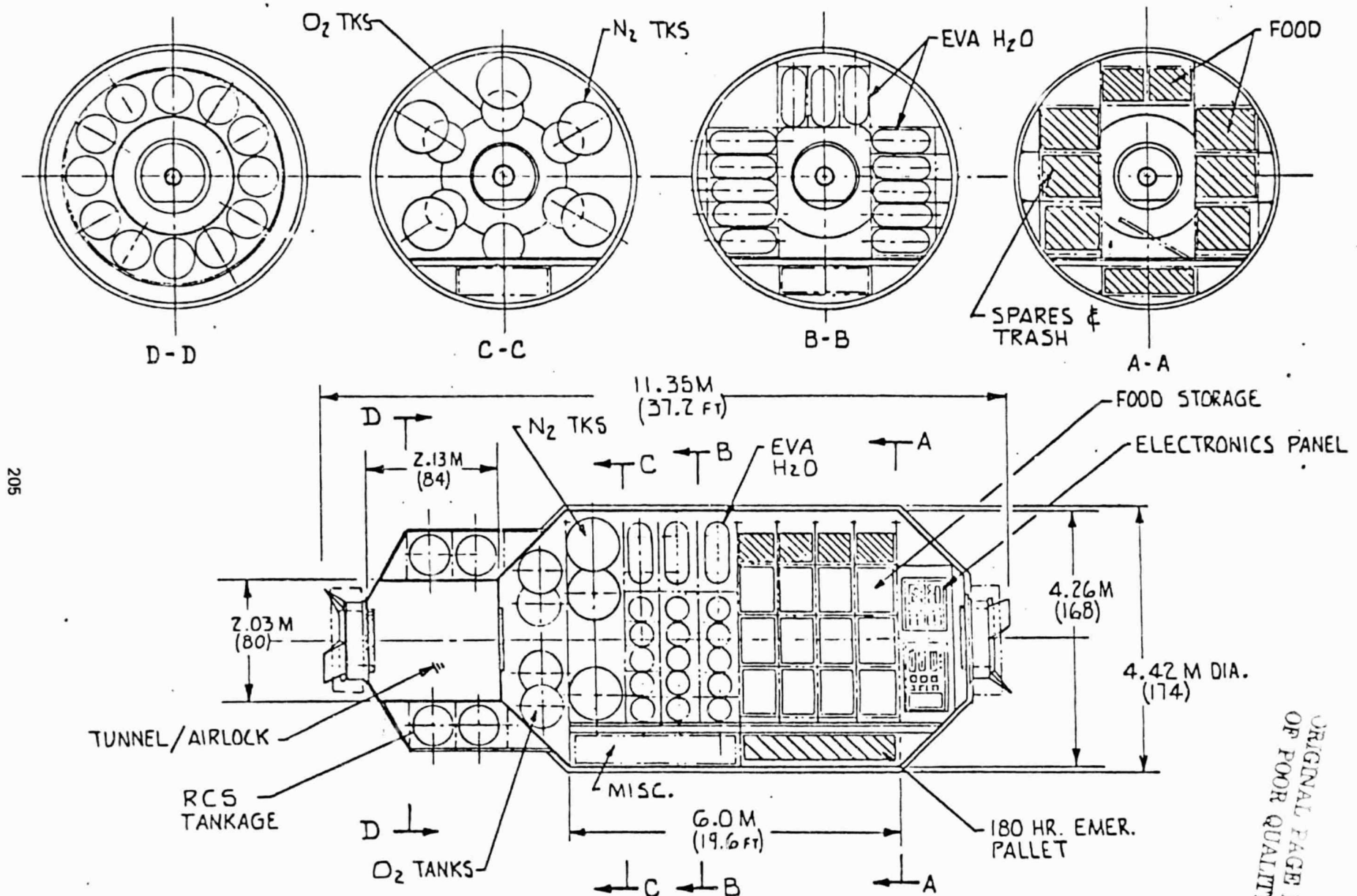
Baseline Mission

The baseline mission used to evaluate logistics resupply for continuously-manned missions is a crew of five operating for 60 days. Using mission support planning consumables, developed on the actual Skylab program, typical crew and mission support consumables requirements for a continuously-manned mission is presented in Figure 2.4.4.4-4. The food includes frozen, refrigerated, and dry/canned. Water has been allocated for metabolic, showers, housekeeping, EVA-EMU cooling circuit, and a system purge with each resupply. The gaseous nitrogen will supply makeup gas for cabin leakage and a repressurization of the Skylab. This requirement leaves an excess of approximately 18% nitrogen in two Skylab tanks at rated pressure. The gaseous O_2 will also supply these requirements plus the O_2 for metabolic requirements and has an excess of approximately 2%. Crew equipment is based on an average of actual crew expendables used in the three Skylab missions. The spares are replaced at the lowest replaceable unit (LRU) which is based on continuous usage of systems. Trash stowage is available in the OWS LOX tank and by using a trash compactor, over 4500 man-days of collection are available (approximately 2-1/2 years with a five-man crew). An alternate approach to trash disposal is to return it in the logistics module.

CONSUMABLES STOWAGE REQUIREMENTS



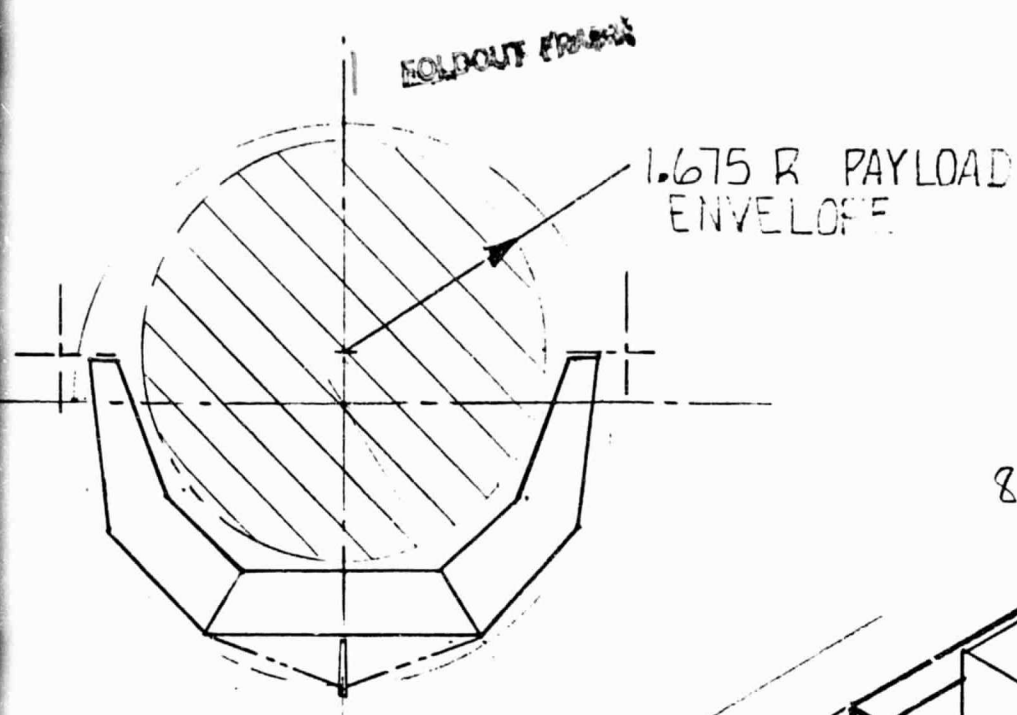
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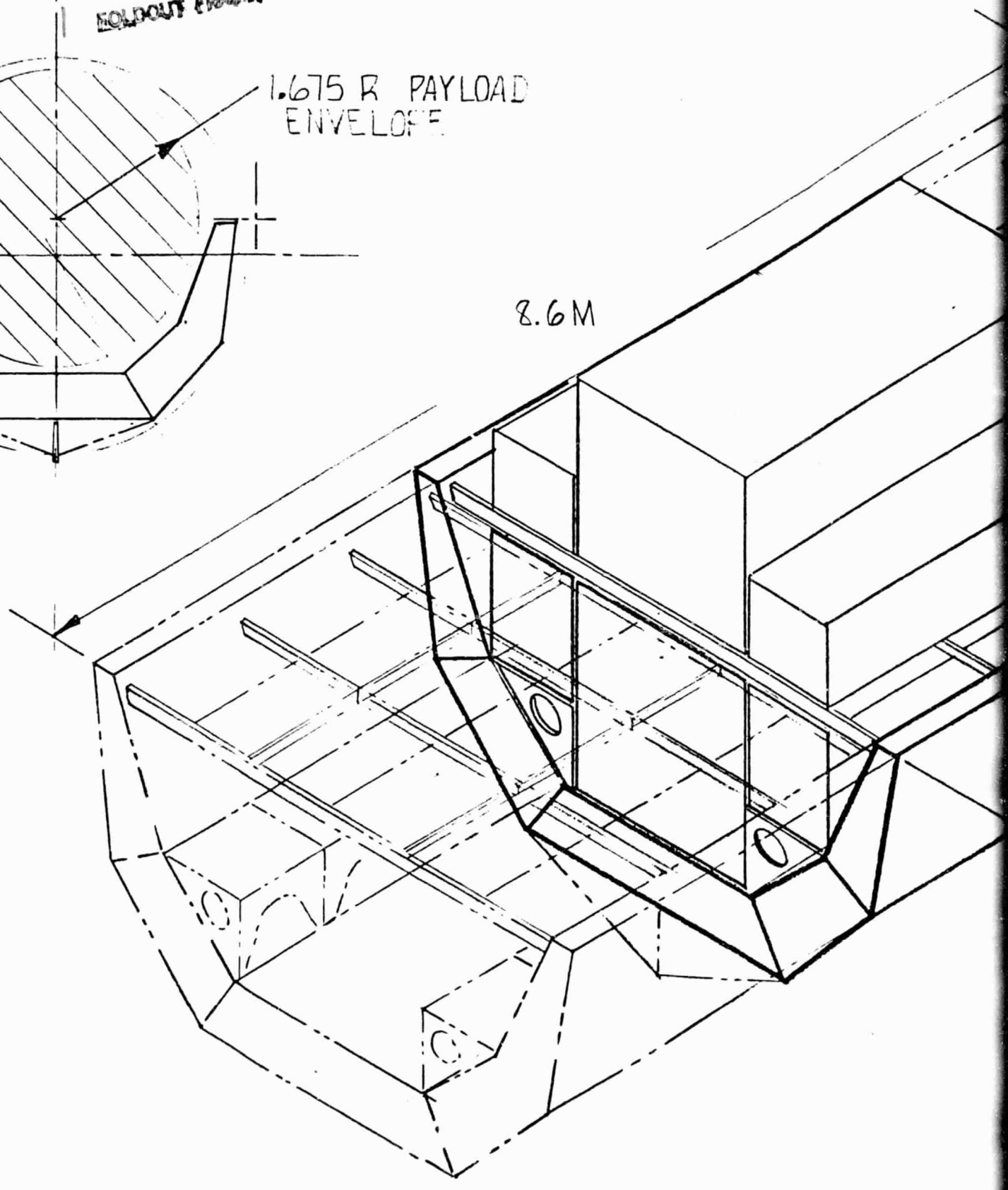
205

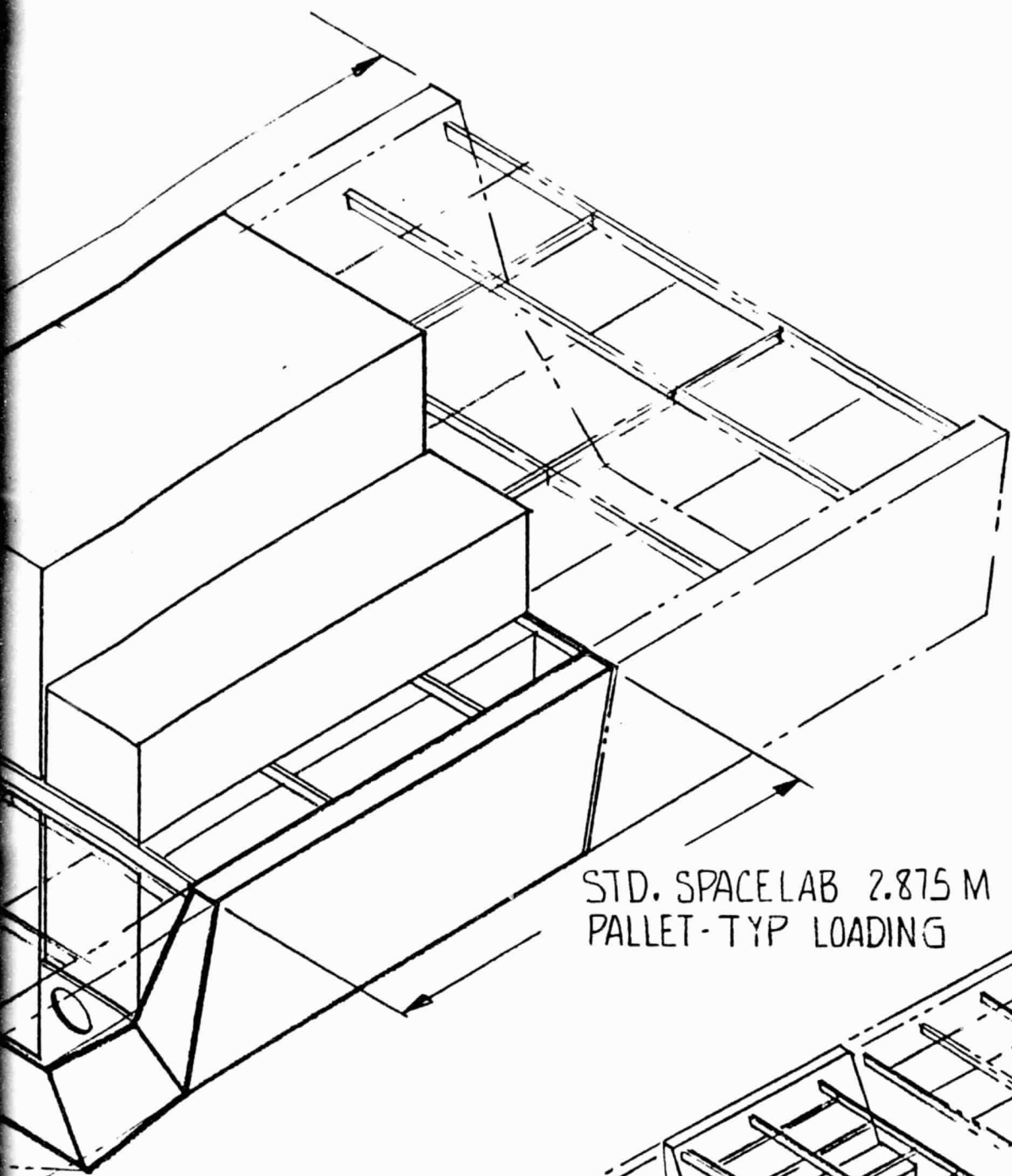
Figure 2.4.4.4-2. Logistics Module Concept

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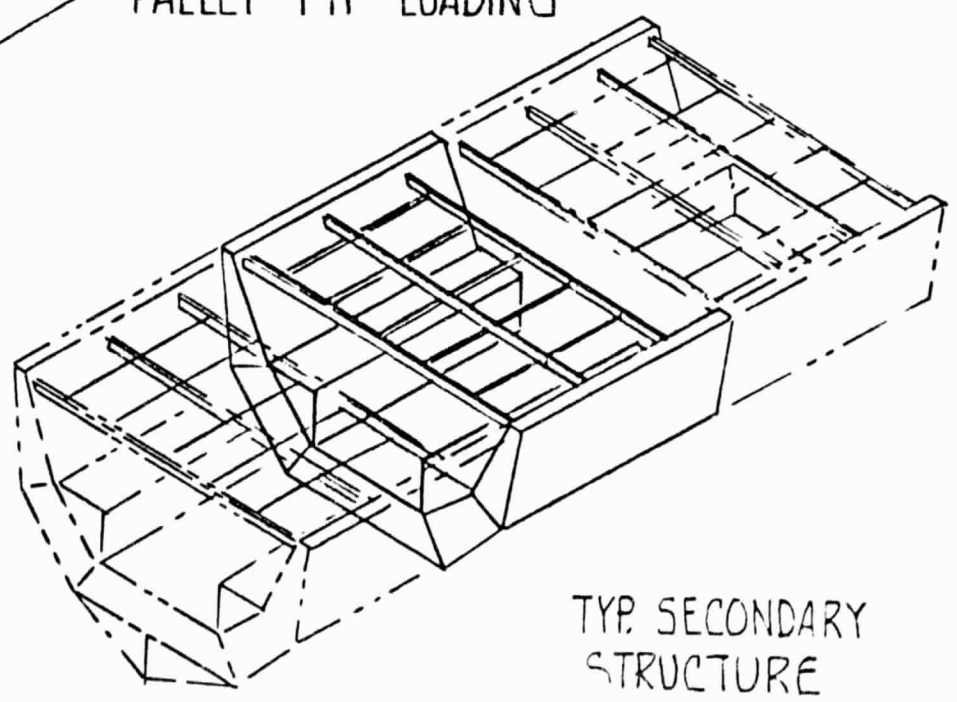
8.6M





1 FOLDOUT FRAME

STD. SPACELAB 2.875 M
PALLET-TYP LOADING



TYP. SECONDARY
STRUCTURE

Figure 2.4.4.4-3. Spacelab - Double Pallet

TYPICAL LOGISTIC STOWAGE REQUIREMENTS

(5 CREW - 60 DAY RESUPPLY + 30 DAY RESERVE)

<u>FUNCTION</u>	<u>VOLUME (FT³)</u>
• CONSUMABLES STORAGE	465
- FOOD	97
- WATER (~ 7 TANKS)	77
- NITROGEN (1 TANK)	19
- OXYGEN (2 TANKS)	116
- CREW EQUIPMENT	156
• SPARE (LRU) STORAGE	23
• ATTITUDE CONTROL (GN ₂)	99
• EXPERIMENT SUPPORT	TBD
• TRASH STORAGE	53
TOTAL VOLUME	640 + (TBD)
•• LOGISTICS SYSTEM VOLUME = 2,000 TO 2,500 FT ³	

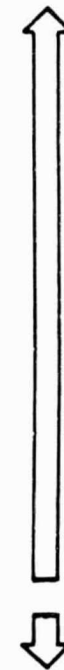


Figure 2.4.4.4-4

To determine the total volume of a logistics module, a 25% stowage efficiency factor was used for the pressurized module and 30% for an open pallet. This factor includes the access requirements, open space corridors, and difficult areas (e.g., end domes) as well as the basic consumables packaging. This accounts for the stowage within the pressurized volume. The high pressure gases (GN_2 at 19 cubic feet/ GO_2 at 116 cubic feet) would be installed as external stores.

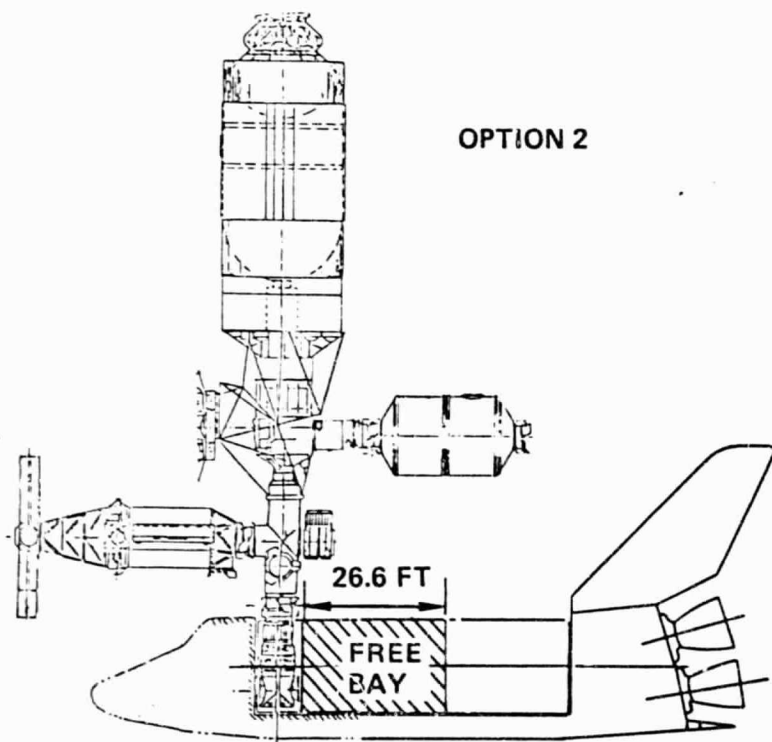
Logistic Support System Options

One of the key operational considerations required to reactivate and maintain a Skylab Reuse program is consumables resupply. In the early missions, during Phase II (i.e., inspection/refurbishment) and Phase III (i.e., Shuttled-tended operations) the consumables will be supplied by the baseline Orbiter. Presently this is capable of 28 man-days of orbital operations (e.g., four crew members for seven days). Extending the Orbiter will involve the installation of various kits which have been conceptually defined by the STS program.

The investigation of the logistics systems concepts shown in Figure 2.4.4.4-5 has been accomplished as an element of eventual continuously-manned missions when the Orbiter is docked only during consumables resupply and crew transfer.

Option 5 is sufficient for the initial refurbishment phases since a crew of up to five can be supported for approximately 32 days. For the continuously manned phases, Option 2 berthed to the Skylab cluster is the preliminary selection. Utilizing the broad data base which has been developed on both space station and Skylab studies, this option was selected on the basis of operational efficiency, maximum crew convenience, and crew safety. In all cases beyond 30 days logistics, some form of logistic module/pallet scheme is required. Those berthed to the Skylab cluster provide the added advantage of reducing crew time in direct support of logistic resupply but also serves as a pantry for improved inventory control of consumables and trash stowage. Several decisive factors favoring a pressurized system are: (1) EVA consumables transfer not required, (2) ease of access, (3) secondary retreat center with manned consumables, (4) EVA rescue access if required, and (5) ground packaging with new crew(s) familiarization.

LOGISTIC SUPPORT SYSTEM OPTIONS (5 CREW)



LOGISTIC SYSTEM OPTION	LOCATION	MISSION DURATION (DAYS)			TRANSFER		CARGO BAY FREE LENGTH (FT)
		DESIGN POINT	MAXIMUM STOWAGE		PEAK CREW	OPS TIME (DAYS) MODE	
			SKYLAB	LOGISTIC SYSTEM			
1. LOGISTICS MODULE	ORB	90	~ 100	110	1-2	3 SHIRT SLEEVE	21.9
2. LOGISTICS MODULE BERTHED	SKYLAB	90	100	110	1-2	A/R SHIRT SLEEVE	26.9
3. SPACELAB PALLETS	ORB	90	~ 90	(1) 115/75	5	6 EVA	19.3 29.7
4. SPACELAB PALLETS BERTHED	SKYLAB	90	~ 90	(1) 115/75	5	4 EVA	17.3 27.7
5. MODIFIED ORBITER	CABIN	60	~ 100	32	1-2	2 SHIRT SLEEVE	53.3

(1) 3 PALLETS/2 PALLETS
(2) 30 DAYS RESERVE ON-BOARD SKYLAB

Outboard profile concepts for each of the five options are shown in the following Figures 2.4.4.4-6 thru 2.4.4.4-10. The basic interface connections have been identified and conceptually shown. Crew traffic patterns along with salient characteristics are also included.

The conceptual options developed in this study will be subjected to detailed trade studies during any follow-on activity. Trade study parameters must include at least: crew safety, crew operational efficiency, available hardware, installation complexity, mission timeline, Orbiter operations, subsystem interfaces, cost, and schedule.

Design implementation can also be analyzed to determine the most effective approach to the installation of the fluids resupply manifolds. Initial evaluation of the attach umbilical connections has determined that: (1) the AM atmospheric gases (N_2/O_2) would be the most difficult to reach. However, several points should be considered. There are 21 tanks each with separate fill connections and a single outlet pressurization manifold with back-flow check valves attached to all tanks. Therefore, if a tank fill port cannot be safely reached, it can be omitted. This is due to the original gas storage system sizing which supported the entire 170-day manned period without resupply. If a logistics module is berthed to the Skylab during manned operations, a single umbilical connection can be made and the atmosphere resupply source on the logistics module be used as the primary supply; (2) the OWS water bottles can be recharged with a temporary or permanent refill line coming through a bulkhead-type fitting mounted in a scientific airlock; and (3) external manifolds which extend along the permanently installed cluster can be flexible hoses with fixed restraint points.

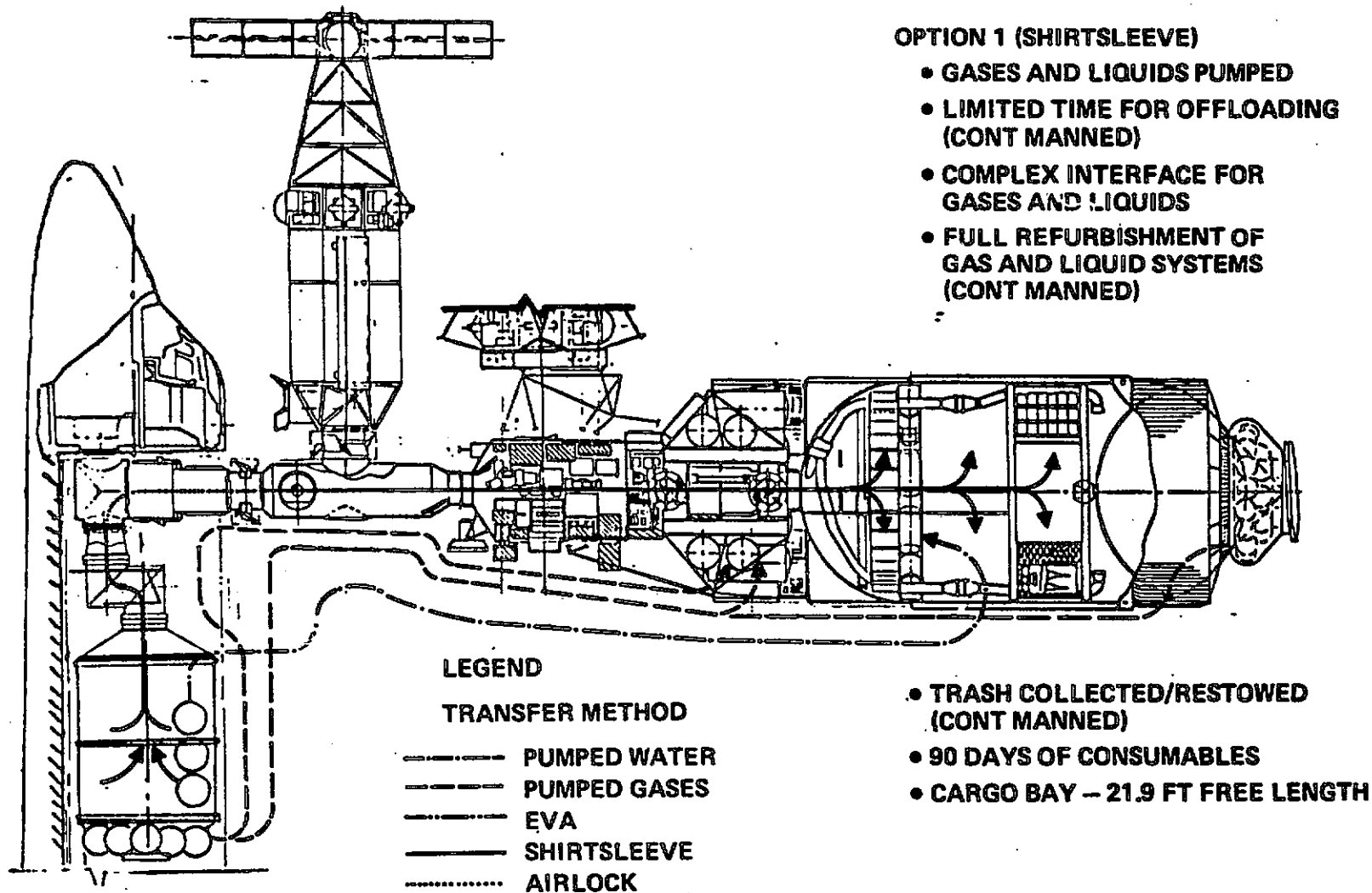


Figure 2.4.4.4-6. Option 1 - Pressurized Module in Orbiter Cargo Bay - Shirtsleeve Transfer

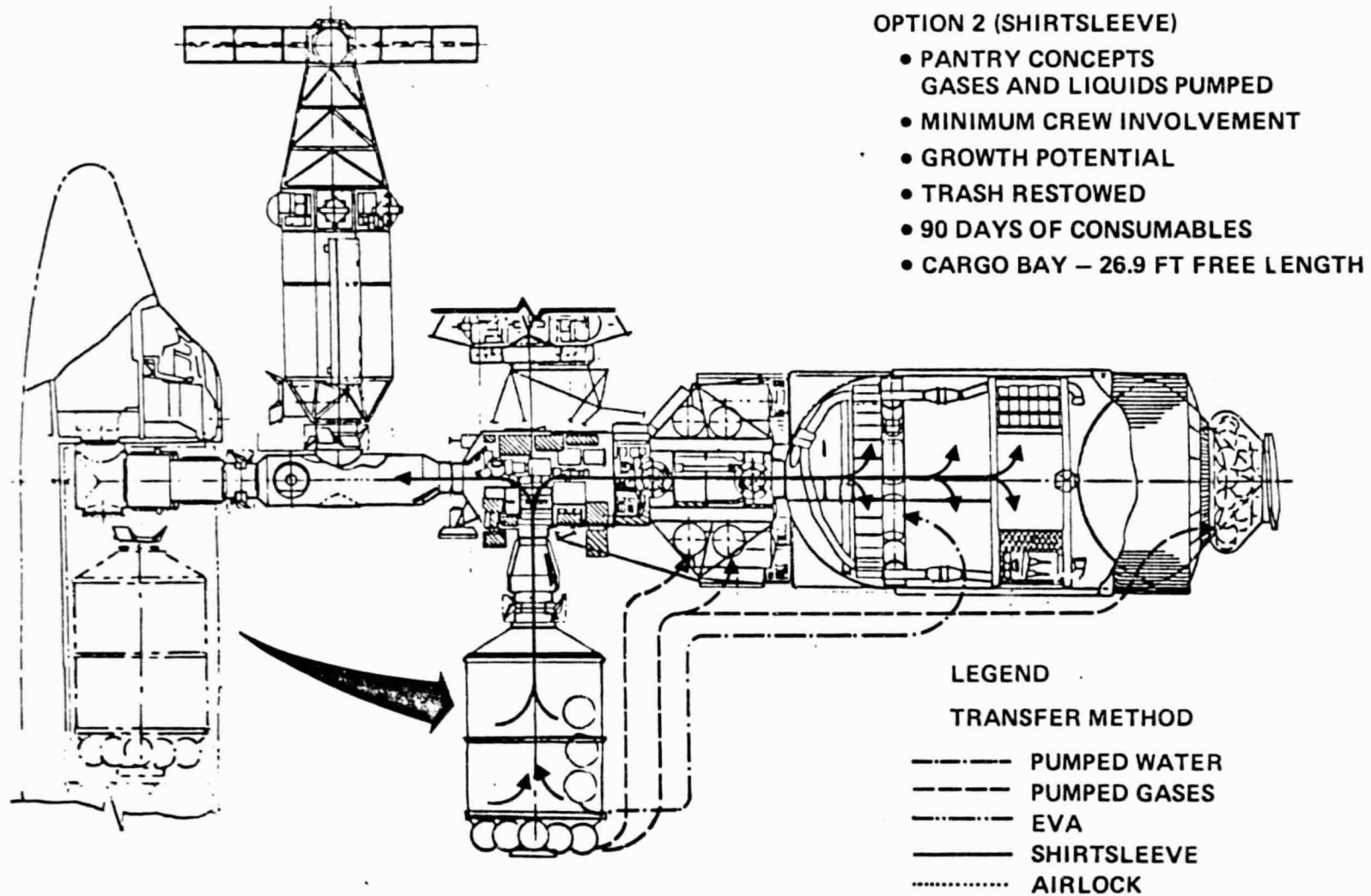


Figure 2.4.4.4-7. Pressurized Module Berthed to Skylab Option 2 - Shirtsleeve Transfer

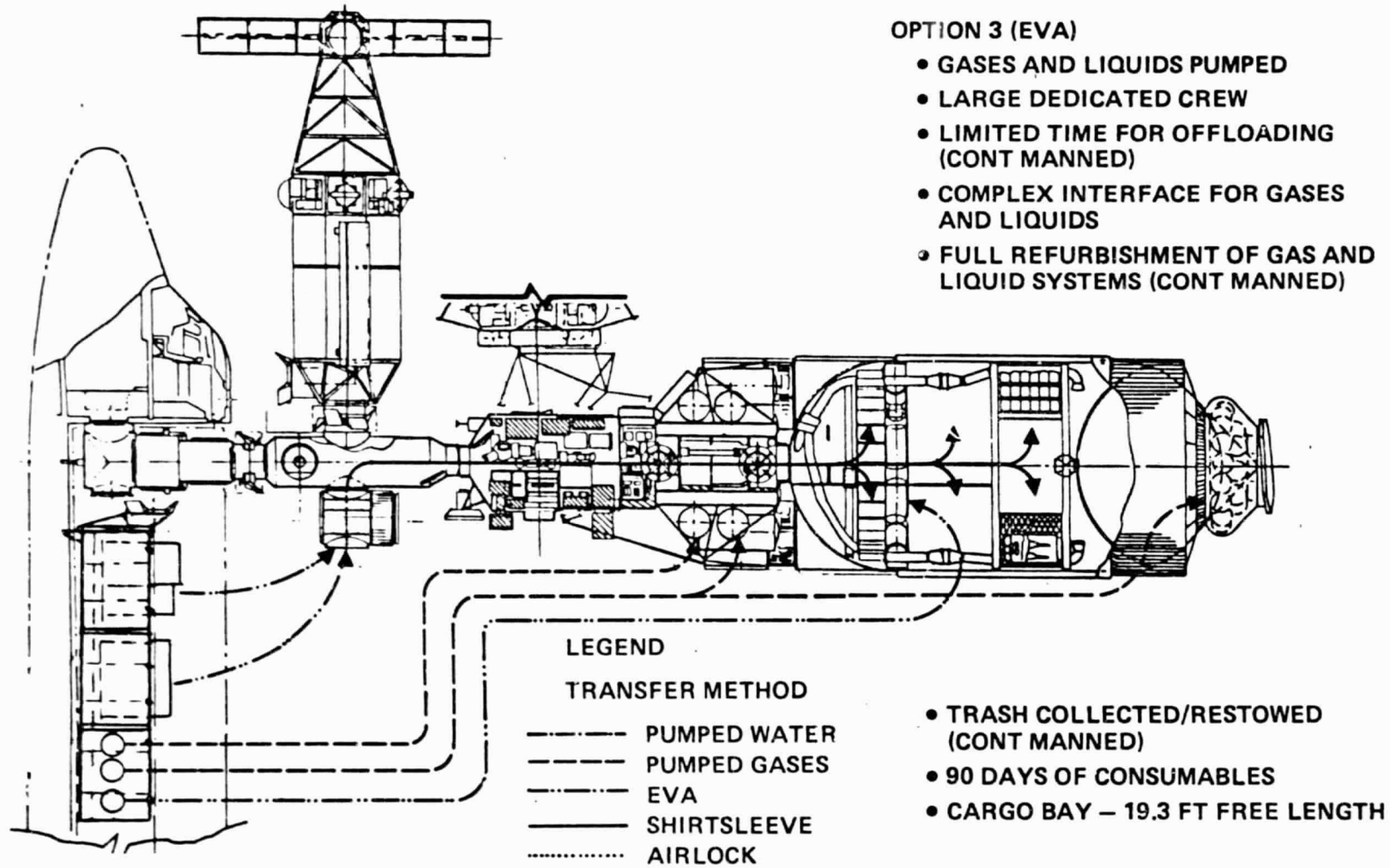


Figure 2.4.4.4-8. Option 3 Spacelab Pallets in Orbiter Cargo Bay - EVA Transfer

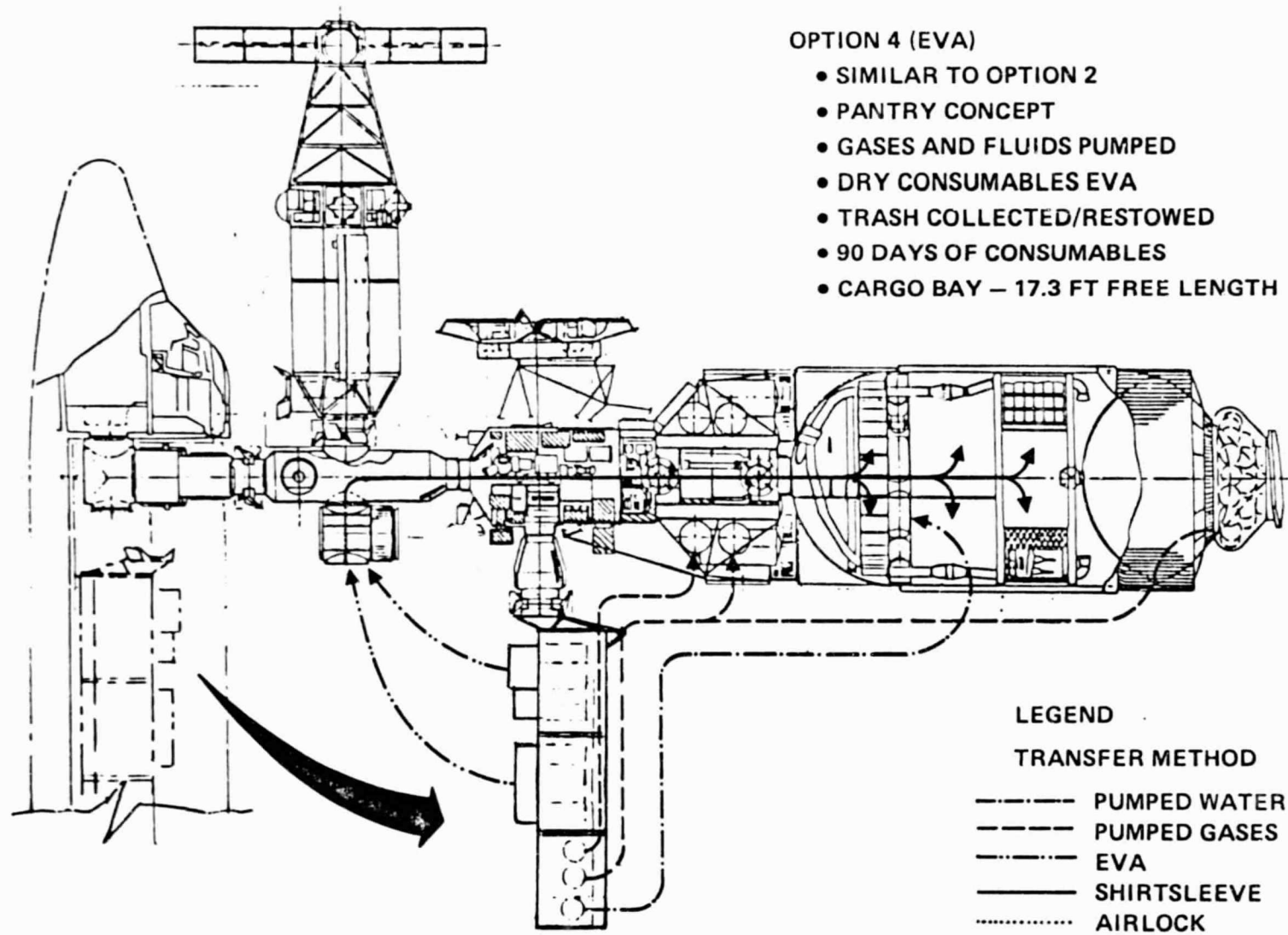


Figure 2.4.4.4-9. Option 4 Spacelab Pallets Berthed to Skylab - EVA Transfer

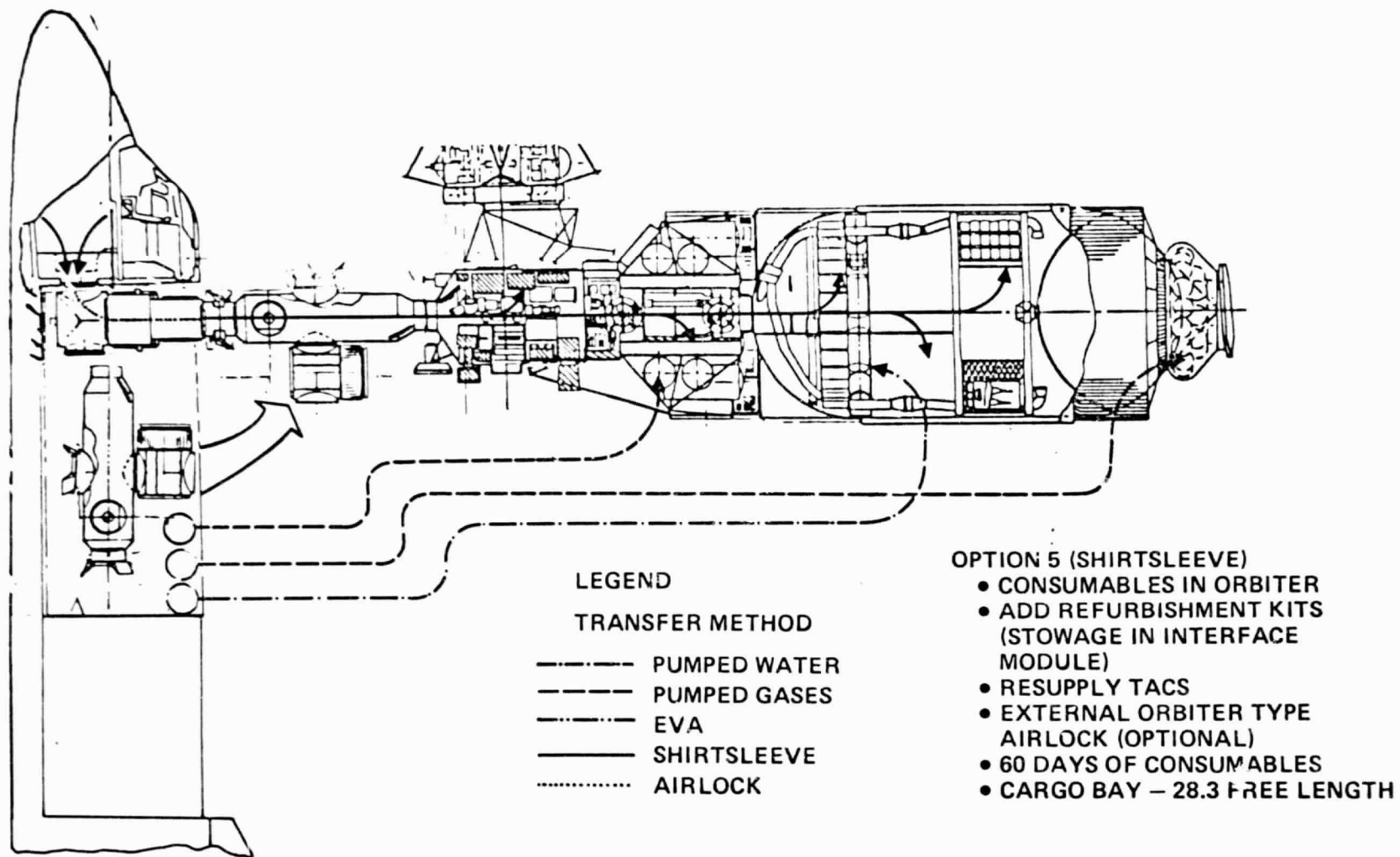


Figure 2.4.4.4-10. Option 5 - Modified Orbiter - Shirtsleeve Transfer

Section 3 CONCLUSIONS

The following conclusions have been drawn from a variety of data sources. Although these conclusions are valid at the time of this report preparation, the key conclusion which cannot be made is the operational life expectancy of the vital components that are required for rendezvous and docking maneuvers. The data sources include the following: original performance information, end-of-mission status, reactivation/interrogation results, and the reuse study.

- o Skylab system/subsystems are healthy
- o Skylab reuse will enhance STS operations--especially long-duration missions
- o Reuse can benefit life sciences, material processing and engineering studies (material exposure, space construction)
- o Skylab can provide habitability accommodations for crews of five to seven with minimum modifications
- o Skylab's IOC (circa 1983) is appropriately timed to support payload development scenarios
- o Long-duration missions ≤ 30 days or $\leq 3-4$ crew will require a dedicated logistics system
- o Skylab can effectively support both crew and capability growth in concert with a controlled (i.e., rapid or slow) evolutionary plan

A further and important conclusion is the near-term potential of Skylab utilization with minimum refurbishment and without the addition of a power module. This class of mission could include Orbiter habitability support, utilization of existing experiment equipment, carry-on experiments, and materials analysis.

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