SECOND INTERIM BRIEFING (DR-8)

EVOLUTIONARY SCIENCE AND APPLICATIONS SPACE PLATFORM

(CHARACTERIZATION OF CONCEPTS)

(TASKS A AND B)

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY
SECOND INTERIM BRIEFING (DR-3)

EVOLUTIONARY SCIENCE AND APPLICATIONS SPACE PLATFORM
(CHARACTERIZATION OF CONCEPTS)
(TASKS A AND B)

NOVEMBER 1981

MDC 9744
PREFACE

This document contains material prepared by McDonnell Douglas Astronautics Company* for the
Second Interim Briefing on a Characterization of Concepts for an Evolutionary Science and
Applications Space Platform as defined in the Statement of Work for Contract NAS8-33592 by
Marshall Space Flight Center, where the contact is:

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*Hamilton Standard has been given a $5000 subcontract for provision of selected ECLSS
concepts and data.
STUDY OBJECTIVES

Define, Evaluate, and Select Concepts for Evolving:

- A Space Station in Conjunction with the Space Platform for NASA Science, Applications, Technology ($250K) and, DoD ($140K)

- A Permanently Manned Presence in Space Early, with a Maximum of Existing Technology
SPACE PLATFORM EVOLUTION

- Power System Platform (Three Payloads)
- Spacelab Sortie
- Manned Platform
- Six Payload Unmanned Platform
- Advanced Manned Platform
- Advanced Unmanned Platform

Timeline:
- 1987
- 1990
STUDY TASKS

A. Special Studies of Unmanned Platform in Areas Highlighted in Prior Study ($50K)

- Innovative Basic Concepts
- Control System Dynamics
- Payload Accommodation Assessment

B. Conceptual Definition of Manned Platform ($250K)

- Requirements and Candidate Concepts
- Systems Analysis and Definition
- Comparisons, Programmatics, and Selection
# AGENDA

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**STUDY TASK FLOW**

**INPUTS**
- SASP STUDY RESULTS
- POWER SYSTEM DEFINITION
- SASP PAYLOAD ACCOMMODATIONS ASSESSMENT
- SPACELAB Risk FOD DEFINITION
- STS HANDBOOKS AND PLANS
- MSFC IN-HOUSE STUDIES ON MANNED PLATFORM

**TASK A** SASP SPECIAL STUDIES
- INNOVATIVE BASIC CONCEPTS
- CONTROL SYSTEM DYNAMICS
- PAYLOAD ACCOMMODATION ASSESSMENT

**TASK B** MANNED PLATFORM CONCEPT
- B.1 REQUIREMENTS
- B.2 CONCEPT IDENTIFICATION
  - EXISTING
  - ADVANCED TECHNOLOGY
  - CUSTOMER APPROVAL

**B.3 SYSTEM ANALYSIS AND DEFINITION**
- SYSTEM
- VEHICLES
- SUBSYSTEMS
- INTERFACES

**B.4 COMPARISON OF CONCEPTS**

**B.5 PROGRAMMATICS**

**OUTPUTS**
- INNOVATIVE SASP CONCEPTS, DYNAMICS AND P/L ACCOMOD
- REQUIREMENTS FOR MANNED PLATFORM
- CANDIDATE CONCEPTS
- DEFINITION OF COST EFFECTIVE APPROACH TO EVOLVING MANNED PLATFORM
- TRADES AND ANALYSES
- WBS, COSTS AND SCHEDULES
- SYSTEM INTERFACES
- PHYSICAL CHARACTERISTICS
- IMPACT OF REPRESENTATIVE MISSIONS ON:
  - POWER SYSTEM
- TECHNOLOGY REQUIREMENTS
STUDY SCHEDULE

A. Unmanned Platform Special Studies
   1. Innovative Basic Concepts
   2. Control System Dynamics
   3. Payload Accommodations

B. Manned Platform Concept
   1. Requirements
   2. Concepts Identification
   3. Systems Analysis and Definition
   4. Comparison of Concepts
   5. Programmatic
CONTENTS OF BRIEFING

- Image Motion Compensation Interfaces

- Payloads
  - Early: 90-Day Solar-Terrestrial and Life Science Activities
  - Late: OTV Operations Impacts

- Updated Design Guidelines and Criteria
- Crew Size Sensitivities
- Configuration Design and Accommodations
  - Airlock/Adapter
  - Habitat/Control Center
  - Logistics Module
- Habitability for Each Configuration

- Subsystem Design
  - Approach Options and Sensitivities
  - Division of Functions and Distribution of Equipment
  - Hamilton Standard Inputs on ECLS

- Operations
  - Shuttle Loading
  - Configuration Buildup

- Attitude Durations/Atmospheric Density

- Safety and Reliability
  - Relationship to Power System
  - Redundancy vs Spares
  - Meteoroid Protection

- Programmatics Plans/WBS and Dictionary
Special Studies

1. Innovative Basic Concepts: Tether Data Gathering Only in Report Period

2. Control System Dynamics: Data Gathering and Study of “No Pointing System” Case
   (Image Motion Compensation Interfaces)

3. Payload Accommodations Assessment (Started Dynamics/Damping Emphasis)

   Started 1 November
PLATFORM/PAYLOAD IMAGE MOTION COMPENSATION INTERFACE STUDY (SUBTASK A.2)

Objectives
- Gain Insight Into IMC Requirements For Platform Payloads; Particularly When No Auxiliary Pointing System (APS) Is Used
- Increase Overall Understanding of Platform, APS, and Payload Pointing Requirements
- Establish Dialogue Between Platform and Pointing Payload Designers

Approach
- Discuss IMC System Designs and Capabilities With IMC System Designers
- Survey Ground- and Space-Based Pointing and IMC System Designs and Operations
- Generate Potential IMC Requirements For Selected Payloads Assuming No APS Used

Progress
- Contacts With SIRTF and SOT Designers Established
- Survey of SOT and SPIE Pointing Conference (Feb 81) Papers Completed, Summarization Underway
Questions

- What is Appropriate Division of Labor Between Image Motion Compensation (IMC), Auxiliary Pointing Systems (APS), and Space Platform (SP)?

- What Are the Implications/Sensitivities to Increasing the Role of IMC While Reducing the Role of APS?

- Same as Above But Increasing the Role of APS or SP and Reducing the Roles of the Remaining Components
IMC = Image Motion Compensation
APS = Auxiliary Pointing System
TYPICAL POINTING COMPONENT FUNCTIONS/ROLES

Image Motion Compensation

- Small Amplitude, High Bandwidth Stabilization of Target in Experiment Field of View
- Often Combined With Offset Pointing and Chopping Functions
- Mechanized Within Facility

Auxiliary Pointing System

- Medium-Amplitude, Medium-Bandwidth Stabilization of Facility or Target in Experiment Field of View
- Often Combined with Large Angle Facility Orientation Capabilities
- Mechanized External to the Facility

Space Platform

- Low Bandwidth Stabilization of the Vehicle
- Orientation of Vehicle
## REPRESENTATIVE POINTING COMPONENT DATA

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<tr>
<th></th>
<th>Stability (Arc Sec)</th>
<th>Accuracy (Arc Sec)</th>
<th>Amplitude* (Arc Sec)</th>
<th>Bandwidth (Hz)</th>
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<td>APS</td>
<td>0.01–10</td>
<td>0.1–5</td>
<td>60–360</td>
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<tr>
<td>SP</td>
<td>1–120</td>
<td>1–1800</td>
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<td>0.01–0.5</td>
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*Maximum Amplitude For Which Pointing Component Can Compensate
Example: SIRTF Operations Operational Modes

Point Source Observation
- Chopping Using Secondary Mirror (5-420 Sec Arc)
- Nodding Whole Facility (Amplitude of Chopping)

Mapping
- Up to 1 x 1-Deg Area
- Raster Motion of Whole Facility

Searching
- Up to 3 x 3-Min Arc Area
- Spiral Search With Secondary Mirror
- Move Whole Facility to Center the Source

Calibration
- Simultaneous Viewing of a Source by Several Sensors

Target Acquisition
- Accurate Slewing to New Target
- Use of Guide Stars and Offset Pointing
- Man Participation Required Some Times
- Scanning/Searching Sometimes Needed
DIRECT SIRTF MOUNTING TO PLATFORM EXAMPLE

SHUTTLE-MOUNTED CHARACTERISTICS

Required Performance At Science Instrument

Field Of View 7 Arc Min
Accuracy 1 Arc Sec
Stability 0.25 Arc Sec For 20 Min

Fine Guidance Sensor Field-Of-View
30 Arc Min

IMC Characteristics

Range 5 Arc Sec (APS Gyro Scale Factor Limited)
Frequency Response 10 Hz (Gyro Limited)
Secondary Mirror Driven By APS Gyros

Star Trackers

Uses APS Star Trackers
Wide Field Of View (Several Degrees)
DIRECT SIRTGF MOUNTING TO PLATFORM EXAMPLE

APS FUNCTIONS TAKEN BY FACILITY OR PLATFORM

- Rate Gyros
- Star Trackers*
- Nodding
- Slewing
- Rastering
- Medium Amplitude Image Stabilization

*Normally Mounted on Facility Even Though Part of APS
IMPLICATIONS OF MOUNTING PLAYLOAD DIRECTLY TO PLATFORM

- IMC Must Be Designed to Compensate for Platform Stability Characteristics
- Platform Must Provide Accurate Orientation Control and Slewing From Target to Target
- All-Sky Viewing Requires Platform to Have Capability for Holding Large Variety of Orientations
- Increased Operational Conflicts for Multi Pointing-Payloads Operations
DIRECT SIRTF MOUNTING TO PLATFORM

Potential Problem Areas
  Replacement of APS Gyros
    - SP Gyros Located Relatively Far From Facility So Structure Dynamic Deformations (Thermo and Flexible) Degrade Effectiveness
    - May Require Facility-Mounted Gyros

IMC Range Capability
  - Gyro-To-Secondary Mirror Servo Feed-Forward Gain Errors May Have To Be Reduced

Operations Requiring Rastering and Nodding
  - Whole SP Must Move or Facility Redesigned for More Secondary Mirror Motion Capability (Large Off-Boresight Abberations Must Be Considered Also)

All-Sky Viewing
  - SP Has Limited Orientation Capabilities
CY 81 Objectives

- Modify Existing Model as Shown
- Calculate Modes, Frequencies (Real and Complex)
- Calculate Phase and Gain versus Frequency
- Estimate Errors From Real Mode Model
GENERAL OBJECTIVES

- Assess Disturbance Sensitivity – Payload Motions (Open Loop)
- Provide Controls Reference Model
- Perform Damping Benefit Studies
  - Disturbance Reduction
  - Isolation Effectiveness
  - Controllability Improvements
AGENDA

Study Overview

Special Unmanned Platform Studies (Task A)

Manned Platform Concept (Task B)

- Configuration, Structural/Mechanical and Operations
  - Fritz Runge

- System and Payload Requirements, and Performance
  - Dave Riel

- Subsystems, Habitability, and Safety
  - Bill Nelson

- Programmatics
  - Denny Niblo
KEY PROGRAM CONSIDERATIONS

- Foundation of Realistic Payloads
- Conservative Budget Assumptions
- Goals for Initial Capability
- Goals for Capability Growth Steps
- Capabilities of Power System
- Extent of Existing Equipment Use
- Revisit/Resupply Logistics Scope
- Safety and Contingency Management
- Involvement and Impacts of Participants Other Than NASA
OBSERVATIONS TO DATE

- Identifiable Payloads Call For Moderate R&D-Type Manned Platform
  (R For Scientific Research)
  (D For Applications, Technology, And Operations Development)

- Growth Capability Can Easily Be Incorporated To Accommodate Demand (When Definitized)

- Spacelab 1- and 2-Segment Modules Adequate For Numerous Elements Of Platform

- Savings Through Use Of Existing Hardware (From Shuttle and Spacelab) Can Be Important In Very Tight Budget

- Crew Size Of 3—4 Adequate For Early Years

- Technology Advancements Required Are Moderate
MANNED PLATFORM PAYLOADS

- Performance of On-Site Missions

- Support for Remote Missions

- Support for Advanced Capability Testing

- Solar-Terrestrial Science
- Life Science
- Manufacturing Applications

- GEO-Mission Staging
- Subsatellites and Targets
- Large Payload Setup
- Spacecraft Servicing

- Support Operations/Equipment
- Propellant Storage/Handling
- Large Structures
- Environmental Controls
- Sensors and Pointing Systems
- EVA Techniques and Accessories
MANNED PLATFORM PAYLOADS

- Solar-Terrestrial Science
- Life Science
- Manufacturing Applications

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- Environmental Controls
- Sensors and Pointing Systems
- EVA Techniques and Accessories
EARLY MANNED PLATFORM

12-25 kW Power System (Space Platform)

Teleoperator Maneuvering System

Central Docking Adapter With Orbiter Airlock

Spacelab-Derived Hardware
- Payload Carriers (Pressurized and Unpressurized)
- Habitat/Control Center
- Logistics Module

Crew Equipment From Orbiter and Skylab
MANNED SPACE PLATFORM

POWER SYSTEM
- ELECTRICAL PWR
- WIDEBAND COMM
- ALTITUDE CONTROL
- HEAT REJECTION
- ORBIT/STATION KEEPING
- BERTHING
Possible mods:
- VOICE COMM
- EMER PWR

EVA AIRLOCK AND SUBSYSTEMS
- EXISTING FROM ORBITER PROGRAM

INTERIOR PAYLOAD MODULES
- SPACELAB-DERIVED; SINGLE SEGMENTS

EXTERIOR
- PAYLOAD (3 PLCs)

PRESSURIZED ADAPTER
- NEW ITEM
- PWR DIST AND CONTROL
- PWR SYS STATUS
- ATMOSPHERE REVITALIZATION
- WATER SUPPLY
- COMM AND DATA MGMT
- WASTE MGMT
- EMER FOOD
- CREW SUPPORT ITEMS

LOGISTICS SYSTEM
- SPACELAB-DERIVED
- SINGLE-SEGMENT SPACELAB
- UNPRESS TANK SECTION

CONTROL CENTER AND HABITAT DESIGN IMPROVEMENTS
- ADD VOICE INTERCOM
- COMPLEMENT TV SYS
- ADD BERTHING PROVISIONS
- ADD CO\textsubscript{2}/CONTAMIN REMOVAL
- IMPROVE SUBSYS LIFETIME
- IMPROVED INSULATION SYS
  - EXISTING SPACELAB ITEMS
  - STRUCTURE SYS
  - PWR DIST
  - THERMAL CONTROL SYS
  - DATA MGT SYS
  - CONTROLS AND DISPLAYS
  - EXPERIMENT RACKS AND SERVICES
  - INSULATION SYS
  - ATMOSPHERE REVITALIZATION

CREW EQUIPMENT
- FOOD MGMT
- EXERCISE EQUIP
- SLEEP RESTRAINTS

EXISTING FROM ORBITER/SKYLAB PROGRAMS
- EVA SUITS
- STOWAGE LOCKERS

SECTION OF CREW SUPPORT ITEMS
- STOWAGE LOCKERS
SYSTEMS ANALYSIS AND DEFINITION (SUBTASK B.3)

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CONFIGURATION ELEMENT CONCEPTS IDENTIFIED IN FIRST INTERIM BRIEFING

Airlock/Adapter Module
- A Through I Options

Control/Habitat Module
- 2-and 3-Segment Spacelabs

Growth Module
- 1-and 2-Segment Spacelabs

Logistics Module
- Unmanned
- Unmanned + Manned
- Unmanned/Manned
- 90 Days
- 180 Days

Payload Operations Arm
- Short
- Long
- Long With Aux RMS
BASIC MANNED PLATFORM

- Power System
- Airlock/Adapter
- Orbiter Interface
- Habitability/Payload Module
MANNED PLATFORM GROWTH
STEP NO. 1

Teleoperator Maneuvering System (TMS)
Payload Operations Beam
Adapter/Manipulator Control
Manipulator System
MANNED PLATFORM GROWTH
STEP NO. 2
MSP CONCEPT FORMULATION

Orbiter Physical Interface Parameters Established

- Keel Fittings and Longeron Fittings Availability
- RMS Envelope Restrictions
- Orbiter Cabin Clearances
- Orbiter Berthing Envelope

MSP/Orbiter and Intrasytem Interface Requirements Established and Evaluated

- PS to MSP
- MSP to MSP Elements
- MSP to Orbiter
- PS to Orbiter

Subsystem Functions Allocated to Major Elements of MSP

- PS, Airlock/Adapter, Habitability Module
Optional Approaches To Initial Capability

- Primary Unmanned (Manned During Shuttle Visit)
  - Provides Increased Internal Experiment Capability
  - Enables Life Science, Etc., Specimens and Equipment to Be Evaluated On Ground Minimizing On-Orbit Logistics
  - Life-Science-Type Lab Occupies Large Portion of Cargo Bay Wt and Vol On Each Flight-Limits Payload Logistics
  - Enables Design of Maximum Sized Airlock/Adapter For Future Growth Considerations
  - Does Not Require Pressurized Logics System Until Later In Program

- Sustained Manned Residence From Outset
  - After Second Launch – Cargo Wt and Vol Allocated 100% To Payload (Except For Logistics Flights)
  - Internal Experimentation Limited During Early Phase Of Program
  - Design Characteristics Of Airlock/Adapter Module Influenced By Cargo Bay Space Allocation
Nine Candidate Airlock/Adapter Options Investigated

Two Airlock/Adapter Configurations Selected For Further Study. Concepts Measured Against Identified Requirements and Parameters

- Z-Axis-Oriented Concept
- X-Axis-Oriented Concept

X-Axis A/A Concept Selected For Detail Configuration Analysis

- Maximum External Size and Shape Determined Within Established Orbiter Physical Parameters and Launch Envelope
- Internal Arrangements Investigated to Maximize Use of Available Volume
- “1-g” Orientation Selected With Four Radial Berthing Ports and Two End Ports
Two Candidate Habitability/Payload Modules Evaluated

- A 2-Segment Spacelab
- A 3-Segment Spacelab

A 2-Segment Spacelab Was Selected For Detail Configuration Analysis

- Internal Arrangements Investigated to Maximize Use of Available Volume
  - Four Crew Sleep Accommodations Concepts Evaluated
  - 1-g and 0-g Orientations Investigated
  - Internal Volume Allocation Options Investigated
  - Crew Size and Subsystem Volume Requirements Established

1-g Orientation With Private Quarters For Three Crewmen Was Selected For Continued Subsystem Analysis. This Selection Is Considered Minimum Impact on Current Spacelab Systems and Makes Maximum Use of Current Spacelab Equipment.

Detailed Equipment List Prepared: Habitat, Airlock/Adapter, Logistics Module

Five Logistics Options Evaluated

- All EVA Transfer
- IVA Solids, EVA Gases
- IVA Solids, Press Transfer Gases
- IVA Solids From Middeck, Tank Module on MSP
- Tank Module For Gases, Pressurized Module For Solids

An Integrated Pressurized Module With External Mounted Gas Tanks Selected For Additional Configuration and Operational Analysis
Three-Man Basic Sustenance Weight and Volume Requirements Established For a 90-Day and a 180-Day Resupply Cycle

Favored Logistics System Is As Follows

- 1-Segment Spacelab Module With
  - Interior Water Resupply Tanks
  - Exterior Atmospheric Resupply Tanks
- System Sized For 180-Day Resupply Cycle
- Crew Rotated At 90-Day Intervals With Crew Equipment Transported in Middeck
- Interior Stowage Volume for Exchange of Total Payload in Habitability Module
# MANNED PLATFORM ACTIVITIES/ACCOMMODATIONS

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<th>PERFORMANCE OF MISSIONS ON-SITE</th>
<th>SUPPORT FOR REMOTE MISSIONS</th>
<th>SUPPORT FOR ADVANCED CAPABILITY TESTING</th>
<th>STATION OPERATION</th>
<th>LOGISTICS</th>
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<td>• REMOTE CONTROL OPERATIONS</td>
<td>• CONTROLS/INSTRUMENTATION/ DATA HDLG</td>
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<td>• PROPPELLANT STORAGE/HANDLING</td>
<td>• CREW AND RELATED EQUIPMENT (IVA/EVA)</td>
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<td>• MANUFACTURING APPLICATIONS</td>
<td>• LARGE PAYLOAD SETUP</td>
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<td>• SPACECRAFT SERVICING</td>
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Performance of missions on-site includes solar-terrestrial science, life science, and manufacturing applications.

Support for remote missions includes geo-mission staging, sub-satellites and targets, large payload setup, and spacecraft servicing.

Support for advanced capability testing includes remote control operations, propellant storage/handling, large structures, environmental controls, sensors and pointing systems, and EVA techniques and accessories.

Station operations include controls/instrumentation/data handling, crew and related equipment (IVA/EVA).

Logistics cover crew and payload sustenance and exchange.

VFO356
ALLOCATION OF SUBSYSTEM FUNCTIONS

POWER SYSTEM

- STRUCTURE/MECHANICAL
  - PAYLOAD INTERFACE STRUCTURE(S)
  - PAYLOAD INTERFACE MECHANISM(S) (ACTIVE) (3 PLACES)
  - ORBITER BERTHING MECHANISM (UNMANNED SORTIE MODE)

- ELECTRICAL POWER SYS (EPS)
  - POWER SOURCE
  - BATTERIES, CHARGERS, AND REGULATION
  - POWER DISTRIBUTION AND CONTROL

- THERMAL CONTROL SYS (TCS)
  - HEAT REJECTION RADIATOR
  - INTERFACE HEAT EXCHANGERS AND DISCONNECTS
  - TEMPERATURE CONTROLS
  - F-21 LOOP

AIRLOCK/ADAPTER

- STRUCTURE/MECHANICAL
  - ORBITER BERTHING/DOCKING INTERFACE (PASSIVE)
  - POWER SYSTEM/BERTHING INTERFACE (PASSIVE)
  - PRESSURIZED VOLUME FOR SECONDARY SHELTER
  - PAYLOAD BERTHING PORTS (ACTIVE)
  - SECONDARY SUPPORT STRUCTURE
  - PRESSURIZED VOLUME FOR EVA (AIRLOCK)
  - EMERGENCY VENT SYSTEM
  - RERAINTS AND LOCOMOTIVE AIDS

- ELECTRICAL POWER SYSTEM
  - POWER SYSTEM STATUS AND MONITORING
  - POWER DISTRIBUTION AND CONTROL
  - INVERTERS
  - LIGHTING
  - EMERGENCY POWER DISTRIBUTER

- THERMAL/ENVIRONMENTAL CONTROL & LIFE SUPPORT SYS
  - REPRESSURIZATION TANKS
  - ATMOSPHERE REVITALIZATION
  - ATMOSPHERE CONTROL
  - AVIONICS COOLING LOOP
  - WATER LOOP AND PUMP PKGS
  - EVA SUPPORT

HABITABILITY/PAYLOAD MODULE

- STRUCTURE/MECHANICAL
  - INTERFACE MECHANISM — 1 ACTIVE AND 1 PASSIVE
  - PRIMARY PRESSURE SHELL
  - METEOR SHIELDING AND THERMAL BLANKET
  - INTERNAL SECONDARY SUPPORTS
    - RACKS & OVERHEAD STRUCTURE
    - FLOOR
    - OPTIC WINDOW & VIEWPORT(S)

- ELECTRICAL POWER SYSTEM
  - POWER DISTRIBUTION AND CONTROL
  - EMERGENCY POWER DISTRIBUTION (BATTERIES)
    - LIGHTING
    - INVERTERS

- THERMAL ENVIRONMENTAL CONTROL & LIFE SUPPORT SYS
  - ATMOSPHERE CONTROL
  - ATMOSPHERE REVITALIZATION
  - AVIONICS COOLING LOOP
  - WATER DISTRIBUTION
  - WATER LOOP
## ALLOCATION OF SUBSYSTEM FUNCTIONS (CONT)

### POWER SYSTEM
- COMM & DATA MGMT SYS
  - GROUND COMMUNICATION
  - ORBITER COMMUNICATION
  - DETACHED MODULE/EVA COMM
  - PS DATA ACQUISITION
  - PS COMMAND PROCESSING
  - PS PAYLOAD SUPPORT
- REBOOST/DEBOOST SYS
- ATTITUDE CONTROL SYS (ACS)
  - CMG INSTL
  - HORIZON & SUN SENSORS
  - RATE GYROS, ETC
  - MAGNETIC TORQUERS

### AIRLOCK/ADAPTER
- COMM & DATA MGMT SYS
  - ENGINEERING DATA ACQUISITION
  - DATA PROCESSING
  - DATA STORAGE
  - DATA MULTIPLEXING
  - DATA DISPLAY/KEYBOARD
  - C&W PANEL
  - TV CAMERA/MONITOR
  - VOICE INTERCOMM
- HABITABILITY
  - WASTE MANAGEMENT
  - FOOD FREEZERS
  - TOOLS
  - RERAINTS AND LOCOMOTION AIDS
  - EVA SUITS STORAGE AND REPAIR EQUIP
  - EMERGENCY FOOD STORAGE

### HABITABILITY/PAYLOAD MODULE
- COMM & DATA MGMT SYS
  - ENGINEERING DATA ACQUISITION
  - BACKUP DATA PROCESSING
  - DATA DISPLAY/KEYBOARD
  - C&W PANEL
  - TV CAMERA/MONITOR
  - VOICE INTERCOMM
  - SCIENCE DATA ACQUISITION
- HABITABILITY
  - FOOD FREEZER AND REFRIGERATOR
  - EXERCISE AND RECREATION
  - HYGIENE
  - MEDICAL TREATMENT
  - CREW QUARTERS
  - RERAINTS AND LOCOMOTION AIDS
  - TOOLS
  - FOOD PREPARATION AND EATING
  - EMERGENCY WASTE
  - PERSONAL RESCUE SYSTEM
## BASIC MANNED PLATFORM
### ASSEMBLY ITEMS

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* Starred items indicate secondary structure berthing mechanism items.

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AIRLOCK/ADAPTER CONCEPT FORMULATION (CONT)

Platform Adapter (-Y) Berthing
Payload Module Port Prohibited by PowerRMS Rotation System Requirements

-abitability/
OrbiterPayload Module
KLaunch

Parameters
1.0 m Clearance Enveloped Required

1.0 m Clearance Enveloped Required

X-Axis Concept Assembly Analysis

Orbiter Launch Parameters

Favored Concept

X-Axis Concept Assembly Analysis

Orbiter Launch Parameters
CONFIGURATION DEVELOPMENT SEQUENCE
AIRLOCK/ADAPTER MODULE

AVAILABLE CARGO BAY VOLUME

POWER SYSTEM INTERFACE

EXTERNAL BERTHING MECHANISM

TWO-SEGMENT SPACELAB HABITAT INTERFACE

EXISTING ORBITER EVA AIRLOCK-EXTERIOR MOUNT

EXTERIOR CONSUMABLE TANK STOWAGE

EXTERNAL BERTHING, MECHANISMS SEPARATED FOR ASSEMBLY CLEARANCE

ENCLOSURE FOR MINI CONTROL CENTER, SAFEHAVEN, WATER, FOOD, BATHROOM, MINIBENCH, EVA SUPPORT AND PASSAGE

ORBITER TRUNNION AND KEEL FITTING PLACEMENT
VF0488

AIRLOCK/ADAPTER INBOARD PROFILE
(STARBOARD SIDE)

PORTABLE O₂ SYSTEM (AIRLOCK)
URINE COLLECTOR
URINE SEPARATOR
EMU
HANDRAIL
AVIONICS C&D PANEL
Fecal COLLECTOR
WASTE MGMT POWER MODULE WATER HEATER AND BLOWER
EMU WATER HEATER
ORBITER INTERFACE (REF)
1.0 m (39.3)
AIRLOCK/ADAPTER INBOARD PROFILE

+Z

WASTE MGMT COMPARTMENT (REF)

INTERFACES SERVICES ROUTED THIS AREA

1.01 m (40.0)

ORBITER-TYPE HATCH (TYP)

WORKBENCH INSTALLATION

SUBSYSTEMS INSTALLATIONS INTERFACE SERVICES ROUTED THIS AREA

-Z

LIGHT

2.13 m (84.0)

1.04 m (41.0)

-1.04 m (41.0)

0.96 m (38.0)

+Y

POTABLE H₂O

POTABLE H₂O (TYP)

VIEW LOOKING FORWARD

VIEW LOOKING AFT

ORIGRAL PAGE OF POOR QUALITY
**AIRLOCK ADAPTER MODULE**

**VOLUME ALLOCATION**

- **Maintenance Workbench/Storage**: 0.56 m³ (20 ft³)
- **EVA Support Equip., Tools, etc.**: 0.53 m³ (19 ft³)
- **Waste Management**: 3.1 m³ (110 ft³) Total 1.7 m³ (60 ft³) Free Volume
- **Potable H₂O (18 plcs)**: 0.55 m³ (19.5 ft³), 0.08 m³ (3.0 ft³)
- **Free Volume**
  - 0.25 m³ (9.0 ft³)
  - 0.13 m³ (4.5 ft³)
  - 0.08 m³ (3.0 ft³)
  - 1.8 m³ (65 ft³)
HEXAGONAL FRAME — BERTHING INTERFACE MECHANISM

CHARACTERISTICS:
- SIMPLIFIED HEXAGONAL PASSIVE SYSTEM
- HEXAGONAL FRAME ACTIVE SYSTEM WITH 3 CAPTURE GUIDES
- REDUCED PHYSICAL ENVELOPE AND WEIGHT WITHIN PERFORMANCE REQUIREMENTS
- SELF-ALIGNING WITH DUAL-MOTOR ACTUATORS FOR STRUCTURAL RIGIDITY
- INCORPORATES MANUAL OVERRIDE
- PROVIDES 1.0-m OPENING FOR CREW PASSAGE

SELECTION CRITERIA
- SMALLER PHYSICAL ENVELOPE PERMITS INCREASED VOLUME MODULES TO FIT IN CARGO BAY
- CAN BE USED ON ALL STATION ELEMENTS INCLUDING BOTTOM OF SPACELAB PALLET CARRYING PAYLOADS
- REDUCED COMPLEXITY IMPROVES RELIABILITY AND MINIMIZES EVA MAINTENANCE
- DEVELOPMENT UNIT FABRICATED BY MDAC-HB FOR JSC TESTING
- COST ESTIMATED TO BE LESS THAN THAT OF COMPETITORS

DESIGN CRITERIA
- ACCOMMODATE LARGE VEHICLE INTERFACE MOMENT (16,000 FT-LB IN PITCH AND YAW) ORBITER-ORBITER CONTINGENCY DOCK
BERTHING UMBILICAL INTERFACE

PLAN VIEWS

ACTIVE HALF

GROWTH UMBILICAL

PASSIVE HALF

ELECTRICAL DATA CONNECTOR (2 PLCS)

FLUID CONNECTOR (4 PLCS)

ELECTRICAL POWER CONNECTOR (2 PLCS)

UMBILICAL ACTUATOR AND MECHANISM

ACTIVE HALF

BERTHING FRAME AND LATCHES

PASSIVE HALF

1 RETRACTED

SIDE VIEW

ELECTRICAL POWER CABLE

UMBILICAL CARRIER

MANUAL OVERDRIVE CLUTCH

WORM GEAR DRIVE

ENGAGEMENT SEQUENCE

1. GUIDE PIN

2. JACKSCREW

3. CONNECTORS ENGAGED
HABITABILITY MODULE — CONCEPT FORMULATION (INTEGRATION)

Four Rack Payload Vol Reqmt

- Crew Size Option Analysis
  - (2-3 Max)
- Concept Formulation (Elements) Results
- Volume Allocation Analysis
- “Outhouse” Waste Mgt Decision
- High-Comfort Crew Qtrs Volume Decision
- Food Management Analysis
- Exercise Area
- Waste Management Located in Autoclave/Adaptor
- Subsystem Area
- Work Bench
- Food Management
- Control Center
- Window for Space Viewing
- Personal Hygiene and Medical Treatment
- Individual Crew Quarters (2.8 m² Each) (1 Plus)
- 1-g Orientation

- Mass Properties Analysis
- Operational Scenario Analysis
- Detail Design
- Cost Analysis (Min Mods)
HABITABILITY MODULE INBOARD PROFILE

OVERHEAD STORAGE CONTAINERS (7 PLCS)

LIGHTS

AIR DUCT AND DIFFUSER (TYP)

HANDRAIL

FALSE CEILING (AIR AND LIGHT BAFFLE)

ENTERTAINMENT CENTER
- STEREO TAPE PLAYER
- TV TAPE PLAYER
- TV MONITOR

STORAGE
- CLOTHING
- BOOKS, ETC
- PERSONAL HYGIENE ITEMS

ENVIRONMENTAL CONTROL SYSTEM INSTALLATION (REF)

VIEW LOOKING FWD

VIEW LOOKING AFT

MIRROR

CREW COMPARTMENT NO. 2

WRITE IN.

TABLE

ENTERTAINMENT CENTER

STORAGE

ACCESS PANEL TO UNDER FLOOR STORAGE

TRASH BAG

VIEW LOOKING FWD

CABIN AIR

INTERCOM

WRITING TABLE

WRITING TABLE

VIEW LOOKING AFT

RACK NO. 1

RACK NO. 2

RACK NO. 1

RACK NO. 2

AVIONICS COOLING DUCTS

ERROR ON PAGE 58: "OF POOR QUALITY"

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VOLUME AVAILABILITY
(2-SEGMENT, 3-MAN MODULE)

9 Overhead Containers
(0.0558 m³/Container)
0.5022 m³
(17.7 ft³)

Control Center
Rack 2

Frozen Food
Rack 6
0.418 m³
(14.758 ft³)

Under Floor
2.826 m³
(99.8 ft³)

Solar Terrestrial
Rack 4
0.801 m³
(28.3 ft³)

Galley/Food Storage
1.083 m³
(38 ft³)

Personal Hygiene/
Storage Rack 5
0.4180 m³ (14.758 ft³)

Life Science
Rack 3
0.9065 m³
(32.0 ft³)

Work Bench
Rack 1

Sleep Compartment
2.9 m³ (104 ft³) Each
- Storage 0.45 m³ (16.0 ft³)
- Entertainment Center
  0.07 m³ (2.6 ft³)
- Sleeping Bag
  0.65 m³ (23 ft³)
- Free Volume
  1.56 m³ (55 ft³)

Under Floor
2.826 m³
(99.8 ft³)

Constant Center
Rack 2

Frozen Food
Rack 6
0.418 m³
(14.758 ft³)
CARGO BAY ARRANGEMENT
AIRLOCK/ADAPTER
AND TWO-SEGMENT HABITAT
STRUCTURAL/MECHANICAL CONCERNS

Spacelab Module

- End Dome Strength For Docking Loads
- 10-Yr Life Limitations

Airlock/Adapter Module

- High Pressure System Design Assurance
  - Design Factors of Safety
  - Fracture Mechanics Analysis
  - Meteoroid Penetration Protection
- Airlock Fatigue Life

Assembled Platform

- Docking Joint Compliances Increase Assembly Flexibility
  (Dynamics/Control Problem)
- Thermal Distortions Affecting Pointing Requirements
- Design For “Leak-Before-Failure” Condition to Preclude
  Catastrophic Pressure Loss
- Reboost Loads on Modules and Connections
REQUIRED STRUCTURAL/MECHANICAL TASKS

(This Contract) • Define Design Factors of Safety For All Platform Components

(Follow-On) • Estimate Maximum Hole Diameter in Spacelab Module for “Leak-Before-Failure” Design

(Follow-On) • Review Spacelab Module Design For Life Limitation Components

(Follow-On) • Perform Preliminary Fracture Mechanics Analysis on Spacelab Module

(See Example Statement of Work Provided to ERNO For FOD Study. Analysis Not Performed Since US Capability Is Required)
**Objective** Assure That No Major Mods Are Required for Spacelab Module

- Establish the Maximum Flaw Size That Can Exist After Proof Tests

- Determine the Design Fatigue Spectrum For the Pressure Shell, Limit Design Stresses, Temperature, and Cycles/Time For the Following Mission Regimes:
  a) Ground
  b) Prelaunch
  c) Launch and Ascent
  d) On-Orbit (As a Function of Duration and Repeat Flights)

- Determine the Maximum Flaw Growth After the Proof Tests Using Available Material (MDAC) Flaw Growth Rate Characteristics and the Design Fatigue Spectrum (Using a Factor of 4 on Design Cycles)

- Demonstrate Either of the Following With Analysis Results:
  a) Maximum Flaw After Proof Test Does Not Grow Through the Thickness or Become Critical
  b) The Flaw Does Grow Through the Thickness But Does Not Become Critical (E.G., Leak Before Fail Condition). If This Condition Occurs, Show That Spacelab Atmosphere Leakage is Very Low and Can Be Detected Before Endangering the Crew

*Using MDAC-Modified MSFC Code (Used Recently on SRB)*
LOGISTICS WEIGHT AND VOLUME REQUIREMENTS — 180-DAY RESUPPLY CYCLE — THREE MEN

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<td>■ Frozen Food</td>
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<td>■ Water</td>
<td>(4620)</td>
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<td>■ Clothing</td>
<td>(1.6/Man-Day)</td>
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<td>■ Personal Gear</td>
<td>(TBD)</td>
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<td>■ Trash Storage (Compacted to 0.38 Ft³/MD)</td>
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<td>■ EVA Supplies</td>
<td>(TBD)</td>
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<td>■ MSP Spares</td>
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<td>■ ECLS Supplies</td>
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<tr>
<td>■ Solar/Terrestrial</td>
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*This Volume Can be Used for Other Purposes During Delivery to Orbit — But is Reserved for De-Orbit Trash
CONCEPT FORMULATION FLOW
LOGISTICS SYSTEM (CONT)

A

CREW SYSTEMS

B

TRASH MANAGEMENT

TRASH STORAGE

HAB MODULE

LOG. MODULE

COMPACTOR

NO

LOG. MODULE

Y

WHERE

HAB MODULE

LOG. MODULE

HAB MODULE

PERSONAL EQUIPMENT

EVA CARRY AND EXCHANGE ALL RESUPPLY ITEMS

FROM ORBITER THRU AIRLOCK

FROM LOGISTICS RACK THRU AIRLOCK

IVA FROM ORBITER THRU ADAPTER

IVA FROM LOG MODULE THRU ADAPTER

EVA FROM ORBITER THRU AIRLOCK

EVA FROM LOG MODULE THRU ADAPTER

EVA FROM LOG RACK TO EXTERNAL LOCATION

TRANSFER SYSTEM

IVA FROM LOG MODULE THRU ADAPTER/PRESS. TRANSFER GASES, ETC

FROM ORBITER THRU ADAPTER

EVA CARRY FOOD ETC AND EVA EXCHANGE GASES AND LIQUID TANKS

EVA FROM LOG RACK THRU AIRLOCK
LOGISTICS MODULE — 180-DAY CONFIGURATION

- STOWAGE CUSTOMIZED PER FLIGHT
- RMS GRAPPLE FITTING
- INTERCOM REMOTE STATION
- INSULATION SYSTEM
- GO₂ AND GN₂ STORAGE TANKS (30 PLCS)
- ACTIVE BERTHING MECHANISM
- 2.694m (106.07)
- 2.13m (84.0)
- 1.67m (66.0)
- POTABLE H₂O TANK (28 PLCS)
- STORAGE VOLUME (TYP)
- AIR DIFFUSER AND LIGHTS (TYP)
- ORBITER TYPE HATCH (3 PLCS)
- ACCESSORIES CONTROL PANEL (LIGHTS, TV, ETC.)
- 7.31m (288.0)
- 2.84m (112.0)
- 4.32m DIA (170.0)

72
ESTIMATED ORBITER LOGISTICS STOWAGE VOLUME MID-DECK

- AIR LOCK (149.75 FT³)
- MISC STOWAGE AREAS (40.43 FT³)
- AIRLOCK HATCH
- CREW SLEEP STATION (NO 1 = 20.0 FT³, NO 2 = 22.0 FT³, NO 3 = 14.6 FT³, NO 4 = 36.0 FT³)
- PAYLOAD BAY HATCH
- WASTE MANAGEMENT
- LOWER DECK-UNDER FLOOR (39.24 FT³)
- FOOD MANAGEMENT (17.30 FT³)
- STOWAGE (84.0 FT³)

TOTAL MID AND LOWER DECK = 423.32 FT³
ESTIMATED ORBITER LOGISTICS STOWAGE
VOLUME FLIGHT DECK

MISC AREAS
(8.33 FT³)

AFT FLIGHT DECK CREW STATION

PAYLOAD CONSOLE
(13.50 FT³)

INTERDECK ACCESS HATCH

FORWARD FLIGHT DECK CREW STATION

TOTAL = 26.33 FT³

MISSION CONSOLE
(4.50 FT³)
CANDIDATE DELIVERY FLIGHT SEQUENCE

**1st Launch**
- Power System
- One Solar Payload Pallet (Full Cargo Bay) (32,000 Lb)

**2nd Launch**
- Airlock/Adapter (90 Days' Supplies + 30-Day Contingency)
- 3-Man, 2-Segment Control/Habitat Module
- First 3-Man Crew (Full Cargo Bay) (~33,000 Lb)

**3rd Launch**
- Logistics Module (Sized for 180 Days' Earth Supplies)
- Life Science Payload (1-Segment Module)
- Earth-Looking Payload (One Pallet)
- Short Payload Operations Beam with 360-Deg Rotation
- Exchange Crew (Full Cargo Bay) (~29,000 Lb)

**Crew:**
- 3-4
4th Launch
- Life Science Payload (1-Segment Module)
- Material Processing Payload (One Module)
- New 3-Man Crew (Orbiter Provides Storage Space in Middeck for Unprogrammed Logistics) (Room for Other Payload Delivery) (~20,000 Lb)

5th Launch
- Logistics Module
- New Crew
- Payload Support Adapter (Airlock/Adapter 11)
- (Full Cargo Bay) (~26,000 Lb)

6th Launch
- One-Segment, 3-Man Habitability Module
- 1-Segment Payload Module
- Payload Operations Beam/RMS
- (Orbiter Provides Middeck Storage for Logistics)
- Add 3 Men to Crew (Full Cargo Bay) (~30,000 Lb)
SPACE STATION GROWTH

POWER SYSTEM

+ AIRLOCK/ADAPTER I
+ CONTROL CENTER/HABITAT I

+ PAYLOAD
+ HABITAT II

+ PAYLOAD MODULE I
+ LOGISTICS MODULE

+ PAYLOAD OPERATIONS BEAM/RMS

+ PAYLOAD MODULE III

OF POOR QUALITY
PAYLOAD ACCOMMODATIONS
(✓-EXTERNAL BERTHS, * INTERNAL RACKS)

36 RACKS

3 BERTHS

5 BERTHS
4 RACKS

5 BERTHS
14 RACKS

9 BERTHS
26 RACKS

9 BERTHS
36 RACKS

ORIGINAL PAGE 13 OF POOR QUALITY
OTV/PLATFORM OPERATIONS
AND FACILITIES

- Manipulation and Berthing of Large and/or Multiple OTV Propellant Tanks and Payloads

- OTV (RE)Fueling

- Resupply Other Expendables (I.E., Gases, Batteries, Hydraulic Fluid)

- OTV Checkout — Maximize Self-Checking

- OTV Maintenance — Simple Functions Only

- Propellant Storage/Transfer Tanks

- Propellant Transfer Equipment

- Pressurant Transfer Equipment

- Platform/OTV Umbilical

- Checkout Console

- Checkout Support Equipment

- Control Center

- Remote Manipulator System for Payload Interchange
OTV OPERATING SCENARIO (LAUNCH SEQUENCE)

1. OTV/PAYLOAD CHECKOUT AND LAUNCH CONTROL CENTER

2. TELEOPERATOR MANEUVERING SYSTEM (TMS)

3. OTV IN LAUNCH POSITION

4. OTV LAUNCH SUPPORT STRUCTURE (PART OF OTV SYSTEM)

5. SEPARATE OTV FROM LAUNCH STRUCTURE WITH SPRING DEVICES

6. PAYLOAD INSTALLED ON OTV USING PLATFORM MANIPULATOR

7. FIRE MAIN ENGINE AND DELIVER PAYLOAD (TBD) DISTANCE FROM PLATFORM
OTV CHECKOUT ON PLATFORM

**Propulsion**
- Leak Checks
- Valve Functional Checks
- Instrumentation Calibration

**Thermal**
- Insulation
- Heaters

**Mechanical**
- Engine Gimbaling
- Berthing Mechanism — Separation
- Payload/OTV Separation and Berthing

**Electrical**
- Power Subsystem Checkout
- Guidance and Navigation Subsystem
- Telemetry and Comm System

**Avionics**
- Data Management Subsystem
- Computer C/O

---

**How Different From Ground?**

- Limited (or No) On-Line Replacement of Hardware
- Multiple Firing (Use of Cryogenic Engines with Minimum C/O
- Limited Crew Size — Maximize Self-Checking and Computer C/O
- On-Orbit Updating of Controls Software
- Limited Data Processing Capability
- Limited Power Resources
- Limited Capability For Cooling Electronics
Postmate Checks of OTV With Launch/Test Module (LTM)

- Load Launch Test Module With Test Software
- Apply Test Power to OTV From Test Module
- Verify Communication Between OTV and LTM Computers (Auto Test)
- Limit Check OTV Instrumentation (Auto Test)
- Functional Test/Calibration of Guidance and Navigation System (Auto Test)
- Control System Verification (Auto Test)
- Propulsion System Checks
- RF System Checks (Manual Test)
- Power Transfer Check (Manual Test)
- Ordnance Systems Check (Manual Test)
- Simulated Launch Sequence Test (Auto/Manual Test)

Static Health Checks

- Minimum Power and System Operation
- Limit Checks By LTM Computer to Verify
  - Safe/Arm Status
  - Environmental Status
  - Power System Status
PLATOFORM/OTV CHECKOUT OPERATIONS (CONT)

Prelaunch Checks

- Limit Check of OTV Instrumentation (Auto Test)
- Functional Test/Calib of GN&C System (Auto Test)
- Open-Loop RF Checks
- Simulated Launch Sequence Test (Auto/Manual)
- Transfer OTV To Internal Power
- Launch Sequence

Post Launch

- Maintain Communication Via Link
- Verify All Systems Normal Via Limit Check (Auto)
- Verify Normal Engine Start Sequence
- Monitor OTV Performance During Mission
- Record Data For Postmission Analysis

Predocking Checks

- Verify OTV Safe To Dock Via Auto Limit Check
- Monitor OTV Docking Sequence

Postdocking Checks

- Establish Hardline Comm Link Between LTM and OTV
- Transfer OTV To LTM Power
- Perform Functional Postmate Checks
STAGE/PLATFORM INTERFACE EQUIPMENT

Requirements

- Provide Two-Way Command/Response Communication Between the Platform Systems and Crew and:
  - Stage Vehicle (Fly-Away)
  - Interface Equipment (Power, Propulsion, Mechanical, Electronic)
  - Fault Detection and Safing System

- Sequence and Manage all Predeployment Functional Activity
  - Propulsion System Preps
  - Mechanical Unlatch and Erection Systems
  - Stage Vehicle (Fly-Away) Preps
  - Spacecraft Preps (If Required)

- Perform Fault Detection and Automatic Safing

Safety: No Two Equipment Failures or Operator Errors Shall Cause a Catastrophic Condition to Exist While in or Near the Platform

Reliability and Contingency Recovery

- System is Tolerant to Single-Point Failure
- Critical Power Systems Will be Redundant
- Crew Access to Critical Modularized Elements for Adjustment, Maintenance, Repair, or Replacement
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<td>20 x 20 x 40</td>
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<tr>
<td>Printer/Plotter</td>
<td>20 x 30 x 20</td>
</tr>
<tr>
<td>CRT/Keyboard</td>
<td>20 x 20 x 30</td>
</tr>
<tr>
<td>Computer</td>
<td>20 x 20 x 40</td>
</tr>
<tr>
<td>Mass Memory</td>
<td>20 x 20 x 40</td>
</tr>
<tr>
<td>Power Switch. Unit</td>
<td>20 x 10 x 20</td>
</tr>
<tr>
<td>Control &amp; Monitor Panel</td>
<td>20 x 30 x 10</td>
</tr>
<tr>
<td>Data Storage Unit</td>
<td>20 x 40 x 30</td>
</tr>
<tr>
<td>Resupply Unit</td>
<td>20 x 20 x 30</td>
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<tr>
<td>Telemetry Unit</td>
<td>20 x 20 x 30</td>
</tr>
<tr>
<td>Rendezvous Radar Unit</td>
<td>20 x 20 x 40</td>
</tr>
</tbody>
</table>

Total Height of 20 In. Racks Req'd = 240 In.

+ 60 Contingency

300 In.
OTV OPERATING SCENARIO (RETURN SEQUENCE)

1. TMS RETREIVES OTV AND RETURNS TO PLTAFORM

2. TMS PLACES OTV IN RANGE OF MANIPULATOR
   MANIPULATOR PLACES OTV ON LAUNCH STRUCTURE

3. OTV WITH LAUNCH SYSTEM STOWED
   TMS STOWED
OTV RESUPPLY CONSIDERATIONS

Resupply Options
- Tanker Stays in Orbiter EVA Hookup Transfer Lines-Pressure Transfer
- Tanker Removed and Berthed to Platform-Pressure Transfer Through Berthing Interface
- Interchange OTVs

Transfer Umbilical
- OTV Design Same As Used in Orbiter For Ground Loading
- Tanker Location To Minimize Line Lengths
- OTV and Tanker Side of Interface Passive
- Active Portion Built Into Platform Design

Propellant Transfer
- Transfer Technique Depends on Type of Fuel Selected
- Cryogenic Fuel Will Require Special Passive Screen Devices to Accomplish Transfer
- Energy Addition, Depressurization, and Positive Expulsion Are Primary Transfer Considerations

Propellant Type
- Cryogen
  - Large Residual May Be Required
  - Chilldown Losses
  - Settling Force May Be Required
  - Losses Due to Extended On-Orbit Storage
- Storable
  - MMH/N₂O₄, ETC.
  - Transferable With Minimal Losses
  - State-of-the-Art Expulsion Technique

Problem Areas
- Propellant Selection
- Transfer System
- System Weight
- On-Orbit Handling of Large Stages
OTV OPERATING SCENARIO
(PROPELLANT RESUPPLY SEQUENCE)

- PROPELLANT TANK REMOVED FROM ORBITER AND BERTHEO TO PLATFORM BEAM
- RESUPPLY TANK PRESSURIZED AND PROPELLANT TRANSFERRED THROUGH BERTHING PORT TO OTV

RESUPPLY PROPELLANT TANK

OTV PLACED ON PLATFORM BERTHING BEAM IN LAUNCH POSITION

ORBITER BERTH TO PLATFORM IN A POSITION TO PERMIT PLATFORM MANIPULATOR TO REMOVE PROPELLANT TANK

EMPTY RESUPPLY TANK

EMPTY RESUPPLY TANK RETURNED TO ORBITER

OTV PLACED IN STOWED POSITION USING PLATFORM MANIPULATOR
ORBIT-BASED OTV TECHNOLOGY NEEDS

- Propulsion Subsystem Must Include Additional Redundancy to Preclude Failures
- Electrically Powered Propellant Pumps
- Automated System C/O or Self-Checking
- Automated Launch Sequence With Minimum Data Output or Crew Support
- Long-Life OTV Engine and Multiple Reuse Without Refurbishment
- Leakfree Quick Disconnects
- Propellant Transfer
- Long-Term Cryogenic Propellant Storage
- Propellant Mass Gaging (Loading Accuracy)
- Modular Replaceable Units
AGENDA

Study Overview
Fritz Runge

Special Unmanned Platform Studies (Task A)

Manned Platform Concept (Task B)
Fritz Runge

- Configuration, Structural/Mechanical and Operations

- System and Payload Requirements, and Performance
  Dave Riel

- Subsystems, Habitability, and Safety
  Bill Nelson

- Programmatics
  Denny Niblo
REQUIREMENTS/PERFORMANCE ANALYSES

- Payload Activities
- Platform System Sizing
MANNED PLATFORM — SOLAR/TERRESTRIAL PAYLOAD CANDIDATES

SOLAR PALLET
- Soft X-Ray Telescope
- Active Cavity Radiometer
- Solar Monitor (SUSIM)

EARTH PALLET
- Imaging Spectrometer
- WISP
- Atmos Emission Imager (AEPI)
- SEPAC
- Recoverable PDP/Probes
SOLAR-TERRESTRIAL MANNED PLATFORM PROGRAM

SOLAR EXPERIMENTS
- ACTIVE CAVITY RADIOMETER (ACR) (PALLET ONLY)
- SOLAR ULTRAVIOLET SPECTRAL IRRADIANCE MONITOR (SUSIM)
- SOFT X-RAY TELESCOPE

TERRESTRIAL AND MAGNETOSPHERIC EXPERIMENTS
- SPACE EXPERIMENTS WITH PARTICLE ACCELERATION (SEPAC)
- RECOVERY PLASMA DIAGNOSTIC PACKAGE (RPDP) (PALLET ONLY)
- ATMOSPHERIC EMISSION PHOTOMETRIC IMAGING (AEPI)
- WAVES IN SPACE PLASMA (WISP)

CREW ACTIVITIES
- ACR — NONE
- SUSIM — NONE
- SOFT X-RAY TELESCOPE — POINTING AREA SELECTION AND DATA MONITORING
- SEPAC
  - POINTING CONTROL OF PARTICLE ACCELERATOR
  - BEAM CHARACTERISTIC SELECTION
  - FREE-FLYER CONTROL
  - SENSOR AND DATA MONITORING
- RPDP — NONE
- AEPI — TARGET SELECTION AND POINTING CONTROL
- WISP
  - MEASUREMENT INITIATION
  - POINTING CONTROL
  - DATA MONITORING
HIGH-VALUE CONTRIBUTION OF ON-ORBIT CREW WITH IMAGING PAYLOADS

EXAMPLE DISCIPLINE

SOLAR PHYSICS

SELECTED EXPERIMENTS

H-ALPHA  XUV

GRATING  SPECTROGRAPH SLIT

FIELD OF VIEW ARC MIN 16-35  56

SPOT VIEW ARC SEC 5 x 5  2 x 60

BASIC ROLES OF CREW

CASE 1

• EXECUTE EXPERIMENT MODE SEQUENCES AND MONITOR IMAGES
• INTERPRET/CORRELATE PHENOMENA (VIDEO, DIGITAL, AND AUDIO FLARE ALARM INPUTS)
• CONTROL FINE POINTING IN REAL TIME PER INTEREST
  • MANUALLY SCAN GRATING BACK AND FORTH ACROSS H-ALPHA EMISSION POINTS AND WATCH XUV DETECTOR TO LOCATE AND POINT AT SPOTS OF PEAK EMISSIONS

CASE 2

• STEP 2 x 60 ARC MIN SLIT ACROSS IMAGE IN 2- TO 5-ARC MIN STEPS
  • CHROMOSPHERIC NETWORK CELLS DIFFICULT TO RECOGNIZE (DARK AND BUSHY CLUMPS) (10 ARC SEC BOUNDARIES)
• CREW SELECTS PROMINENT, NOT DISSIPATING CELL
• ZOOM VIEW SO THAT EYE CAN AVERAGE OUT IRREGULARITIES
• POINT AT CELL BOUNDARY AND ZOOM WITHOUT LOSING LOCATION
• CREW ENHANCES POSSIBILITY OF CATCHING FLARE ONSET AND CORONAL TRANSIENTS WHICH OFTEN FOLLOW FLARES

CONTINGENCY ROLL OF CREW

• PLAN SCHEDULE AND RESCHEDULE IN REAL TIME (PRIMARY, SECONDARY, NEW INTERESTS)
LIFE SCIENCES
MANNEO PLATFORM PROGRAM
(EXAMPLE 90-DAY ACTIVITY)

SPACE BIOLOGY EXPERIMENTS

- EFFECTS OF WEIGHTLESSNESS ON FROG EGG FERTILIZATION AND LARVAL MORPHOGENESIS (90-DAY CYCLE)
- ARABIDOPSIS PLANT GROWTH, DEVELOPMENT, AND HEREDITY IN ZERO G (21-DAY CYCLE)
- DROSOPHILA (FRUIT FLY) BEHAVIOR AND LIFE CYCLE PHENOMENA IN ZERO G (15-DAY CYCLE)

SELECTION CRITERIA

- HABITAT-COMPATIBLE
- TWO-RACK ALLOCATION
- EXTENSIVE CREW INVOLVEMENT
- MODERATE INVESTMENT

CREW ACTIVITIES

- HARVEST FROG EGGS AND SPERM
- MIX EGGS AND SPERM IN MODULE CONTAINERS
- ENSURE PHOTOGRAPHY AND SPECIMEN FIXING AT PRESCRIBED INTERVALS
- HARVEST ARABIDOPSIS SEEDS AND PLANT IN AGAR MEDIA
- PRESERVE MATURE PLANT PARTS AS PRESCRIBED
- ENSURE PLANT MODULE OPERATION AND ENVIRONMENT CONTROL
- MAINTAIN DROSOPHILA COLONY
- SEPARATE MALE/FEMALE FLIES
- OBSERVE FOR MUTATIONS
- MONITOR DROSOPHILA BEHAVIOR
- COUNT EGG BATCHES
- MAINTAIN MORTALITY RECORDS
- ENSURE OPERATION OF DROSOPHILA MODULE
## EXPERIMENT ACTIVITY TIMELINES

### SOLAR—TERRESTRIAL EXPERIMENTS (PAYLOAD CREWMAN 1)

<table>
<thead>
<tr>
<th>Experiment Period</th>
<th>2 Hr</th>
<th>1 Hr</th>
<th>3 Hr</th>
<th>2 Hr</th>
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<tbody>
<tr>
<td>A</td>
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<tr>
<td>B</td>
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<tr>
<td>E</td>
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</tbody>
</table>

- **A** — Soft X-Ray Telescope Target Area Selection and Pointing
- **B** — SEPAC Atmospheric Perturbation and Measurement
- **C** — AEPI Pointing and Measurement of Selected Atmospheric Phenomena
- **D** — SEPAC Magnetospheric Measurements Using Sensor Receivers on Free-Flyer
- **E** — WISP Measurements: Initiation, Pointing Control, and Data Monitoring

### LIFE SCIENCES EXPERIMENTS (PAYLOAD CREWMAN 2)

<table>
<thead>
<tr>
<th>Experiment Period</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
</tr>
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<tbody>
<tr>
<td><strong>F</strong></td>
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<td><strong>I</strong></td>
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</tbody>
</table>

- **F** — Frog Egg Experiment Data Collection
- **G** — Drosophila Colony Maintenance
- **H** — Arabidopsis Seed Harvesting and Replanting
- **I** — Drosophila Experiment Activities
EXPERIMENT ACTIVITY TIMELINES

LIFE SCIENCES EXPERIMENTS

1 Hr

Period F, Earth Equivalent Time 8:00 am to 9:00 am

Frog Egg Experiment Data Collection

- Check Experiment Module Temperature, O₂ and CO₂ Levels
- Check Adherence to Fixative Injection Schedule
- Check No. of Exposed Frames in Time-Lapse Photography — Compare With Schedule
- Remove Container Holding Most Recently Fixed Specimen — Examine Progress and Development With Hand Lens
- Record Data

2 Hrs

Period G, Earth Equivalent Time — 10:00 am to 12:00 Noon

Drosophila Colony Maintenance

- Check Displays For Automatically Controlled Temperature and Humidity
- Check Each Drosophila — Containing Capsule in Module
  - Examine For Amount of Yeast Growth — Reinnoculate As Necessary
  - Note Newly Deposited Egg Batches and Record Capsule Number
  - Note Occurrence of Dead Flies — Record No. and Capsule
- Record Data

2 Hr

Period H, Earth Equivalent Time — 1:00 pm to 3:00 pm

Arabidopsis Seed Harvesting and Replanting

- Remove Arabidopsis Experiment Kit From Storage and Setup on Workbench
- Remove Arabidopsis Growth Tubes From Refrigerator and Allow to Warm
- Remove, Separately, Arabidopsis Plants From Experiment Module
- Harvest Seeds, Replant Some in New Tubes, and Package Remainder For Return
- Label Seed-Containing Tubes and Return to Experiment Module
- Examine Mature Plants For Abnormalities — Record Observations
- Remove Specified Plant Parts, Preserve, and Prepare For Return. Dispose of Rest of Plant
- Return Kit to Storage and Dispose of Used Tubes
EXPERIMENT ACTIVITY TIMELINES (CONT)

LIFE SCIENCES EXPERIMENTS (CONTINUED)

3 Hr

Period I, Earth Equivalent Time, 4:00 pm — 7:00 pm

Drosophila Experiment Activities

- Remove Drosophila Experiment Kit From Storage and Setup on Workbench
- Remove Drosophila Container From Experiment Module Previously Noted to Contain Egg Batches
- Anesthetize and Remove Flies
- Using Hand Lens, Separate Males From Females
- Obtain New Containers From Refrigerator
- Place Some Males in One, Females in Another
- Package Remaining Flies For Return
- Using Hand Lens, Count No. of Eggs in Each Egg Batch
- Record Data and Return Containers to Experiment Module

- Remove Containers With Newly Hatched Flies
- Anesthetize Flies, Separate Males From Females, and Examine For Abnormalities
- Place Some Males in One New Container, Females in Another
- Package Remainder For Return

- Remove Containers With Male Flies and Female Flies Which Have Just Reached Maturity
- Anesthetize Flies and Place Some Males and Some Females in New Container
- Allow to Recover and Observe Mating Behavior
- Return Containers to Experiment Module
- Record Observations and Data

- Remove Containers Previously Noted to Contain Dead Flies
- Anesthetize Flies and Remove Dead Specimens
- Package Dead Flies For Return
- Record Longevity Data

- Repack Kit and Return to Storage
- Dispose of All Used Containers and Supplies
CREW TIMELINE — 3 CREWMEN
TYPICAL MISSION DAY

<table>
<thead>
<tr>
<th>HR</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
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<tbody>
<tr>
<td>EQUVALENT EARTH TIMES</td>
<td>5:00</td>
<td>6:00</td>
<td>7:00</td>
<td>8:00</td>
<td>9:00</td>
<td>10:00</td>
<td>11:00</td>
<td>12:00</td>
<td>1:00</td>
<td>2:00</td>
<td>3:00</td>
<td>4:00</td>
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<tr>
<td>AM</td>
<td>PM</td>
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</tr>
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</table>

CREW ACTIVITIES:

CREWMAN 1 (SOLAR TERRESTRIAL)

<table>
<thead>
<tr>
<th>SLEEP</th>
<th>POST SLEEP</th>
<th>MED MEAS</th>
<th>MEAL</th>
<th>EXPER PERIOD A&amp;B</th>
<th>EXER</th>
<th>STA KEEP</th>
<th>EXPER PERIOD C</th>
<th>MEAL</th>
<th>EXPER PERIOD D</th>
<th>EXER</th>
<th>STA KEEP</th>
</tr>
</thead>
</table>

CREWMAN 2 (LIFE SCIENCE)

<table>
<thead>
<tr>
<th>SLEEP</th>
<th>POST SLEEP</th>
<th>MED MEAS</th>
<th>MEAL</th>
<th>EXPER PERIOD F</th>
<th>EXER</th>
<th>STA KEEP</th>
<th>EXPER PERIOD G</th>
<th>MEAL</th>
<th>EXPER PERIOD H</th>
<th>EXER</th>
<th>STA KEEP</th>
<th>EXPER PERIOD I</th>
</tr>
</thead>
</table>

CREWMAN 3 (SYSTEM)

<table>
<thead>
<tr>
<th>SLEEP</th>
<th>POST SLEEP</th>
<th>MED MEAS</th>
<th>MEAL</th>
<th>PLATFORM FUNCTIONS</th>
<th>MEAL</th>
<th>PLATFORM FUNCTIONS</th>
</tr>
</thead>
</table>

EXER = EXERCISE  
STA KEEP = STATION KEEPING

<table>
<thead>
<tr>
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<th>14</th>
<th>15</th>
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<tbody>
<tr>
<td>EQUVALENT EARTH TIMES</td>
<td>5:00</td>
<td>6:00</td>
<td>7:00</td>
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</table>

CREWMAN A

<table>
<thead>
<tr>
<th>EXPER PERIOD A&amp;C</th>
<th>MEAL</th>
<th>LEISURE TIME</th>
<th>PRE SLEEP</th>
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CREWMAN B

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<tr>
<th>EXPER PERIOD A&amp;B</th>
<th>MEAL</th>
<th>LEISURE TIME</th>
<th>PRE SLEEP</th>
<th>SLEEP</th>
</tr>
</thead>
</table>

CREWMAN C

| MEAL | LEISURE TIME | PRE SLEEP | SLEEP |
### MANNED SPACE PLATFORM (STATION)

#### CREW SIZE AND PAYLOAD UTILIZATION

(Candidate Plan)

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Crew</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>4</td>
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<tr>
<td>Size</td>
<td></td>
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</tr>
</tbody>
</table>

**Payload Utilization**

- **Platform Activation and Checkout**
- **Solar Terrestrial Observatory**
- **Lifeline Science**
- **Materials Processing**
- **Tether**
- **TMS Operations**
- **Structure Assembly**
- **Cryo Stage Technology**
- **Life Support Technology**
- **Closed-Loop Life Support Operations**
- **Spacecraft Servicing**
CREW SIZE CONSIDERATIONS

- Man-Hour Capabilities
- Skill Mix
- Work-Rest Cycles
- Volume
- Configuration Layout
- Program History
- Logistics
- Cost Factors
CREW REQUIREMENTS — MOSC STUDY

<table>
<thead>
<tr>
<th>Payload</th>
<th>No. of Crewmen Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Astronomy (11)</td>
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</tr>
<tr>
<td>HE Astrophysics (4)</td>
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<tr>
<td>Solar Physics (1)</td>
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<tr>
<td>Atmos/Space Physics (1)</td>
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<tr>
<td>Earth Observ (4)</td>
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<tr>
<td>Earth/Ocean Physics (5)</td>
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<tr>
<td>Space Processing (6)</td>
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<tr>
<td>Life Sciences (4)</td>
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<tr>
<td>Space Technology (7)</td>
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<tr>
<td>Comm/Nav (3)</td>
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</tbody>
</table>

SAMSP Mission Categories

ORIGIN PAGES ARE OF POOR QUALITY.
# CREW SKILL UTILIZATION

<table>
<thead>
<tr>
<th>Spacelab Crew Skill Classification</th>
<th>Utiliztion on 50 MOSC Payloads</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Biological Technician</td>
<td>Electromechanical Technician</td>
</tr>
<tr>
<td>2. Biochemist</td>
<td>Astronomer</td>
</tr>
<tr>
<td>3. Medical Doctor</td>
<td>Chemist</td>
</tr>
<tr>
<td>4. Behavioral Scientist</td>
<td>Oceanographer</td>
</tr>
<tr>
<td>5. Astronomer/Astrophysicist</td>
<td>Electronics Engineer</td>
</tr>
<tr>
<td>6. Optical Scientist</td>
<td>Physicist</td>
</tr>
<tr>
<td>7. Electromechanical/Optical Technician</td>
<td>Geologist</td>
</tr>
<tr>
<td>8. Photo Technician/Cartographer</td>
<td>Geographer</td>
</tr>
<tr>
<td>9. Geologist</td>
<td>Agronomist</td>
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<tr>
<td>10. Meteorologist</td>
<td>Behavioral Scientist</td>
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<tr>
<td>11. Oceanographer</td>
<td>Photo Technician</td>
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<td>12. Agronomist</td>
<td>Meteorologist</td>
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<td>13. Geographer</td>
<td>Biologist</td>
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<td>14. Electronics Engineer</td>
<td>Biochemist</td>
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<td>15. Mechanical Engineer</td>
<td>Medical Doctor</td>
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<td>16. Thermodynamician</td>
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<td>21. Biologist</td>
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<td>22. Biomedical Technician</td>
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<tr>
<td>23. Crewman</td>
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</table>

1. Biological Technician
2. Biochemist
3. Medical Doctor
4. Behavioral Scientist
5. Astronomer/Astrophysicist
6. Optical Scientist
7. Electromechanical/Optical Technician
8. Photo Technician/Cartographer
9. Geologist
10. Meteorologist
11. Oceanographer
12. Agronomist
13. Geographer
14. Electronics Engineer
15. Mechanical Engineer
16. Thermodynamician
17. Metallurgist
18. Chemist
19. Physicist
20. General
21. Biologist
22. Biomedical Technician
23. Crewman
COMBINED SKILL SPECIALIST CATEGORIES

MOSC Study

A — Earth Sciences
B — Life Sciences
C — Meteorologist/Photographer
D — Material Sciences
E — Physical Sciences
F — Engineering Technician
G — Astronomical Sciences

Manned Space Platform

Solar/Terrestrial Sciences
Life Sciences
Material Sciences
Engineering Technician
CREW WORK/REST CYCLES

Time of Day (hr)

0 4 8 12 16 20 24

3-Man Crew

No. 1 Work

Sleep

No. 2 Work

Sleep

No. 3 Work

Sleep

4-Man Crew

No. 1 Work

Sleep

No. 2 Work

Sleep

No. 3 Work

Sleep

No. 4 Work

Sleep
3-MAN HABITABILITY MODULE

Bay 6
(Food Freezer, Chiller, Etc)

Bay 4
(Double Rack)

Bay 2
(Controls)

Food Mgmt

Sleep

Sleep

Personal
Hygiene

Bay 3
(Double Rack)

Bay 1
(Workbench)
4-MAN HABITABILITY MODULE

Rack 6 (Personal Hygiene)

Rack 4

Rack 2 (Controls)

Sleep

Sleep

Racks 3 and 5 (Food Mgmt, Food Freezer, Chiller, Etc)

Rack 1 (Workbench)
2 + 2-MAN HABITABILITY MODULE

Food Mgmt
(Sized for 4 Men)

Personal Hygiene

Sleep

Food Freezer, Etc

Rack 2

Rack 4
(Double)

Rack 6

Sleep

Rack 5

Rack 3 (Double)

Rack 1
LAUNCH SEQUENCE

I

\[ \text{SP} \quad \text{P} \quad \text{HM(2)} \quad \text{R} \quad \text{P/L1} \quad \text{P/L2} \]

MANNED (3) →

II

\[ \text{SP} \quad \text{P} \quad \text{A} \quad \text{R} \quad \text{P/L1} \quad \text{HM(3)} \]

MANNED (4) →

III

\[ \text{SP} \quad \text{P} \quad \text{A} \quad \text{HM(2)} \quad \text{R} \quad \text{HM + P/L2} \quad \text{P/L1} \]

MANNED (2) →

+2 →

P — Pallet
A — Airlock/Adapter
P/L — Payload
R — Resupply Module
HM — Habitability Module
BUILDUP SEQUENCE

LAUNCH NO. 1

I (3-MAN)
+ (1) 3.0m PAYLOAD

II (4-MAN)
+ (1) 3.0m PAYLOAD

III (2+2-MAN)

NO. 2

NO. 3

2 MEN

2 MEN
PAYLOAD
RACKS/CREW — HABITABILITY MODULE.

Number

1 — 3 Men, 2 Segments
II — 4 Men, 3 Segments
III — 2 + 2 Men, 2 Segments

Dedicated Payload Racks
Crew Size

VFO619
CREW SIZE HISTORY

Mercury  Gemini  MOL  Apollo  Skylab  MOSC (Study)
CREW SIZE COST FACTORS

- Training
- Ground Facilities
- Habitation
- Logistics
  - Rotation
  - Resupply
<table>
<thead>
<tr>
<th>Crew Size</th>
<th>Module Segments</th>
<th>Manning Sequence</th>
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<tr>
<td>3</td>
<td>2</td>
<td>$3 \rightarrow 4 \rightarrow 6$</td>
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<td>4</td>
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<td>$2 + 2$</td>
<td>$2 + 1$</td>
<td>$2 \rightarrow 4 \rightarrow 6$</td>
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AGENDA

Study Overview

Special Unmanned Platform Studies (Task A)

Manned Platform Concept (Task B)

- Configuration, Structural/Mechanical and Operations

- System and Payload Requirements, and Performance

- Subsystems, Habitability, and Safety

- Programmatics
**SUBSYSTEM EFFORT IN SYSTEMS ANALYSIS AND DEFINITION (SUBTASK B.3)**

### Inputs
- Power System Design
- Design and Operational Requirements
- Spacelab Hardware Descriptions
- Orbiter Hardware Descriptions
- Star No. 17
- STS User's Handbook
- K-STSM-14.1 Launch Site Accommodation Handbook
- Support Analysis and Trades

### Subtask Activity Flow
- **B.2** Concepts Identification
- **B.3.1** In-Depth Analysis of Concepts
- **B.3.2** Modules/Elements for Evolutionary Growth
- **B.3.3** Operations Analysis
- **B.3.4** Maintenance, Reliability, and Safety Analyses
- **B.3.5** Subsystems Conceptual Definition
- **B.3.6** Interface Definition

### Outputs
- Engineering Drawings
- System Schematics
- System Specifications
- Weight Statements
- Mass Characteristics
- Dynamic Characteristics
- System Constraints
- Hardware Trees
- System Tradeoffs
- Subsystem Equipment List

### Arrangements and Subsystem Limitations

### Subsystem Impacts
- Existing Hardware Tradeoff Support
- Characteristic Development
REPORT ON VISIT TO ERNO

Spacelab Hardware Delivery
- Engineering Model Nov 1980
- First Flight Unit Nov 1981
- Second Flight Unit May 1982

Spacelab Follow-On Development Program
- Initial Step (Phase A)
  - Completed in Early 1981
  - Mission Extension to 20 Days, Experiment Power to 4 kW, Greater Cooling, and CDMS Improvements
  - 18 to 22 MAU Addition

- Medium-Term improvement Study (July Start)
  - Degree of Spacelab Element Autonomy
  - Reliability and Redundancy Studies
  - Subsystem Accommodation
  - Implementation Strategy
ECLS SUBSYSTEM TOPICS

Tradeoffs
Mass Balances
Equipment Locations
Applicability of Existing Hardware
Approach to Long Life/High Reliability
REGENERABLE CO₂ REMOVAL ADVANTAGE FOR BASIC MSP

Note: Specimen-Holding Facility Doubles the LiOH Weight and Adds 50% to the SAWD Weight
CONDENSATE PROCESSING
ADVANTAGE FOR BASIC MSP

Mission Length (days)

Weight Penalty (lbm)

Waste Water Return Weight

Condensate Processing for Hygiene Water

Drinking Water Launch Weight

Drinking + Hygiene Water Launch Weight
KEY FEATURES OF MSP ECLS

- Regenerable CO₂ Removal
- Partial Water Loop Closing
- Fail-Operational/Fail-Safe
- Maintainable Equipment
- 100% Crew Overload Capability
- No Throwaway Growth Design
- On-Orbit Evaluation of Water Processing
- Optimum Use of Existing Qualified Equipment
- Low Cost and Low Program Risk
16 WATER TANKS

FORCED AIR MIXING

ANIMAL EXP MODULE

SPACELAB ECLS
PLUS: 1 REGEN CO₂ ASSEMBLY
1 CAT. OX ASSEMBLY

LIFE SCIENCES MODULE

CO₂ DUMP

COOLANT LOOP A

O₂/N₂

HABITAT MODULE

SPACELAB ECLS
PLUS: 1 REGEN CO₂ ASSEMBLY
1 CAT. OX ASSEMBLY
1 MULTIFILTRATION ASSEMBLY
1 HANDWASH
1 GALLEY

HYGIENE WATER

WASTE WATER

POTABLE WATER

CO₂ DUMP

COOLANT LOOP B

AIRLOCK ADAPTER MODULE

COMMODE

VACUUM

CO₂ DUMP
## EXISTING HARDWARE APPLICABILITY FOR BASIC MSP

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<th>Existing Item</th>
<th>Remarks</th>
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<td>Condensing Heat Exchanger</td>
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<td>Fan Separators</td>
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<tr>
<td>Cabin Fan Package</td>
<td>Use as Is</td>
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<tr>
<td>Avionics Fan Package</td>
<td>Use as Is</td>
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<td>Avionics Heat Exchanger</td>
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<tr>
<td>LiOH/Temperature Control Valve Package</td>
<td>Retain as Is But Use for Odor Control and Emergency CO&lt;sub&gt;2&lt;/sub&gt; Removal</td>
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<td>Water Pump Package</td>
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<td>Potable/Wastewater Tanks</td>
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<tr>
<td>Two Gas Controller</td>
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<td>N&lt;sub&gt;2&lt;/sub&gt; Tanks</td>
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<td>O&lt;sub&gt;2&lt;/sub&gt; Tanks</td>
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<td>Galley</td>
<td>Use as Is</td>
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<tr>
<td>Suits and Backpacks</td>
<td>Use as Is</td>
</tr>
<tr>
<td>Miscellaneous Valves, Sensors, Etc</td>
<td>Use as Is</td>
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</table>
APPROACH TO LONG-LIFE/RELIABILITY
APPROACH ENVIRONMENTAL
CONTROL/LIFE SUPPORT SUBSYSTEM

Existing Design

1. Already Designed for Long Life

2. Some Rotating Equipment Run in Excess
   of 20,000 hr (2-1/4 yr)

3. Qualification Times/Cycles Less Than 10 yr

Approach

1. Design for On-Orbit Maintenance

2. Trade Built-In Redundancy Versus Spares

3. Qualify on Orbit Where Practical

4. Include Built-In Redundancy Where Necessary
   for Fail-Operational/Fail-Safe
AIR COOLING
VERSUS COLD PLATE COOLING

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<th>Consideration</th>
<th>Avionics Loop</th>
<th>Cold Plate</th>
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<td>High Density</td>
<td>Low Density</td>
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<td></td>
<td>(Per kW)</td>
<td>(Per ft³)</td>
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<td>Weight (lb)</td>
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<td>Power (W)</td>
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<tr>
<td>Volume (ft³)</td>
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<td>0.4</td>
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Other Considerations:
1. Unique Designs for Cold Plating
2. Water-Loop Pressure Drop Considerations
3. Air-Cooled Avionics Run About 15 to 20°F Hotter
4. Fire Detection

Conclusions:
Recommend Cold Plates Where Practical, Especially for High Power Density Applications
WATER LOOP INTEGRATION OPTIONS

Each Loop to Both ECS

- Only One Loop Normally Operating
- Full Performance With One Loop Out
- More Expensive
- Poor Separation of Redundant Lines
- Orbiter Hardware

One Loop to Each ECS

- Maximum Separation of Redundant Lines
- Degraded Performance With One Loop Out
- Satisfies Two-Compartment Requirement
- Less Expensive
- Spacelab Hardware
ATMOSPHERE HUMIDITY AND TEMPERATURE CONTROL TRADE

Goals

- Use Spacelab Hardware
- Maximize Performance
  - Dew Point Below 60°F
  - Maximize Available Cooling
  - Low Load Capability
- Provide Capability to Grow
- Allow Reduced Cooling Water Flow Rate

Options

- Dual Function (Each HX Cools Air and Controls Humidity)
  - Series Arrangement
  - Parallel Arrangement
- Separate Function
  - No Water Loop Temperature Control
  - With Temperature Control
SERIES ARRANGEMENT OF DUAL-FUNCTION HEAT EXCHANGERS

- Controls Interaction
- Performance Limits on Downstream HX
- Minimal Mod to Spacelab Hardware

**PAYLOAD MODULE**

- 2.91 kW TOTAL (0.43 kW LATENT)

**HABITABILITY/PAYLOAD MODULE**

- 3.82 kW (0.23 kW LATENT)

**AIRLOCK/ADAPTER**

- 592 LB/HR/LOOP
- 43°F DEW POINT
- 75°F DEW POINT
- 59°F DEW POINT
- 55°F DEW POINT
- 75°F
PERFORMANCE OF SERIES ARRANGEMENT OF DUAL-FUNCTION HEAT EXCHANGERS

Effectiveness, Available 0.8
Second HX.

Minimum Cooling Water Flow.

Effectiveness Required for Humidity Control in Second Module.

Cooling Water Flow Rate (lb/hr)

Cooling Available at First HX (kW)

Heat Exchanger Hot Side Effectiveness

0 0.5 0.6 0.7 0.8

300 350 400 450 500 550 600

OF SERIES ARRANGEMENT
OF DUAL-FUNCTION HEAT EXCHANGERS

VF02

PERFORMANCE 
OF DUAL-FUNCTION HEAT EXCHANGERS

Effectiveness

0.5 0.5

0.0 0.0

0 1.0

1.5

2.0

2.5
PARALLEL ARRANGEMENT
OF DUAL-FUNCTION HEAT EXCHANGERS

- Marginal Humidity Control
- Limited Growth

1. Payload Module
   - 3.27 kW (0.43 kW Latent)
   - 75°F
   - 59°F Dew Point

2. Habitability/Payload Module
   - 3.36 kW (0.23 kW Latent)
   - 75°F
   - 54°F Dew Point

3. Airlock/Adapter
   - 71°F
   - 54°F Dew Point

4. Loads
PERFORMANCE FOR
PARALLEL ARRANGEMENT OF
DUAL-FUNCTION HEAT EXCHANGERS

Cabin Dew Point
Temperature

Dew Point
Limit

Total Sensible
Cooling

Spacelab
Design

Sensible Cooling for Each Condenser

Sensible Cooling (kW)

Cabin Dew Point Temperature (°F)

No. of Heat Exchangers

10

65

0

50

2

3

4

5

6

7

0

5

6

7
ALTERNATE CONCEPT
FOR SERIES ARRANGEMENT
OF DUAL-FUNCTION HEAT EXCHANGERS

- No Minimum Load in Airlock/Adapter
- Full Water Flow in All HXs
- Growth Capability
- Control Needed to Prevent Starving Downstream HX

75°F DEW POINT
60°F DEW POINT

1.33 kW

66°F
100 CFM

PAYLOAD MODULE

75°F
54°F DEW POINT

3.36 kW (0.23 kW LATENT)

AIRLOCK/ADAPTER

LOADS
74.1°F

75°F
56°F DEW POINT

4.06 kW (0.66 kW LATENT)

LOADS
65°F

592 LB/HR/LOOP

HABITABILITY/PAYLOAD MODULE

75°F
60°F DEW POINT

66°F

L3.36 kW (0.23 kW LATENT)
SEPARATE-FUNCTION
HEAT EXCHANGERS WITH NO
COOLING WATER TEMPERATURE CONTROL

- Marginal Humidity Control
- Narrow Allowable Heat Loads for Cabin
- Interchange Flow Required

* A PORTION OF THIS COOLING AVAILABLE FOR PAYLOAD MODULE
PERFORMANCE FOR SEPARATE-FUNCTION HEAT EXCHANGERS WITH NO COOLING WATER TEMPERATURE CONTROL

- 75°F Cabin
- 2244 Btu/hr Latent
- 43°F Water Supply

Diagram:
- Cabin Sensible Cooling Capability (kW)
- Condenser Air Flow (lb/hr)
- Condenser Outlet Air Temperature (°F)
- Total Cooling
- Spacelab Design
- Condenser Flow
- Condenser Cooling
PERFORMANCE FOR SEPARATE-FUNCTION HEAT EXCHANGERS WITH COOLING WATER TEMPERATURE CONTROL

- High Minimum Load for Condensers
- Larger Number of Heat Exchangers
- Interchange Air
## SUMMARY OF TRADE STUDY RESULTS
### ATMOSPHERE HUMIDITY AND TEMPERATURE CONTROL

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Dual-Function HXs</th>
<th>Separate-Function HXs</th>
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<td>Series</td>
<td>Parallel</td>
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<tr>
<td>Sensible Cooling</td>
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<tr>
<td>Per Compartment (kW)</td>
<td>1.51-3.59</td>
<td>2.84-3.13</td>
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<td>Total (kW)</td>
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<td>Minimum Load (kW)</td>
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<td>Cabin Dew Point Temp (°F)</td>
<td>48-59</td>
<td>53-57</td>
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<td>Penalties</td>
<td>Small</td>
<td>Small</td>
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<td>Growth</td>
<td>Single Module Limits</td>
<td>Limited</td>
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<tr>
<td>Water Flow Sensitivity</td>
<td>Sensitive</td>
<td>Very</td>
</tr>
</tbody>
</table>

(1) Function of Water Pump Design Flow
THEORETICAL LIMITS
FOR ATMOSPHERE COOLING

75°F Cabin
Average Latent

65°F Cabin
High Latent

Range for
Concepts
Studied

Theoretical Limit to Atmosphere Cooling (kW)

Total MSP Heat Load (kW)
GROWTH CONCEPT FOR ATMOSPHERE HUMIDITY AND TEMPERATURE

Cooling Available

Loop 1 — 5 to 6 kW Total
Loop 2 — 5.5 to 6.2 kW Total

Initial Configuration

Growth Addition
POWER SUBSYSTEM
ISSUES TO BE RESOLVED

- AC Power Distribution
  — Central vs Distributed Inverters

- DC Power Distribution For Distant Loads (Spacelab Impacts to be Considered. (30-V vs 120-V Distribution)

- Emergency Power Requirements

- Housekeeping Power Requirements

- PS and Spacelab Equipment Capabilities/Limitations

- Power Management
DC POWER DISTRIBUTION - INITIAL VERSION
(30-V DISTRIBUTION)

SM

2 kW
DISTRIB
R = 8.4 MΩ
CB = 1.0 V

5 kW EXP
LINE LOSS = 267.8 W
CB LOSS = 178.6 W
446.4 W (8.2%)

2 kW
DISTRIB
R = 6.0 MΩ
CB = 0.6 V

5 kW EXP
LINE LOSS = 191.3 W
CB LOSS = 107.1 W
298.4 W (5.5%)

R = 3.6 MΩ
CB = 0.4 V

POWER SYSTEM

DISTRIB

AIRLOCK/ADAPTER

0.1 kW
DISTRIB

LOGISTICS MOD

R = 7.2 MΩ
CB = 0.6 V

2.1 kW

5 kW

5 kW EXP
LINE LOSS = 229.6 W
CB LOSS = 107.1 W
336.7 W (6.3%)

16.38 kW TO USERS
DC POWER DISTRIBUTION -
GROWTH VERSION
(30-V DISTRIBUTION)

- 5 kW
  - LINE LOSS: 267.8 W
  - CB LOSS: 178.6 W
  - CB w/ R = 8.4 MΩ, CB = 1.0 V
  - R = 3.6 MΩ, CB = 0.2 V
- 2 kW
  - LINE LOSS: 191.3 W
  - CB LOSS: 107.1 W
  - CB w/ R = 6.0 MΩ, CB = 0.6 V
- 2 kW
  - LINE LOSS: 446.4 W (8.2%)
- 5 kW
  - LINE LOSS: 497.4 W
  - CB LOSS: 321.4 W
  - CB w/ R = 15.6 MΩ, CB = 1.8 V
- 2 kW
  - LINE LOSS: 191.3 W
  - CB LOSS: 107.1 W
  - CB w/ R = 13.2 MΩ, CB = 1.4 V
- 2 kW
  - LINE LOSS: 420.9 W
  - CB LOSS: 250.0 W
  - CB w/ R = 10.8 MΩ, CB = 1.0 V
- 2.1 kW
  - LINE LOSS: 229.6 W
  - CB LOSS: 107.1 W
  - CB w/ R = 7.2 MΩ, CB = 0.8 V
- 0.1 kW
  - LINE LOSS: 49.6 W
  - CB LOSS: 29.8 W
  - CB w/ R = 3.0 MΩ, CB = 0.2 V

LOGISTICS MOD

AIRLOCK/ADAPTER

PAYLOADS

0.77 kW TO USERS

(120-V LINES TO BE CONSIDERED TERMINATING IN 30-V REGULATORS)
TRANSMISSION VOLTAGE CONSIDERATIONS FOR DISTANT LOADS

- **Power System**
  - 30 VDC
  - Voltage Drop
  - High-Current Flow
  - Increased Wire Weight

- **Power System**
  - 120 VDC
  - Voltage Drop Resolved
  - Lower Current
  - Adds Regulator(s)
  - Regulator $\eta \approx 95\%$
  - Reduction in Wire Weight
Operational Mode Assumptions

- Initial Shuttle-Tended Mode
  - Airlock/Adapter or AFD Control Center
- Manned Free-Flyer Mode
  - Habitat Module Contains Primary Control Center
  - Airlock/Adapter Has Backup Capability

Hardware Selection Options

- Spacelab-Derived
- Other Current-Technology Hardware
- New-Technology Hardware

Additional Redundancy for Increased Reliability
Minimize Impact to Power System and Orbiter
Provide Capability for Evolutionary Platform Growth
## CDMS FUNCTION ALLOCATION

<table>
<thead>
<tr>
<th>Function</th>
<th>Power System</th>
<th>Airlock Adapter</th>
<th>Payload Module</th>
<th>Habitat</th>
<th>Logistics Module</th>
<th>Beam</th>
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(G) Growth (I) Initial
CANDIDATE  
CDMS HARDWARE APPROACHES 

- Spacelab/Shuttle Hardware 

- STACC Hardware (Ref PS Approach) 

- FMDM Hardware 

- New-Technology Hardware
CDMS SELECTION CRITERIA

- Requirement Accommodation
- Flexibility/Growth Capability
- Cost/Cost Risk
- Reliability
- Volume, Weight, and Power
- Compatibility With Other Subsystems
- Availability/Schedule Risk
# COMPARISON OF CDMS HARDWARE APPROACHES

<table>
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<tr>
<th>Approach</th>
<th>Advantages</th>
<th>Disadvantages</th>
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<tbody>
<tr>
<td>Spacelab/Shuttle</td>
<td>• Developed</td>
<td>• Reliability</td>
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<tr>
<td></td>
<td>• Low Risk</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Compatible With Orbiter</td>
<td></td>
</tr>
<tr>
<td>STACC</td>
<td>• Developed</td>
<td>• Capacity</td>
</tr>
<tr>
<td></td>
<td>• Qualified for Long Mission Life</td>
<td>• Flexibility</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• No Man/Machine Interface</td>
</tr>
<tr>
<td>FMDM</td>
<td>• Potential for Distributed Processing</td>
<td>• No Man/Machine Interface</td>
</tr>
<tr>
<td></td>
<td>• Flexible</td>
<td></td>
</tr>
<tr>
<td>New-Technology Hardware</td>
<td>• Potential Improvements in Performance, Reliability and Packaging</td>
<td>• Requires Development and Qualification</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Cost Risk</td>
</tr>
</tbody>
</table>

**SELECTED**
CDMS FEATURES

- Utilizes Developed Equipment
- Provides Flexible Crew Accommodation
- Accommodates PS and Orbiter Interfaces
- Exhibits Improved Reliability
- Accommodates Platform Growth
PLATFORM DATA MANAGEMENT SUBSYSTEM

NOTE: ALL UNITS DERIVED FROM SPACELAB EXCEPT PRINTER
PLATFORM
VOICE COMMUNICATION SUBSYSTEM

NOTE: ALL UNITS DERIVED FROM SHUTTLE/SPACELAB EXCEPT SIGNAL PROCESSOR AND TAPE RECORDER
PLATFOR
CLOSED-CIRCUIT TV SUBSYSTEM

NOTE: ALL UNITS DERIVED FROM SHUTTLE/SPACELAB EXCEPT VIDEO PROCESSOR AND VIDEO STORAGE UNIT
PLATFORM TIMING DISTRIBUTION

NOTE: ALL UNITS DERIVED FROM SHUTTLE/SPACELAB
## CDMS EQUIPMENT SUMMARY

<table>
<thead>
<tr>
<th>Unit</th>
<th>Pedigree</th>
<th>Airlock/Adapter</th>
<th>P/L Mod</th>
<th>Hab Mod</th>
<th>Log Mod</th>
</tr>
</thead>
<tbody>
<tr>
<td>I/O Unit</td>
<td>Spacelab</td>
<td>1</td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>DDU/KB</td>
<td>Spacelab</td>
<td>1</td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Computer</td>
<td>Spacelab</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MMU</td>
<td>Spacelab</td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Exp RAU</td>
<td>Spacelab</td>
<td></td>
<td>2</td>
<td>2</td>
<td></td>
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<tr>
<td>Subsys RAU</td>
<td>Spacelab</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
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<tr>
<td>HRM</td>
<td>Spacelab</td>
<td>1</td>
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<td>HDRRR</td>
<td>Spacelab</td>
<td></td>
<td></td>
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<tr>
<td>Printer</td>
<td>New</td>
<td></td>
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<tr>
<td>TV Camera</td>
<td>Orbiter</td>
<td>1</td>
<td></td>
<td>1</td>
<td>2</td>
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<td>Video Monitor</td>
<td>Spacelab</td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
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<td>Video S/W Unit</td>
<td>Orbiter</td>
<td>1</td>
<td></td>
<td></td>
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<tr>
<td>Video Processor</td>
<td>New</td>
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<td>Video Storage Unit</td>
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<td></td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Camera Control Pnl</td>
<td>Orbiter</td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
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<tr>
<td>Intercom Master Sta</td>
<td>Spacelab</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercom Remote Sta</td>
<td>Spacelab</td>
<td>2</td>
<td>2</td>
<td>3</td>
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<td>Loudspeakers</td>
<td>Spacelab</td>
<td></td>
<td>1</td>
<td></td>
<td>2</td>
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<td>EVA Comm Set</td>
<td>Orbiter</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Audio Sig Proc</td>
<td>New</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
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<tr>
<td>Audio Recorder</td>
<td>New</td>
<td></td>
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<td></td>
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<tr>
<td>C&amp;W Processor</td>
<td>Orbiter</td>
<td></td>
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<td></td>
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<td>C&amp;W Distr Unit</td>
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<tr>
<td>C&amp;W Annunciator Pnl</td>
<td>Orbiter</td>
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<td>1</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Timing Distr Unit</td>
<td>Orbiter</td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Timing Display Unit</td>
<td>Orbiter</td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>
IMPACT OF 2- VERSUS 3-SEGMENT MODULE ON CDMS HARDWARE

- 1 or 2 Additional Experiment RAUs

- 1 or 2 Additional Subsystem RAUs

- Extend Data Buses

- Additional Intercom Remote Station(s)
CDMS APPROACH
TO POWER SYSTEM COMPATIBILITY

Issues

• Man-Rated Design

• Interface Compatibility

• Support Costs (Common Spares)

Approach

• PS Initial Design for
  Manned Safety

• PS Interface Adaptation in
  Airlock/Adapter Option: Use Single
  Design Approach From Start
CDMS OPEN ISSUES

CDMS Reliability

- Additional Redundancy
- Onboard Spares, Fault Isolation, Repair
- Design/Manufacturing Upgrades

Utilization of New Technology

- Distributed Data Processing
- Improved IC and Computer Technology
- Fiber Optic Data Transmission
- Voice Recognition and Synthesis
- Display Technology
MSP/POWER SYSTEM ACS CAPABILITY ANALYSIS

Reference Power System (25 kW)
Three Modified Skylab CMGs
Four Space Telescope Magnetic Torquers

Conditions Analyzed
200 and 235 nmi Altitudes
0, 40, and 80 deg \( \beta \)-Angles
57.5-deg Inclination
Medium, High, and Worst-Case Atmospheric Densities
June 21 — Time of Year
Five Inertial Orientations
Two Local Vertical Orientations
MSP ORIENTATION DURATION WITH REFERENCE 25KW POWER SYSTEM

Medium Atmospheric Density

<table>
<thead>
<tr>
<th>Principal Axes Orientation</th>
<th>Orientation Hold Duration (Orbits)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>235 nmi</td>
</tr>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>XPOP-YPSL</td>
<td>∞</td>
</tr>
<tr>
<td>XPPOP-ZPSL</td>
<td>∞</td>
</tr>
<tr>
<td>YPOP-ZPSL</td>
<td>∞</td>
</tr>
<tr>
<td>ZPOP-YPSL</td>
<td>62</td>
</tr>
<tr>
<td>ZSI-XIOP</td>
<td>∞</td>
</tr>
<tr>
<td>ZLV-XPOP (YVV)</td>
<td>14</td>
</tr>
<tr>
<td>ZLV-YPOP (XVV)</td>
<td>∞</td>
</tr>
</tbody>
</table>

Three Skylab CMGs and Four Space Telescope Electromagnets
### MSP ORIENTATION DURATION WITH REFERENCE 25KW POWER SYSTEM

**High Atmospheric Density**

<table>
<thead>
<tr>
<th>Principal Axes Orientation</th>
<th>Orientation Hold Duration (Orbits)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>235 nmi</td>
</tr>
<tr>
<td></td>
<td>( \beta ) (deg)</td>
</tr>
<tr>
<td>XPOP-YPSL</td>
<td>( \infty )</td>
</tr>
<tr>
<td>XPOP-ZPSL</td>
<td>( \infty )</td>
</tr>
<tr>
<td>YPOP-ZPSL</td>
<td>8</td>
</tr>
<tr>
<td>ZPOP-YPSL</td>
<td>7</td>
</tr>
<tr>
<td>ZSI-XIOP</td>
<td>26</td>
</tr>
<tr>
<td>ZLV-XPOP (YVV)</td>
<td>2</td>
</tr>
<tr>
<td>ZLV-YPOP (XVV)</td>
<td>( \infty )</td>
</tr>
</tbody>
</table>

Three Skylab CMGs and Four Space Telescope Electromagnets
VF0722

MSP ORIENTATION DURATION WITH REFERENCE 25KW POWER SYSTEM

Worst-Case Atmospheric Density

<table>
<thead>
<tr>
<th>Principal Axes</th>
<th>Orientation</th>
<th>Orientation Hold Duration (Orbits)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>β (deg)</td>
<td>235 nmi</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>XPOP-YPWL</td>
<td>∞</td>
<td>✗</td>
</tr>
<tr>
<td>XPOP-ZPSL</td>
<td>∞</td>
<td>✗</td>
</tr>
<tr>
<td>YPOP-ZPSL</td>
<td>5</td>
<td>&lt;1</td>
</tr>
<tr>
<td>ZPOP-YPWL</td>
<td>4</td>
<td>&lt;1</td>
</tr>
<tr>
<td>ZSI-XIOP</td>
<td>3</td>
<td>&lt;1</td>
</tr>
<tr>
<td>ZLV-XPOP (YVV)</td>
<td>1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>ZLV-YPOP (XVV)</td>
<td>∞</td>
<td>∞</td>
</tr>
</tbody>
</table>

Three Skylab CMGs and Four Space Telescope Electromagnets
MSP/POWER SYSTEM ACS CAPABILITY SUMMARY

- XPOP-YPOL Orientation Best Suited For Long-Term, High-Power Operations

- ZLV-YPOP Orientation Is Acceptable For Low-\(\beta\)-Angle Operations

- Orientation Restrictions For Low Altitudes and High and Worst-Case Atmosphere Conditions

- Additional CMGs and Electromagnets Desirable To Increase Orientation Flexibility and Margins For Uncertainties, Failures and Maneuvers
SAFETY/RELIABILITY SUBJECTS

- Comparison of Safety/Reliability Criteria, MSP Versus Power System
- Built-In Redundancy Versus Spares/Maintenance
- Approach to Safety and Reliability
- Meteoroid Protection
## COMPARISON OF SAFETY/RELIABILITY CRITERIA

<table>
<thead>
<tr>
<th>MSP</th>
<th>Power System</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No Single-Point Failure or Credible</strong></td>
<td><strong>No Single-Point Failure Prevents PS</strong></td>
</tr>
<tr>
<td><strong>Combination</strong> Endangers Crew Members</td>
<td><strong>Recovery or Causes Loss of Mission</strong></td>
</tr>
<tr>
<td>or Causes Abandonment of Platform</td>
<td></td>
</tr>
<tr>
<td>Capability for On-Orbit Repair</td>
<td>Maintainable On-Orbit to Orbital</td>
</tr>
<tr>
<td></td>
<td>Replacement Unit (ORU)</td>
</tr>
<tr>
<td>Fault Isolation, Checkout, and</td>
<td>Fault Isolation to ORU Level;</td>
</tr>
<tr>
<td>Built-in-Test Capability</td>
<td>Verification of Critical System Elements</td>
</tr>
<tr>
<td>Provide for Crew Rescue (180 hr)</td>
<td>Safe-Hold Capability for 24 to 72 hr</td>
</tr>
<tr>
<td>Subsystem Design for Minimum Risk</td>
<td>No Propagation of Failures Into</td>
</tr>
<tr>
<td>to Subsystems and Crew Injury, and</td>
<td>Payload Systems Resulting in Damage</td>
</tr>
<tr>
<td>No Propagation of Failures</td>
<td>or Loss of Payloads, Vehicle, or Crew</td>
</tr>
<tr>
<td>Fail-Operational/Fail-Operational</td>
<td>Fail-Operational/Fail-Safe</td>
</tr>
<tr>
<td>(Reduced)/ Fail-Safe</td>
<td></td>
</tr>
<tr>
<td><strong>Emergency-Level Performance With</strong></td>
<td><em>Electrical Power Subsystem Designed</em></td>
</tr>
<tr>
<td>One Module or a Subsystem and</td>
<td>for Graceful Degradation</td>
</tr>
<tr>
<td>Portion of Backup Subsystem Inactive</td>
<td></td>
</tr>
<tr>
<td><strong>Autoswitching and C/W for Time</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Critical Functions</strong></td>
<td></td>
</tr>
</tbody>
</table>
## COMPARISON OF SAFETY/RELIABILITY CRITERIA (CONT)

<table>
<thead>
<tr>
<th>MSP</th>
<th>Power System</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Separation or Protection of</strong></td>
<td><strong>—</strong></td>
</tr>
<tr>
<td><strong>Redundant Utilities</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Conservative Factors of Safety for</strong></td>
<td><strong>No Single-Failure Points Except</strong></td>
</tr>
<tr>
<td><strong>Single-Point Failures</strong></td>
<td><strong>Pressure Bottles Which Shall Use</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Conservative Design Safety Factors</strong></td>
</tr>
</tbody>
</table>

**Note:** Italics Denote Criteria Not in Agreement

**Sources:**
1. 25 kW Power System Projects Requirements Document, DCN 8-1-9-PP-00868, Part IV
2. MSP Design Guidelines and Criteria, Preliminary
### ADVANTAGES AND DISADVANTAGES OF BUILT-IN REDUNDANCY

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Duration of Failure Protection Extended If Standby Component Not Exposed to Operating Stresses</td>
<td>✓ 1. Built-In Provisions — Higher Weight, Cost, and Complexity</td>
</tr>
<tr>
<td>2. Ease of Checkout of Standby Component</td>
<td>2. Fault Detection and Switching Mechanism Introduces Unreliability</td>
</tr>
<tr>
<td>3. Efficient Use of Crew Maintenance Capability</td>
<td></td>
</tr>
<tr>
<td>✓ 4. Satisfies Fail-Operational Criteria</td>
<td></td>
</tr>
</tbody>
</table>

✓ Driving Considerations
## ADVANTAGES AND DISADVANTAGES OF SPARES/MAINTENANCE

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Potentially Troublesome Switching Circuits Are Eliminated</td>
<td>2. Special Tools and/or Skills May Be Required</td>
</tr>
<tr>
<td>3. Spares Can Be Restocked as Used</td>
<td>3. Inventory Control System May Be Required</td>
</tr>
<tr>
<td>4. Failed Equipment Can Be Replaced by Improved Items Rather Than by Duplicates</td>
<td>4. Disconnects and Means of Isolation Are Required to Allow Replacement, Increased Leakage Paths</td>
</tr>
<tr>
<td>5. System Can Be Restored to Initial Status</td>
<td>5. Does Not Satisfy Fail-Operational Criteria</td>
</tr>
</tbody>
</table>

- Driving Considerations
APPROACH TO SAFETY AND RELIABILITY

- Built-In Redundancy Where Maintenance Is Difficult or Required for Fail-Operational Criteria

- Maintenance/Spares to Achieve High Statistical Reliability Goals

- Two Separate Subsystems Where Practical for the Two Volumes
SPACELAB
METEOROID PROTECTION ANALYSIS

- ERNO-Proposed Configuration
- Spacelab Requirement Is 0.95 Probability for 350 Days
- 0.95 Probability for Four 2-Segment Modules for 10 yr Requires 0.987 Per Module
- Analysis Method According to Burton G. Cour-Palais

DOUBLE THICKNESS OF FIBERGLASS CLOTH $T_B = 0.016$ IN.

MODIFIED SPACELAB WALL
METEOROID PROTECTION ANALYSIS
TWO-SEGMENT SPACELAB STRUCTURE

1.00
0.95
0.90
0.85
0.80
0.75
0.00
1 yr
6 yr
10 yr
0.987 Design Goal

Probability of No Puncture

Shield Spacing (cm)

0 1 2 3 4
HIGH-PERFORMANCE INSULATION DAMAGE BY METEOROIDS

![Graph showing the relationship between shield thickness and insulation destroyed in 10 years.](image)

- **Penetration**
- **Shield (Fiberglass)**
- **Insulation**
- **Damage Cone (30 deg)**
- **Pressure Shell**
- **ERNO-Proposed Design**
SPACELAB METEOROID RESULTS

- MDAC Results Slightly Lower Than ERNO Predictions
  - MDAC — 0.965 Per 2-Segment Module
  - ERNO — 0.987 Per 3-Segment Module

- Greater Shield — Wall Spacing May Be Required

- Test Recommended to Determine Ballistic Limit of Configuration

- Insulation Damage From Meteoroids Not Expected to Be Significant

- Meteoroid Protection Not Considered a Program Driver
PLANNED SUBSYSTEM EFFORT

- Complete Trades
- Detailed Definition — Weight, Power, Volume
- Integrate NASA Comments
- Incorporate ERNO "Medium-Term Study" Results
- Implement Safety/Reliability Approach
AGENDA

Study Overview

Special Unmanned Platform Studies (Task A)

Manned Platform Concept (Task B)

- Configuration, Structural/Mechanical and Operations
  Fritz Runge

- System and Payload Requirements, and Performance
  Dave Riel

- Subsystems, Habitability, and Safety
  Bill Nelson

- Programmatics
  Denny Niblo
PROGRAMMATICS FOR REFERENCE CONCEPT

- Products For Phase C/D Planning
  - WBS and Dictionary
  - Program Schedules
  - Cost Data
  - Facility Requirements
  - Environmental Assessment

- Final Manned Platform Concept Identified End of November
WORK BREAKDOWN STRUCTURE/DICTIONARY

- Submitted Preliminary WBS At First Interim Review
  - MSFC Comments Incorporated

- Completed Preliminary Draft of Dictionary Defining
  - Nonrecurring (DDT&E)
  - Recurring Production
  - Recurring Operations

- WBS Dictionary Baselines DR-6 Organization
  - Review With MSFC
WORK BREAKDOWN STRUCTURE

0.0
Manned Space Platform

1.0
Project Management

2.0
Systems Engineering and Integration

3.0
Manned Space Platform Modules

4.0
System Test and Evaluation

5.0
Ground Support Equipment

6.0
Flight Support Equipment

7.0
Operations

8.0
GFE
PROGRAM SCHEDULES

Task

- Develop Overall Program Schedules for Phase C/D

Output

- Program Level Schedule
  - Identifies Major Milestones and Events
  - Subsystems Details/Timelines

- Summary Logic Network

Review/Submittal

- Submit Final Schedule Package as Part of DR-4
- Prior Coordination With MSFC
COST DATA

Task

- Develop Phase C/D Cost Estimate for Selected Platform Concept

Format

- Compliant With Requirements of DR-6
- Data Provided for Each WBS Element
- Segregation Among DDT&E, Production, and Operations

Review/Submittal

- Review Format, Estimating Techniques, and Ground Rules With MSFC
- Review Preliminary Data With MSFC Prior to Final Review
- Submit Final DR-6 as Separate Volume of Final Report
SPACE PLATFORM STATION
CONTRACTOR FUNDING PROFILE
(Millions of 1981 Dollars)

- Adapter/Airlock Module
- Manned Habitat Module
- Logistics Module
- Dedicated Power System

Fiscal Year

Cum Dollars


0 100 200 300 400 500 600 700 800 900 1000

△ Space Platform/Station ATP
△ Dedicated Power System (Second Unit) ATP
△ Orbital Operation
Facilities

- Identify New or Unique Requirements
- Identify Major Modifications to Existing Facilities
- Submit Any Impacts as Part of DR-6

Environmental Assessment

- Identify Any Potential Impacts
- Compliant With NHB 8800.11
- Submit as Part of DR-4