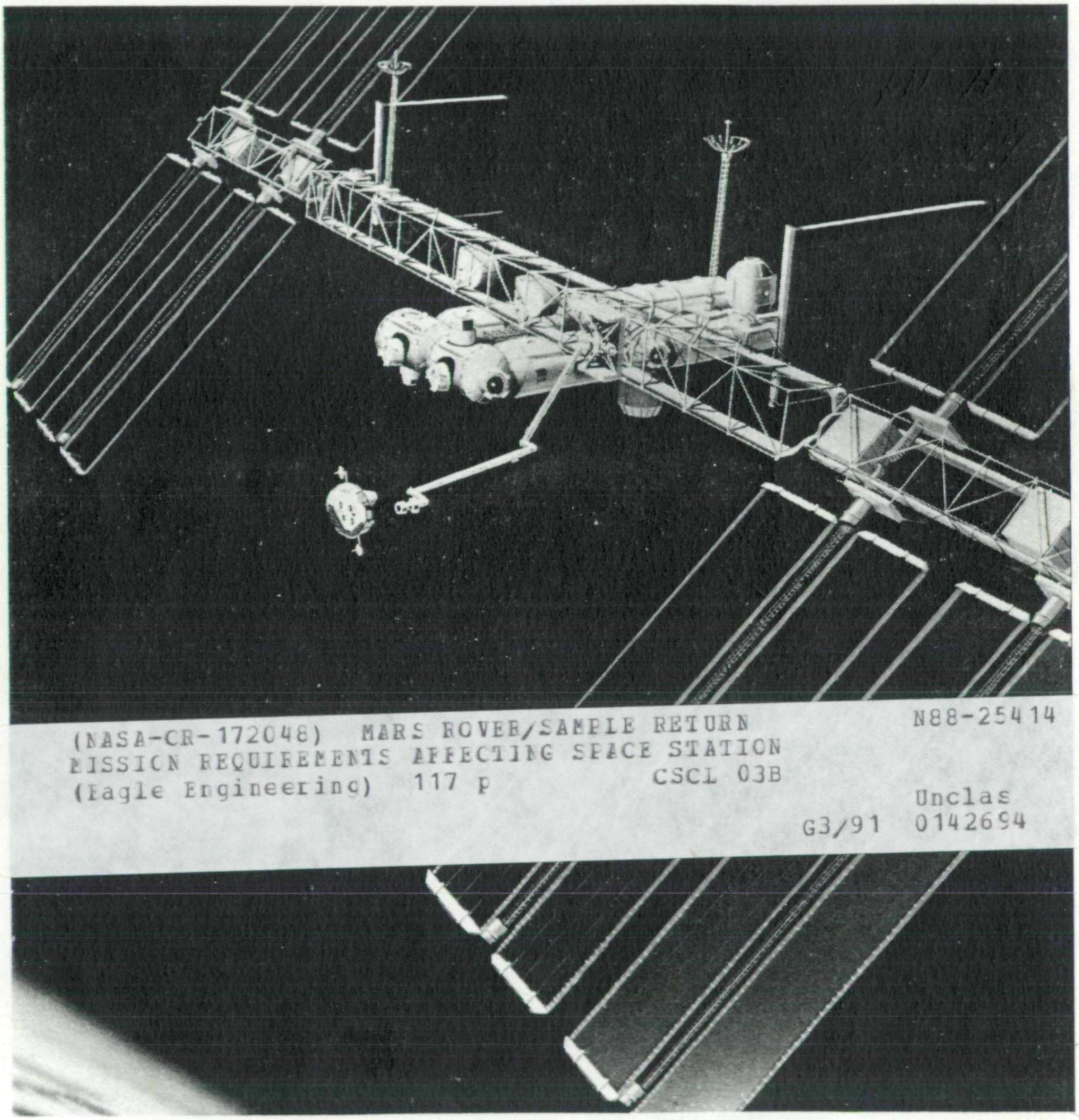
CR-172048

Mars Rover Sample Return Mission Requirements Affecting Space Station



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EAGLE

Mars Rover/Sample Return Mission
Requirements Affecting Space Station

A Report to the National Aeronautics and Space Administration
Johnson Space Center

NASA Contract No. NAS9-17878
Eagle Engineering Report No. 88-183

March 31, 1988

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Foreword

This study defines the possible interfaces between the Space Station and the Mars Rover/ Sample Return Mission. It is intended to help Space Station designers accommodate the MRSR mission needs better by defining them during the period when some aspects of the Space Station design can still be influenced.

The following individuals participated in the study:

Dr. John Alred was the NASA technical monitor for the Advanced Space Transportation System (ASTS) Contract under which this study was performed.

Mr. David Thompson was the NASA task manager for this particular study.

Dr. Douglas P. Blanchard, Dr. James L. Gooding, and Mr. Joe Gamble provided valuable advice, data, and technical review.

Mr. Barney Evans was the Eagle ASTS Contract Project Manager.

Dr. Charles Simonds was the Eagle Task manager for this study and responsible for all the Space Station interior sample handling work and the overall study.

Mr. Bill Stump was responsible for the Space Station exterior sequence and facility work.

Dr. Alex Adorjan was responsible for the thermal analysis.

Mr. Mark Dowman provided the sketches, graphics, and art.

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LIST OF TERMS AND ACRONYMS

ACRC	Alternate Crew Return Capability, formerly Crew Emergency Return Vehicle(CERV)
BCD	Space Station Baseline Configuration Document (JSC 30256)
C&T	Communications and Tracking
Canister Pallet	Attachment on Truss of JEM EF to hold EOC +SRC
Columbus Module	European Space Agency's Space Station Laboratory
DC	Direct Current
DMS	Data Management System
DRM	Design Reference Mission
ECLSS	Environmental Control and Life Support System
EDP	Embedded Data Processor, a computer on a card
ELM PS	Experiment Logistics Module, Pressurized
ELM	Experiment Logistics Module (part of JEM)
EMU	Extravehicular Mobility Unit (Space Suit plus life support unit)
EOC	Earth Orbiting Capsule (ERV minus propulsion stages)
ERV	Earth Return Vehicle (EOC plus propulsion stages)
ESA	European Space Agency
EVA	Extravehicular Activity
GN&C	Guidance Navigation and Control
HMPF	Hatch Mounted Processing Facility
Hook	Software provision to add additional functions
IVA	Intravehicular Activity
JEM	Japanese Experiment Module
JSC	Johnson Space Center
LEO	Low Earth Orbit
LRL	Lunar Receiving Laboratory, used for Apollo
MR/SR	Mars Rover/Sample Return
MRMS	Mobile Remote Manipulator System, part of Mobile Servicing Centre
MSC	Mobile Servicing Centre (Canada)
NASA	National Aeronautics and Space Administration (U.S.)
NASDA	National Space Development Agency of Japan
OMV	Orbital Maneuvering Vehicle
PAM	Payload Assist Module
PCF	Pound per cubic foot
PDCA	Power Distribution and Conditioning Assembly
PDR	Preliminary Design Review
psia	Pounds per square inch, absolute
QD	Quick Disconnect
RMPF	Rack Mounted Processing Facility
RMS	Remote Manipulator System
SC	Sample Canister
SCA Canister	Space Station based container for SCA
SCA	Sample Canister Assembly
Scar	Hardware provision to add additional functions
SCF	Cubic foot of gas at Standard Temperature and Pressure
SDP	Standard Data Processor, approximately equivalent to a VAX
SPCS	Servicing and Performance Checkout System
SRC	Sample Return Container
TBD	To Be Determined

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REQUIREMENTS MARS SAMPLE AND RETURN VEHICLE AT SPACE STATION

Executive Summary

This report lays out the first order requirements that several Mars sample handling options will impose on the Space Station. Eight options for sample handling at the Space Station are laid out in some detail, including conceptual design of the required hardware. The options reduce down to three major types. These types, with their most significant Space Station requirements are given below.

1. The entire sample is removed from the Earth Orbit Capsule (EOC) and repackaged, external to the Space Station, with manipulators in a sturdy, temperature controlled container, and sent to Earth. Initial evaluation shows passive thermal control may be adequate when the sample is on the truss. Power requirements are on the order of 300 watts average. As many as three transverse truss payload fittings may be needed to mount two sample containers and an orbital maneuvering vehicle (OMV). A place to dock the OMV and perhaps changeout its propulsion module (if two Mars missions are flown simultaneously) is required. Another option is to place the sample containers near the Japanese Module pallet and use the Japanese manipulator to do the repackaging.

2. The sample is repackaged as described in 1. above, and then the new container with the entire sample in it is brought into the station and placed in a temperature controlled glove box. A small subsample is removed and sent to Earth for biological analysis. The bulk of the sample is retained at the Station. All the requirements mentioned in 1. above concerning external sample handling are still needed for this option. In addition, a glove box facility and a way into the Station are required. If the glove box facility is a double standard rack in the Station, power requirements on the order of 600 watts may be needed. The thermal control requirements needed to hold the sample at -40°C will tax the Station facilities to their present limits. A less taxing option, though probably more expensive, would be to place a glove box/airlock on a node hatch such that an external radiator could be used. The availability of a node hatch is questionable. The Japanese module airlock and manipulator may also be used to bring the sample with container into the station without EVA.

3. The sample, again repackaged externally, is brought into a new Station module dedicated to biological analysis. The sample is then analyzed on-orbit. Nothing less than a dedicated module appears adequate to do satisfactory analysis on-orbit. The requirements for this option are all those of item 1. plus the requirements for adding a new station module. The new module will have external radiators for glove box temperature control.

The preferred solution of the authors was option 1 but more work is needed. In particular, a risk analysis comparing these three options to each other and to the direct entry and shuttle retrieval options is required.

Many assumptions were made in this report concerning aspects of the mission that are not agreed upon. Work is required by the community to define:

1. Procedure for a fault tolerant sterile transfer in Mars Orbit.
2. Temperature, pressure, and gas type within which to hold the sample.

3. Sterilization procedure and failure tolerance of sample containment.
4. Biological analysis protocol for certifying the sample safe.

All these factors significantly influence the impacts on the Space Station. The Space Station Preliminary Design Review (PDR) should be monitored to make sure MRSR requirements are considered.

1.0 Introduction

NASA is defining a program to return samples of the Martian surface to Earth. This report analyzes the interfaces between the sample return mission and the Space Station, should that sample pass through the Space Station on its way to the surface of the Earth.

The baseline mission is the Mars Rover/Sample Return Mission to be launched in 1998 with the sample returning to the vicinity of Earth in 2001. The mission is a complex one, and this report covers only a relatively small part, the Space Station as part of the process of repackaging the sample and evaluating its biological nature. This study assumes that very strict biological isolation requirements will be placed on the Mars sample and that Mars based pathogens will be extremely hardy and able to survive temperature extremes of space, hard vacuum, as well as the strong oxidants such as were found to be present on the surface of Mars by Viking. It is further assumed that contamination of the Mars sample by Earth derived materials is to be avoided with precautions equal or greater than those currently used in the Lunar sample processing facilities.

A number of scenarios for Space Station handling of the sample and hardware conceptual designs are presented in this report. These are all generated options, that have by no means been baselined. Other very different options, including direct entry of the sample to the surface and Shuttle retrieval are still good possibilities and have not been addressed in this report.

1.1 Scope of Report

This report seeks to define the impacts of the Space Station on the MRSR mission and vice versa. In order to constrain the scope of the report a series of seven design reference missions divided into three major types were assumed. These missions have been defined to span the probable range of Space Station-MRSR interactions. The report then summarizes the MRSR sample handling requirements and baseline assumptions about the MRSR hardware and the key design features and requirements of Space Station. Only the aspects of the design reference missions necessary to define the interfaces, hooks and scars, and other provisions on the Space Station are considered. The next part of the report is an analysis of each of the three major design reference missions, presenting conceptual designs of key hardware to be mounted on the Space Station, a definition of weights, interfaces, and required hooks and scars.

1.2 Definition of Design Reference Scenarios

NASA is considering four general modes of bringing the sample to Earth: 1) direct entry of the Sample to the surface of the Earth, 2) recovery of the sample in Earth orbit using the Orbital Maneuvering Vehicle (OMV), transferring the sample to the Space Shuttle for reentry, possibly using the Space Station as a staging point, 3) recovery of the sample in Earth orbit, opening the sample and bringing a small subsample to Earth for biological testing while holding the bulk of the sample in biological isolation in Earth orbit and, 4) extensive analysis on-orbit in the Space Station. In the last mission, the analyses must be sufficient to certify either that the sample is biologically sterile, or that it is biologically active. The analysis must then provide sufficient data to determine the best course of action for handling the sample on Earth. The latter program is that described in the DeVincinaii and Bagby (1976) Antaeus Report.

Figure 1 shows the steps of the Mars Rover/Sample Return (MRSR) Mission. The MRSR mission scenario is defined in JSC (1987 a and b). Figure 2a, b and c summarize one of the preferred launch on 4 configurations. Discussions with Dr. Douglas P. Blanchard and Joe Gamble of the MRSR team have supplemented the information in those reports. The components returning to earth are shown in Figure 3. The following definitions will make the discussion easier to understand.

Earth Return Vehicle (ERV) -

Sample Canister (SC) - the container that went to the surface of Mars in which the samples were placed. When the SC is referred to in this text, it is generally assumed to contain all or most of the Martian samples. Since it was on the surface and not involved in a sterile transfer, it is assumed to be contaminated inside and out.

Sample Canister Assembly (SCA) - the SC is brought to the orbiting vehicle in Mars orbit. A sterile transfer is assumed to take place there. The SC is placed inside the SCA and a lid is closed. The SCA is assumed to be contaminated on the inside, but not on the outside.

SCA Canister - When the EOC is brought to the Space Station, it discharges the SCA, which is then placed in another canister, the SCA canister. This additional canister provides an independent, verifiable biological barrier, hook-ups for active thermal control, instrumentation, etc., and a sturdy container, configured for remote manipulation and capable of external heat sterilization while maintaining internal specified temperatures. The SCA Canister provides an additional, verifiable biological barrier and all the protection, cooling, instrumentation, etc., one would have put on the SCA for ease of handling from the Space Station on down, if weight had not been a problem.

Earth Orbiting Capsule (EOC) - this is the vehicle which carries the SCA to Earth and aerocaptures into LEO. It is nominally completely sterile, since a sterile transfer took place in Mars orbit. Its nominal external sterility is required at a minimum since it passes through the Earth's atmosphere during aerocapture.

EOC Canister - on return to the Space Station, the EOC is sealed in a large can as a backup for failure of sterile transfer in Mars Orbit. This can is the EOC canister.

Canister Pallet - the EOC canister and SCA canister are delivered to the Space Station on a small pallet, which includes all instrumentation, a small CO_2 pressurization system, thermal control devices, and a data processor.

The following aspects of the MRSR are assumed by Eagle in defining the design reference missions. These assumptions and the Design Reference Missions summarized in Tables 1 and 2 represent a tool used by Eagle to conduct this study. Their inclusion does not represent a position of NASA or the United States government, the European Space Agency or the National Space Development Agency of Japan.

1) Two Sample Canisters (SC) will be placed in two separate Earth Orbiting Capsules (EOC) by a nominally aseptic transfer in Mars orbit. Each SC will be enclosed in a biological containment package. The biological containment package is the Sample Canister Assembly (SCA) (Figure 3). Samples inside each cannister are assumed to be in tubes (Figure 4). The outside of the SCA is be considered nominally sterile.

However, sterility of the SCA exterior cannot be established from telemetry and therefore it will be assumed to be contaminated.

2) The SC and SCA will have a small amount of instrumentation to measure temperature and pressure during flight. The total mass of sample will be about 5 kilograms in numerous small geologic soil or rock samples packed in separate containers, possibly tubes within the SC (Figure 3).

3) The two Earth Orbiting Capsules (EOC) will go into low circular Earth orbits within a week of one another. Nominally the circular orbits will be at an altitude of 250 nautical miles inclined at 28.5 degrees. The EOC will have the shape of the Apollo Command Module but be much smaller, only about 5.5 feet in diameter. The Sample Return Vehicles will have a mass of about 500 kg.

4) The Orbital Maneuvering Vehicle will retrieve each EOC and bring it to the vicinity of the Space Station.

5) Nominally only passive thermal management will be provided to the sample containers while in transit with the OMV. Thermal management will be by simply pointing the SCA end of the EOC toward deep space.

6) The OMV/EOCs will be grappled by the Space Station RMS on the Canadian Mobile Servicing Centre at a position visible to Space Station crewmen in the Cupolas.

7) The different design reference missions (DRMs) considered in this report begin once the OMV/EOCs are positioned, ready to be grappled. See Table 1 for a summary. The three major types of DRMs considered are:

DRM 1) The SCAs will be repackaged on the Space Station but not opened. The SCAs will be extracted from the EOC. Each will be placed in separate containers mounted on the outside of the Space Station. The SCAs, sealed in containers, will then be sent to Earth in the Orbiter.

DRM 2) Small subsamples of Martian material will be sent to Earth for analysis, but the bulk of the sample will remain on-orbit. Each SCA will be extracted from the EOC and stored in a biological and thermal enclosure outside the pressurized volume. One SCA will be transferred into the Space Station inside yet another biological canister. The entire assembly will be transferred to a processing cabinet airlock and then into a cabinet itself. In there, the SC will be extracted from its two enclosing assemblies. The SC will be opened and a small amount of sample called the Bioassay Sample removed for biological analysis on Earth. The SC will then be resealed, and held in the Space Station awaiting the results of the analysis. The Bioassay Sample will be packaged in a series of sterile packages, in a container able to maintain biological isolation in the event of an accident. The sample and enclosing container will be transferred in the Orbiter Mid-Deck and to the Earth's surface for analysis. Once the Bioassay Sample has been analyzed, the results certified, and acceptable procedures established and tested, the entire SC will then be transferred to Earth via the Orbiter.

DRM 3) In this mission the bioassay analysis is done on-orbit. The SCAs will be extracted from the Return Vehicle as before, but one will be transferred inside the Space Station. The SC will be opened and Bioassay Samples extracted. The samples will be analyzed in a biological containment facility attached to the Space Station. Once the sample is determined to be biologically benign, or proper procedures have been defined and tested, the samples inside the Space Station and the other SCA still outside will be transferred to Earth. This design reference mission is assumed to require use of a dedicated Space Station module not in the baseline configuration.

MARS ROVER SAMPLE/RETURN: LAUNCH CONFIGURATION B

SEPARATE LAUNCHES OF ROVER AND ASCENT/RETURN FLIGHT ELEMENTS

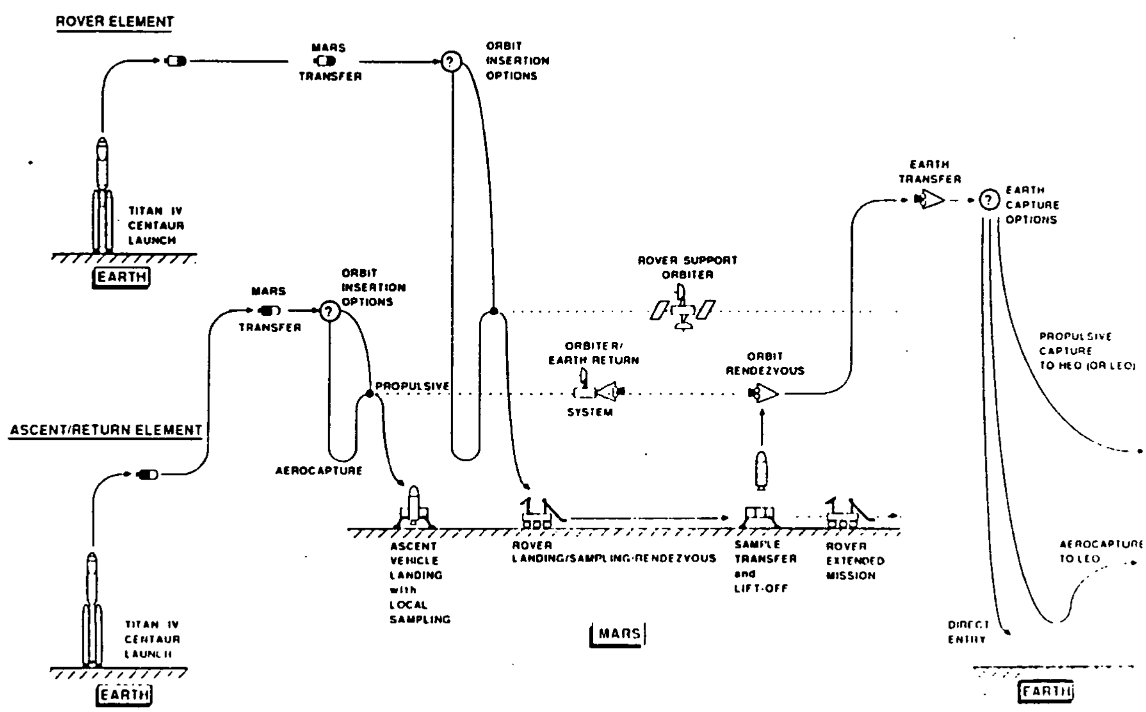


Figure 1, Mars Rover/Sample Return Scenario for Launch Configuration B provided by D.P. Blanchard

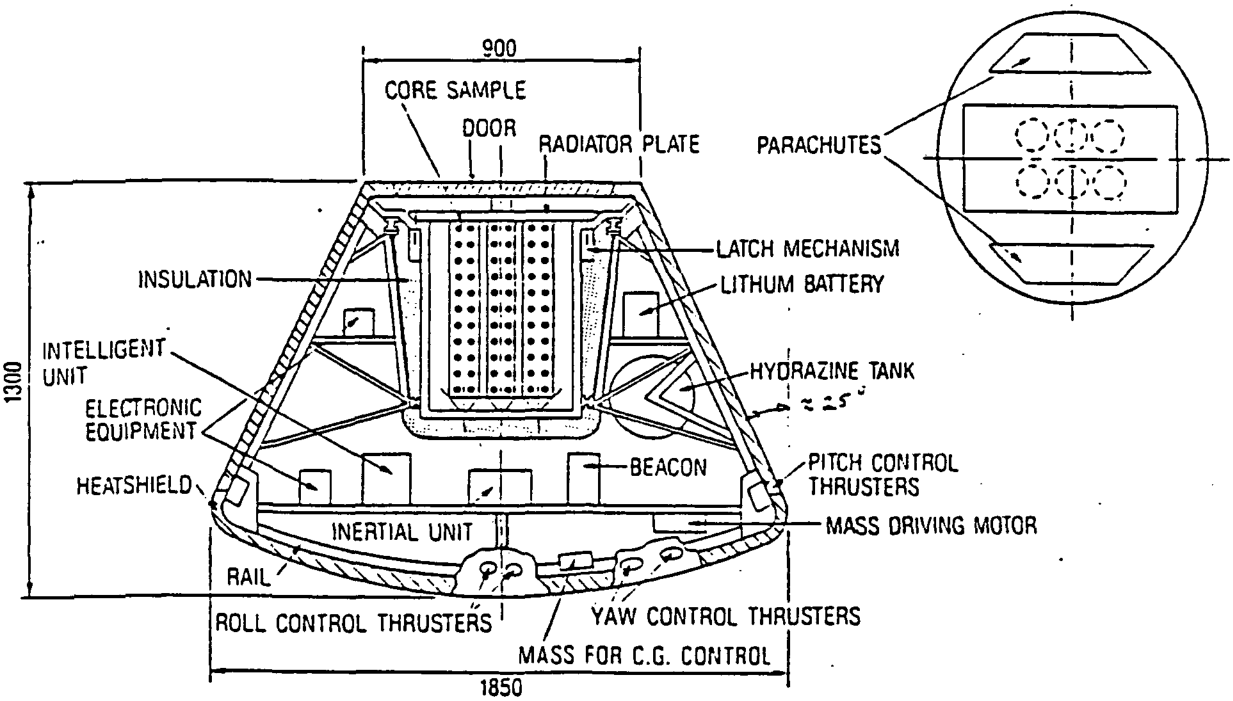
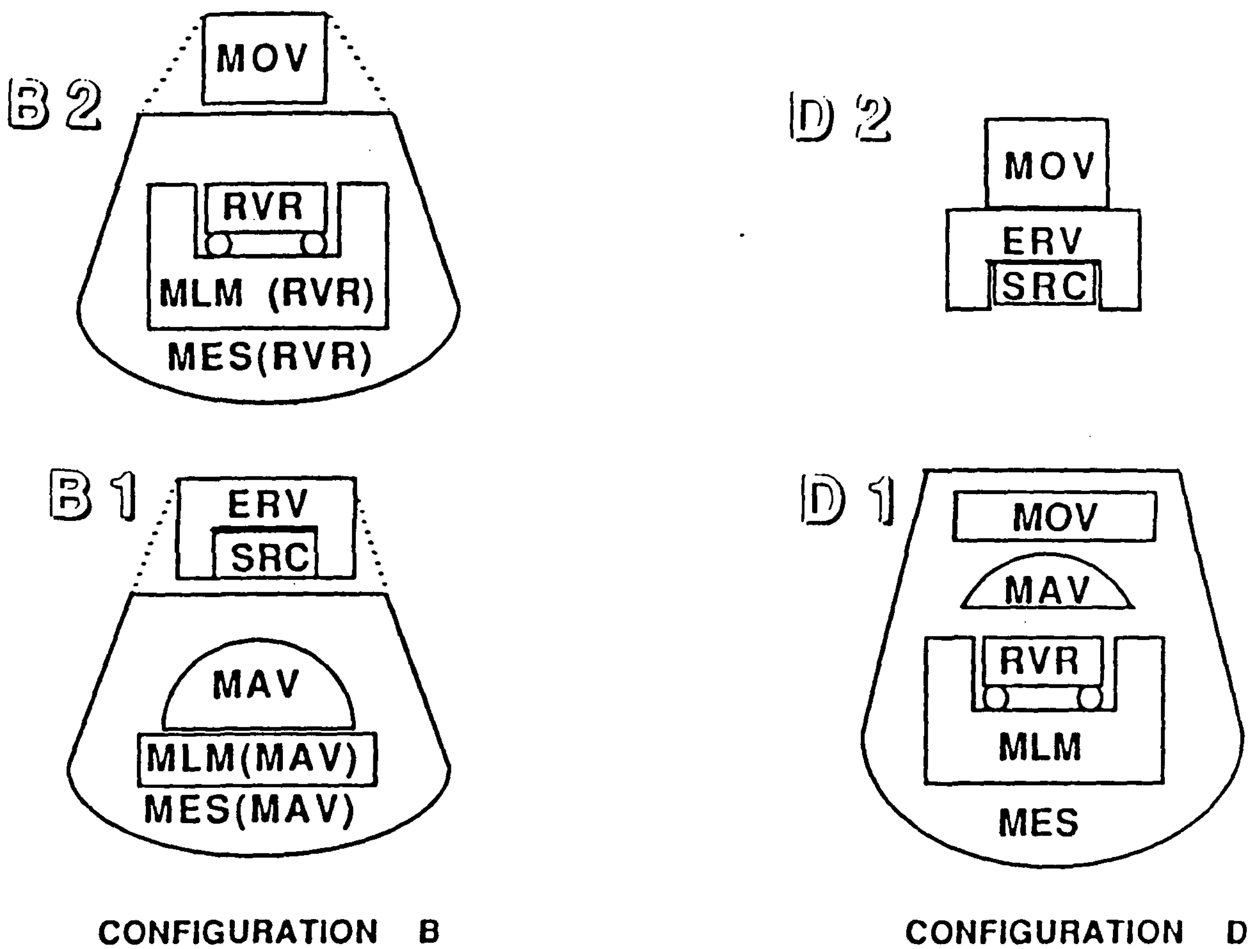


Figure 2a, Comet Sample Return Vehicle, which could be similar to the Earth Orbiting Capsule portion of the Earth Return Vehicle from Kerridge and Atzei, 1987

Figure 2b, Option B MRSR packing showing the Earth return vehicle from Rea (1988)
Figure 2c, Option D MRSR (the preferred option by NASA) from Rea (1988)



LEGEND:

MOV = MARS ORBITING VEHICLE
ERV = EARTH RETURN VEHICLE
(inc. MARS RENDEZVOUS FUNCTION)
SRC = SAMPLE RETURN CAPSULE

MAV = MARS ASCENT VEHICLE
RVR = ROVER
MLM = MARS LANDING MODULE
MES = MARS ENTRY SYSTEM

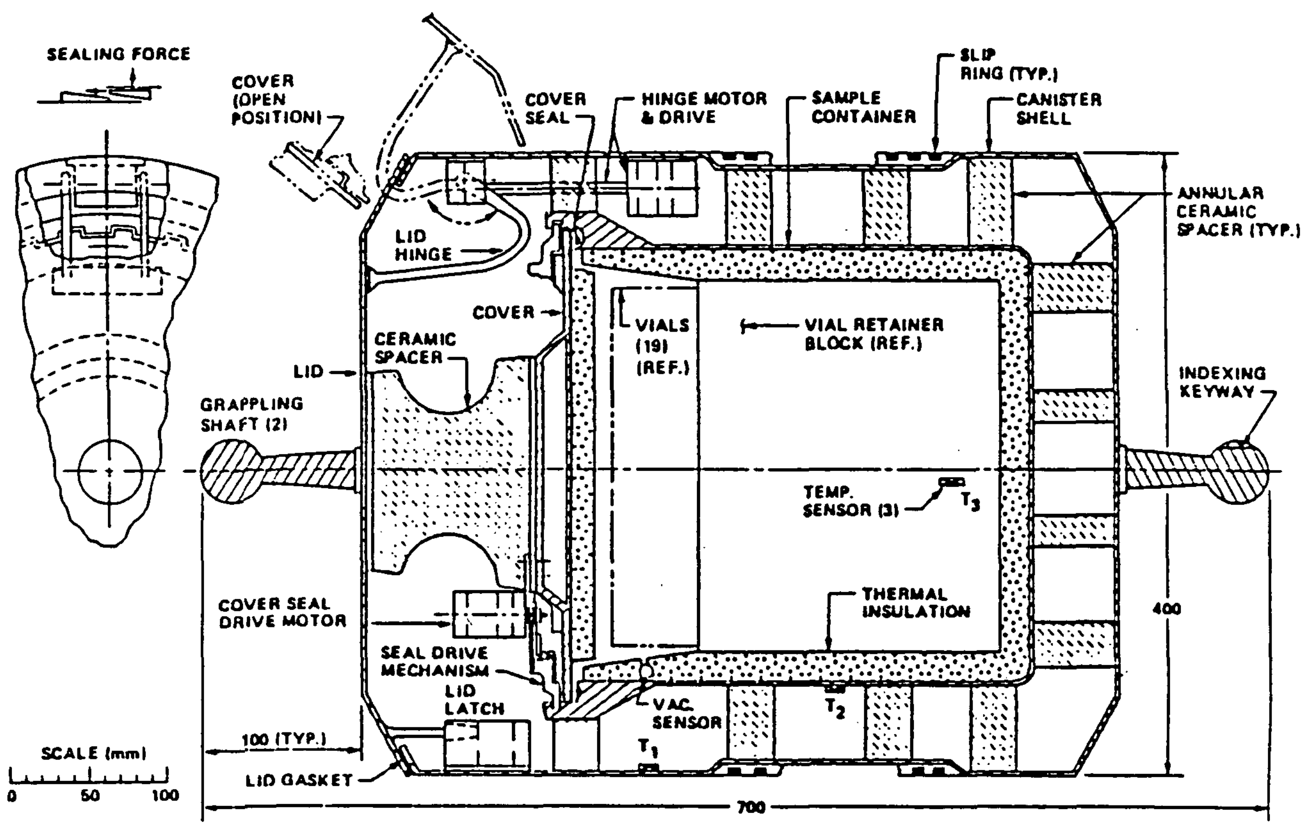


Figure 3, Mars Sample Canister Assembly (SCA) or Sample Return Canister (SRC) from French and Blanchard (1985)

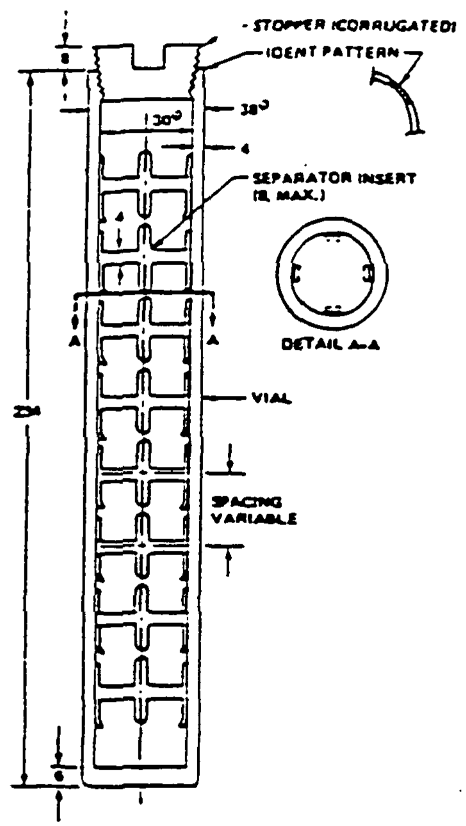


Figure 4, Sample Vial for Geologic Rock and Soil Sampler from DeVries, et al (1984)

Table 1, Design Reference Mission Matrix

1) Repackaging without bringing inside pressurized volume

   1A) On Transverse Boom

   1B) On JEM Exposed Facility

2) Bring sample return container inside pressurized volume. Split off test sample for terrestrial analysis, hold remainder on-orbit

   2A) Astronaut EVA/IVA transfer, process in U.S. Lab module

   2B) Astronaut EVA/IVA transfer, process in JEM module

   2C) JEM RMS transfer via JEM airlock, process in JEM

   2D) JEM RMS transfer via JEM airlock, process in US lab module

   2E) SSRMS transfer to new airlock on a node to be determined (TBD), hatch TBD, process in glove box attached to hatch

3) Perform biological analysis on-orbit in dedicated module

Table 2, Design Reference Mission Characteristics

DRM Number	Airlock	Processing Locale	Processing Extent	Feature
1A	None	None	None	Uses all Phase 1 attachment fittings
1B	None	None	None	Use JEM Exposed Facility
2A	Airlock	US Lab	Subsample Only	Hold most
2B	Airlock	JEM	Subsample Only	sample on orbit
2C	JEM Airlock	US Lab	Subsample Only	while subsample
2D	JEM Airlock	JEM	Subsample Only	analyzed on Earth
2E	Node Airlock (new)	Node Hatch	Subsample Only	
3	Biological isolation Module		Biological isolation Module Analyze On-Orbit	Complete bio-testing done on-orbit

2.0 Definition of Biological Containment Requirements

2.1 Nature of the Hazard

Formal requirements for handling a Mars sample do not exist as yet. For purposes of this study, Eagle has made a series of assumptions:

The sample will be considered to be hazardous until completion of detailed analysis. The biological hazard is assumed to be caused by a tough spore, single cell organism, or virus, or other similar organism capable of surviving persistent space exposure on the exterior environment of the Space Station. The organism is assumed to be extremely tolerant of oxidizers such as hydrogen peroxide. Exposure to the atomic oxygen effects at the Space Station's orbit are also assumed inadequate to neutralize the hazard.

It is assumed that once the sample has been determined to be biologically active, either on Earth in the DRM 2 series or on-Orbit as in DRM 3, that procedures can be developed which are appropriate for the type of hazard encountered. Thus the function of the analysis is not only to determine whether or not a hazard exists, but to develop methods for dealing with the hazard.

2.2 Sterilization Requirements

It is assumed by Eagle for purposes of this study, that prior to understanding the true nature of the hazard posed by the samples some sort of sterilization will be necessary. Because all known biological materials can be decomposed by heat, heat sterilization is baselined. The hazard may be eliminated by mere heat sterilization to a temperature of 200°C for a period of 10 minutes. Heat sterilization can be shown feasible if two basic assumptions can be made about the organism:

1. The organism is microscopic, thus has too little insulation to prevent sterilization given a substantial heat input.

2. The construction information for the organism is carried in some type of complex molecule(s) with many bonds.

If agreement can be reached on these subjects, then a heat sterilization system can be devised. Theoretical work by experts in molecular biology on this subject can establish a safe temperature and time limit.

2.3 Biological Isolation Failure Tolerance

Eagle's assumption is that biological contamination of the Space Station is a failure which results in the effective loss of the Space Station and crew. Following Space Station failure tolerance requirements the biological isolation of the sample must remain intact after two failures such as leakage of two biological barriers. Thus the sample must have three independent biological barriers in place at all time.

3.0 Definition of Sample Contamination Requirements

The only sample handling requirements currently defined are those of Gooding (1988). In addition, Eagle has assumed that sample contamination prevention will follow the practices for handling lunar material used by NASA as defined by LSAPT (1976) with additional requirements defined in Planetary Materials Branch (1988) NASA JSC (1976a). It is implicitly assumed in the latter document that the Mars samples will not come from the Martian polar regions, therefore the sample will not contain either water and/or carbon dioxide ice.

3.1 Temperature

According to Gooding (1988) no portion of the sample may exceed a temperature of -10°C (263 °K or -14°F). The nominal temperature is -43°C (230°K, -45°F). Eagle has assumed that the minimum temperature requirement is set by the pressure and composition of the atmosphere in contact with the samples. The temperature will be such that neither water or carbon dioxide ice condense. See Tables 3 and 4. For water at 43°C the vapor pressure of water must be kept below about 0.06 mm or 0.008% of a 1 atmosphere (760mm) pressure atmosphere. For a pure CO_2 atmosphere which is mostly nitrogen with only 10 mm (1.3%) CO_2 the temperature must fall to -158°C before CO_2 will precipitate.

Table 3, Vapor Pressure of Water in Equilibrium with Ice from Handbook of Chemistry and Physics (1962)

PRESSURE OF WATER VAPOR
Vapor Pressure of Ice

Pressure of water vapor over ice in mm of Hg

Temp °C	MM
-90	.000070
-80	.00040
-70	.00194
-60	.00808
-50	.02955
-40	.0966
-30	.2859

Temp	
-29	0.317
-28	0.351
-27	0.389
-26	0.430
-25	0.476
-24	0.526
-23	0.580
-22	0.640
-21	0.705
-20	0.776
-19	0.854
-18	0.939
-17	1.031
-16	1.132
-15	1.241
-14	1.361
-13	1.490
-12	1.632
-11	1.785
-10	1.950
-9	2.131
-8	2.326
-7	2.537
-6	2.765
-5	3.013
-4	3.280
-3	3.568
-2	3.880
-1	4.217
-0	4.579

Table 4, Vapor Pressure of CO_2 in Equilibrium with Dry Ice from Handbook of Chemistry and Physics (1962)

VAPOR PRESSURE OF CARBON DIOXIDE
Solid
From Bureau of Standards Journal of Research
(Mercury column, density = 13.5951 g/cm^2, g = 980.665 cm/sec^2
Pressure in microns of mercury

°C	MM
-180	0.013
-170	.37
-160	5.9
-150	60.5
-140	431
-130	2.31
-120	9.81
-110	34.63
-100	104.81
- 90	279.5
- 80	672.2
- 70	1486.1
- 60	3073.1
- 50	

Critical temperature = 31.0°C. Triple point, -56,062 ± 0.005°C; 3885.2 ± 0.4 mm.

3.2 Pressure

Gooding (1988) states that the atmospheric pressure can range between Mars ambient (0.15 psia, 10 millibars) and nominal terrestrial atmospheric pressure 14.7 psia (1013.2 millibars).

Eagle assumes that the relative pressure of the sample containing area will be less than any inhabited volume by at least 0.1 psi (3 inches of water) to prevent carrying any biota into the inhabited volume in a leak.

3.3 Processing Cabinet Atmosphere and Supply

Eagle has assumed, by De Blanchard's recommendation, that the atmosphere introduced in any processing facilities will be high purity carbon dioxide. The gas may or may not be isotopically tagged, pending recommendations by experts in the field of light element isotopic analysis. The requirements will be such that a dedicated supply will have to be made available to the processing cabinets. The supply is held either on the pallet which receives the EOC, or on the Node Processing cabinet support truss. Plumbing for the gas will be stainless steel pipes which have been cleaned to a standard appropriate for this application, in excess of standards typical of other Space Station fluids lines. No connector or valve on the CO_2 supply system will have any organic parts such as gaskets or O-rings.

Eagle assumes that the atmosphere will be kept oxidizing relative to the Fe_2O_3-Fe_3O_4 buffer. One ppm O_2, less than is anticipated to diffuse through gloves, is sufficient to assure that this condition is met. Mars atmosphere contains about 0.3% O_2.

Eagle assumes that water vapor pressure will be kept at less than ice saturation (Table 3).

For design purposes Eagle assumes that the composition of the atmosphere in contact with Martian material will be periodically monitored, for water and oxygen. The measurement frequency will be more than four times per hour. The composition data provides a measurement of the integrity of the processing cabinets and the biological containment system.

3.4 Particulate Contamination

For purposes of design Eagle assumes that contamination of the samples by dust or other particulate material will seriously degrade its scientific usefulness. The baseline procedures for controlling particulates are assumed to be derived from those used in the Apollo Lunar Sample Storage and Processing Area in JSC Building 31a Planetary Materials Branch (1988). Provisions will be taken to minimize particulate contamination of the samples.

3.5 Tools and Sample Handling Equipment

For purposes of design Eagle assumes that contamination of the samples is most likely to occur by contact with the tools and containers enclosing the samples. The procedures to be used should be a combination of the current particulate controlling procedures combined with the organic contamination controls in place for lunar samples prior to 1975. As part of those procedures only the following materials may come in contact with the Mars sample.

Teflon
Stainless Steels, non-magnetic (300 series)
Aluminum, preferably non-copper bearing alloys

Lunar sample handling practice identified many common materials as element contamination on samples. Therefore, leaving organic or trace the following materials should be specifically avoided. Use of the materials in any volume not physically separated from the sample should not occur without waiver.

Vinylidene Chloride (Saran)
Polyvinyl Chloride
polycarbonate
lead
solder
Viton
Mo_2S lubricants

Cleaning procedures used for all equipment coming into contact with the sample should conform to Cleaning Procedures of Planetary Materials Branch (1988). As a matter of practice Viton and polycarbonate are present in cabinets as windows and seals respectively since no alternative in organic materials exist which is suitable.

3.6 Acceleration

The maximum acceleration to which a sample may be subjected is 10 G, (98 m/sec^2)(Gooding, 1988).

Vibration and acoustic requirements for the samples have not been established.

3.7 Magnetic Field

The maximum acceptable DC magnetic field to which a sample may be subjected is equal to that of the Earth's field (5.7 x 10^{-5} Tesla)(Gooding, 1988).

No alternating field or EMI requirements have been defined.

3.8 Radiation

If practical, the sample should be shielded from natural interplanetary space radiation by at least the equivalent of the Mars atmosphere, 21 g/cm^2. This is equivalent to approximately 8 cm of aluminum alloy. This level of shielding may not be possible during Mars-Earth transit, due to weight limitations.

The radiation dosage to which the sample may be subjected has not been established.

4.0 Definition of Sample Return Container

For purposes of this study, the cylinders confining the samples; the sample canister (SC), and the sample canister assembly (SCA) are those shown in Figures 2A, 2B, and 2C. Dimensions of the devices are scaled from the drawing of the SCA in Figure 2A.

5.0 Definition of Space Station Facilities

This study is underway as the Space Station Program is beginning Phase C/D. Thus it began with the documentation available in early 1987. The MRSR mission will arrive at the Space Station in 2001, well after the core modules and transverse boom of Phase 1 of the Space Station program have been in place. The evolution of the Space Station from Phase 1 to an enhanced configuration are expected to be defined about 1992. It is Eagle's understanding that the Post Phase 1 configuration may not include the dual keel configuration previously defined.

5.1 Overall Configuration and Truss

The overall configuration of the Space Station and Truss is assumed to be the Phase 1 configuration with the horizontal keel, 75 kw of photovoltaic power, four large modules (US Laboratory and Habitation, ESA Columbus Lab Module, Japanese Experiment Module), four Nodes and two airlocks, one with hyperbaric treatment capability (JSC 30255). Figure 5 shows the overall arrangement of the truss. Figure 6 is a side view of the module pattern. It is particularly significant to this study that only two payload attachment points are defined on the Transverse Boom (Figure 5). No provisions exist for mounting or reservicing the Orbital Maneuvering Vehicle in Phase 1. The location of a servicing Bay mounted on the Dual Keel is not currently fixed.

5.2 U.S. Laboratory Module

The US Laboratory Module is one of three pressurized volumes for conducting experiments. The working cylindrical volume of the module is 38.68 feet long and 13.825 feet in diameter Figure 7). Equipment is the module is mounted in racks hinged at one corner so that they may be swung out from the wall (Figure 8).

5.3 Japanese Experiment Module (JEM)

The working definition of the JEM is given in NASDA (1986). The principal parts of the JEM are shown in Figures 9 through 16 and Table 5 from NASDA (1986). The JEM is considered in some detail in this report because its combination of a manipulator, airlock and pressurized experiment module equals the facilities to support DRM 2, and the size of the pressurized module is close to that defined to support DRM 3. The JEM is basically an integrated research facility intended to eventually be transferred to the Japanese Space Station, planned to be in placed in orbit about 2006. The facility consists of a pressurized volume about 2/3 the length of the US Lab module. Attached to it is a pressurized logistics module, an unpressurized logistics compartment, and a gas supply module. Attached to the pressurized module is an unpressurized truss structure for supporting a variety of experiments and antennas. An airlock allows experiments to be passed between the pressurized module and space, where they can then be transferred by a six degree of freedom manipulator which may have a second, smaller six degree of freedom manipulator attached as an end effector.

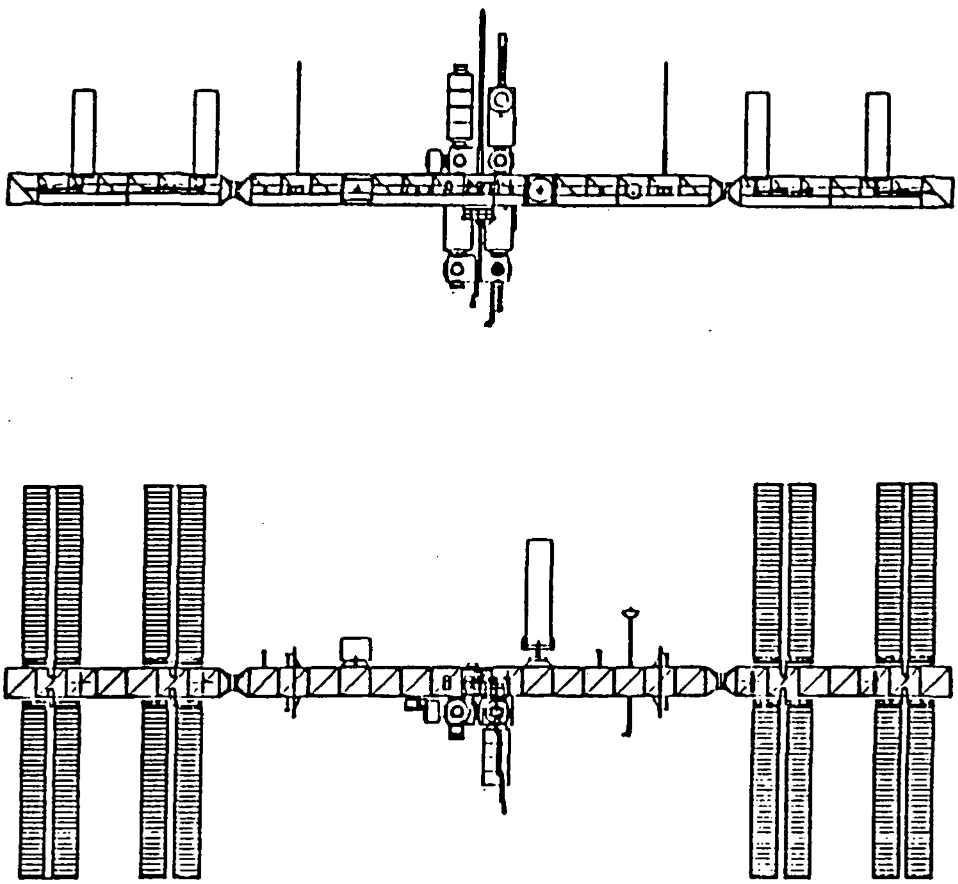


Figure 5, Space Station Truss and Module Pattern, Top and Front View, Completion of Phase 1 from Space Station Program Office (1987). Only two payload attachment points exist on the transverse boom at the point indicated. These positions are also the attachment points for the upper and lower booms of the dual keel configuration.

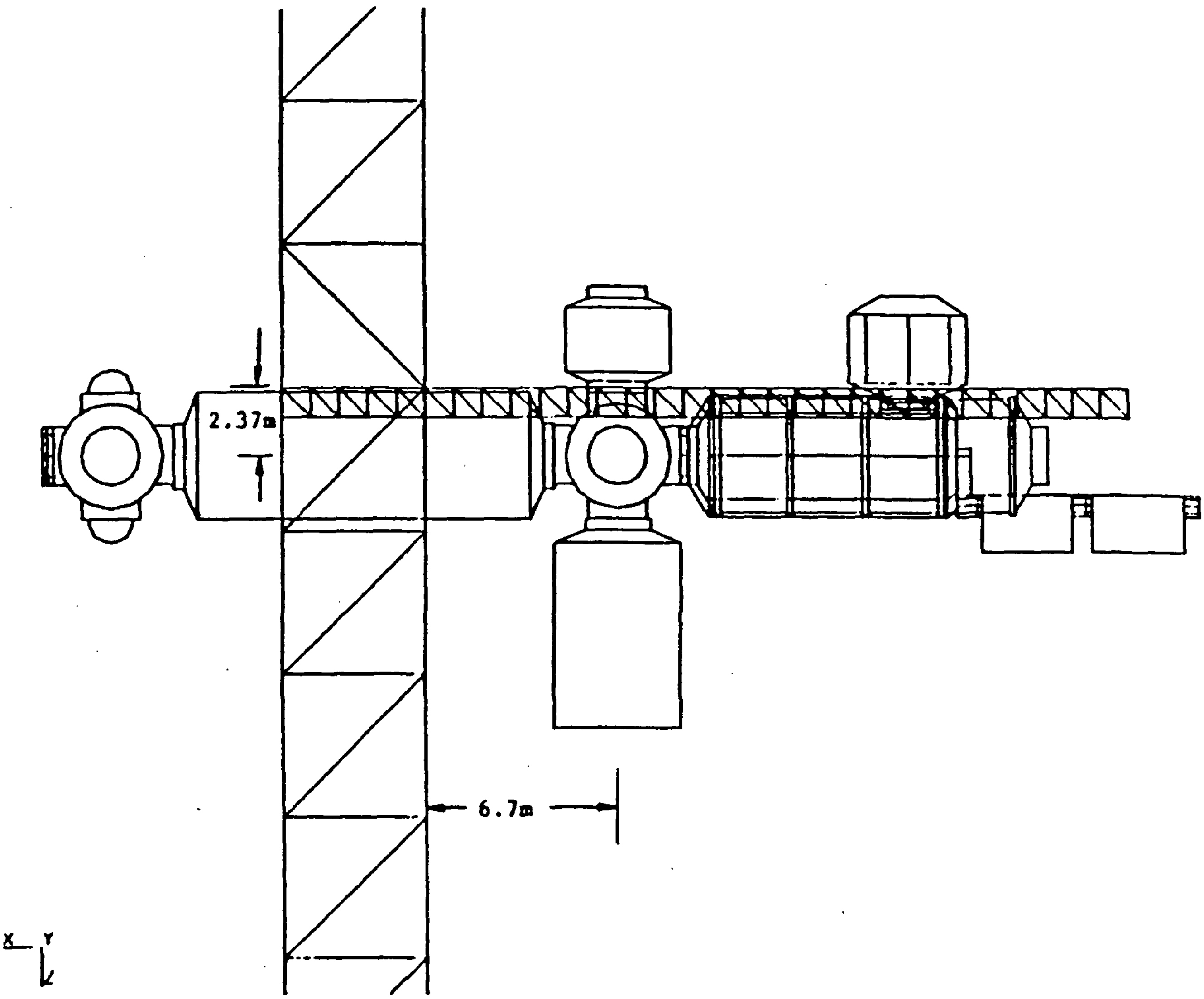


Figure 6, Space Station Truss and Module Pattern, Side View from Space Station Program Office. (1987)

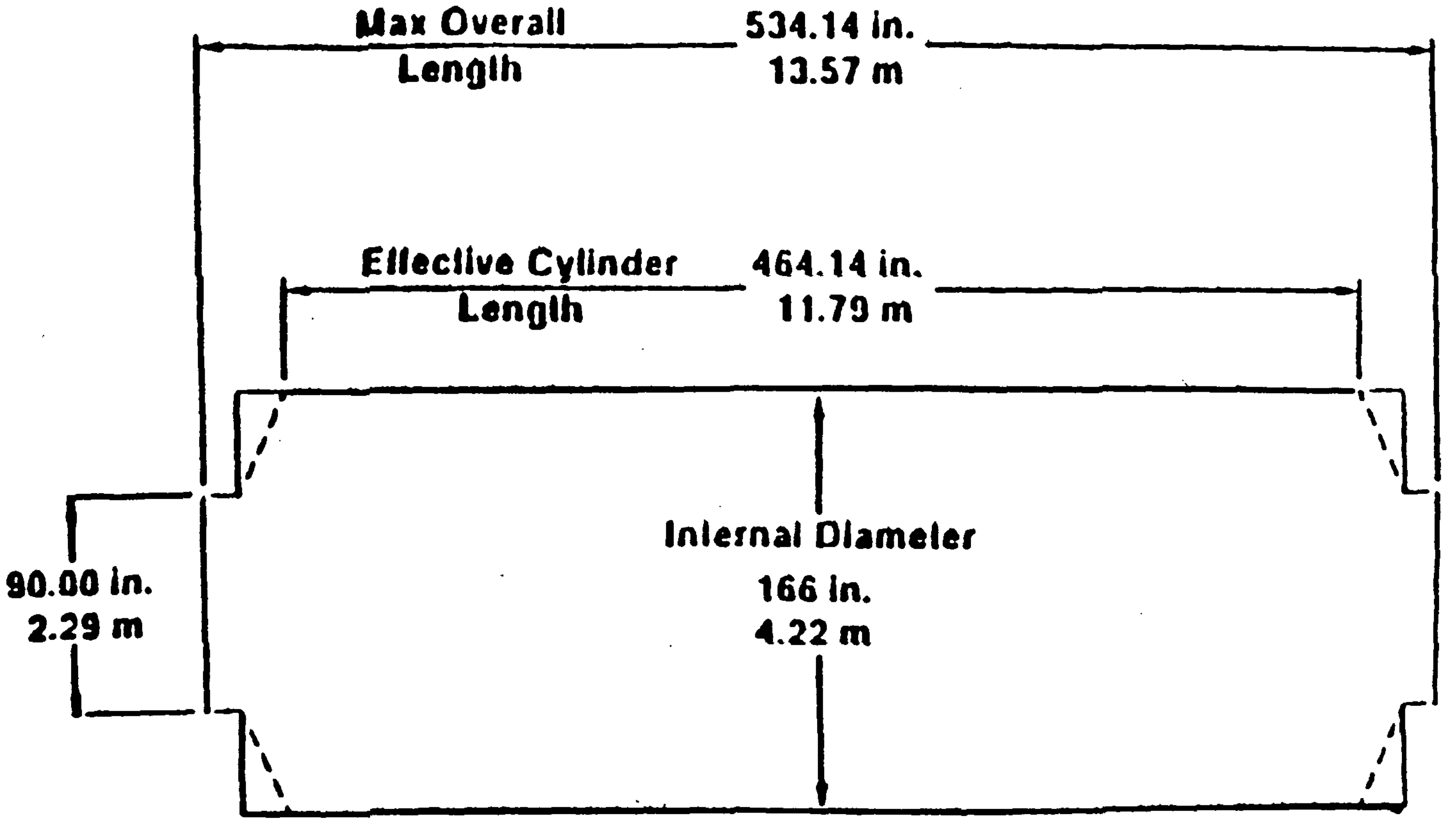


Figure 7, U.S. Laboratory Module Dimensions from Space Station Program Office (1987)

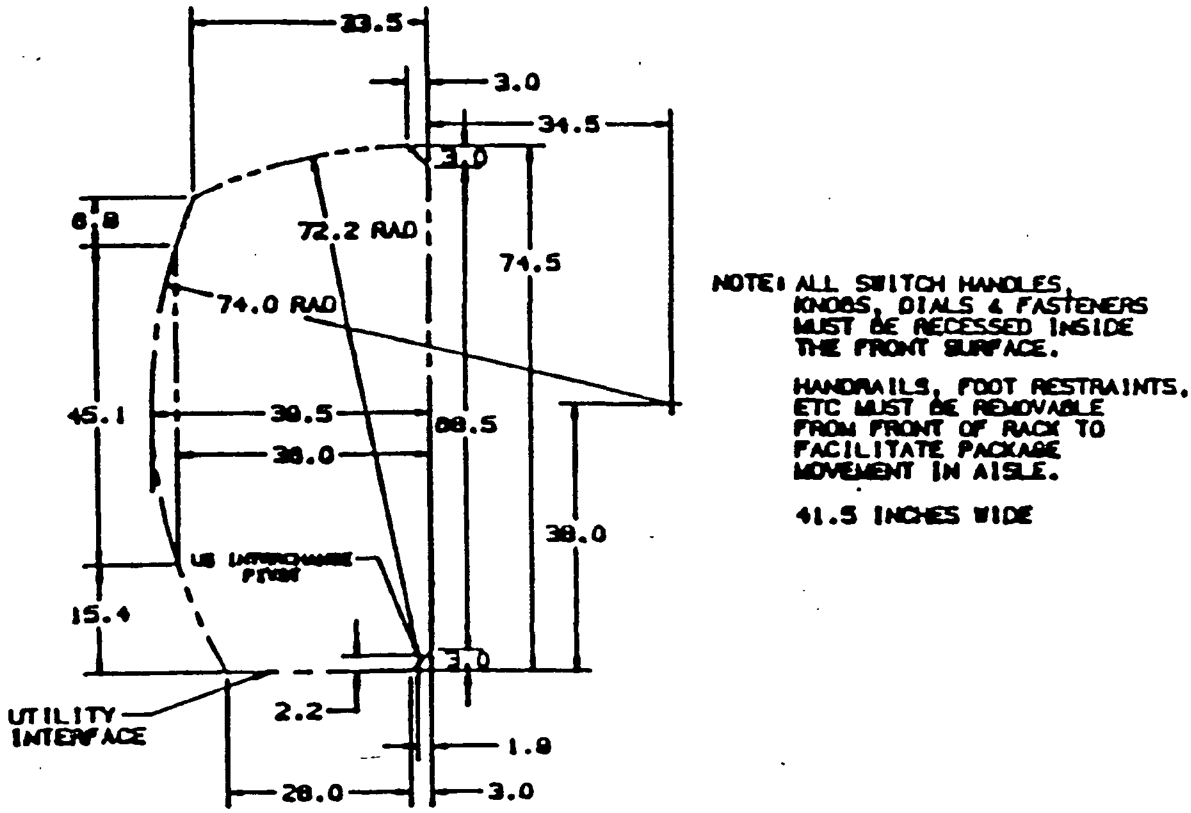


Figure 8, Standard Rack Dimensions from Space Station Program Office (1987)

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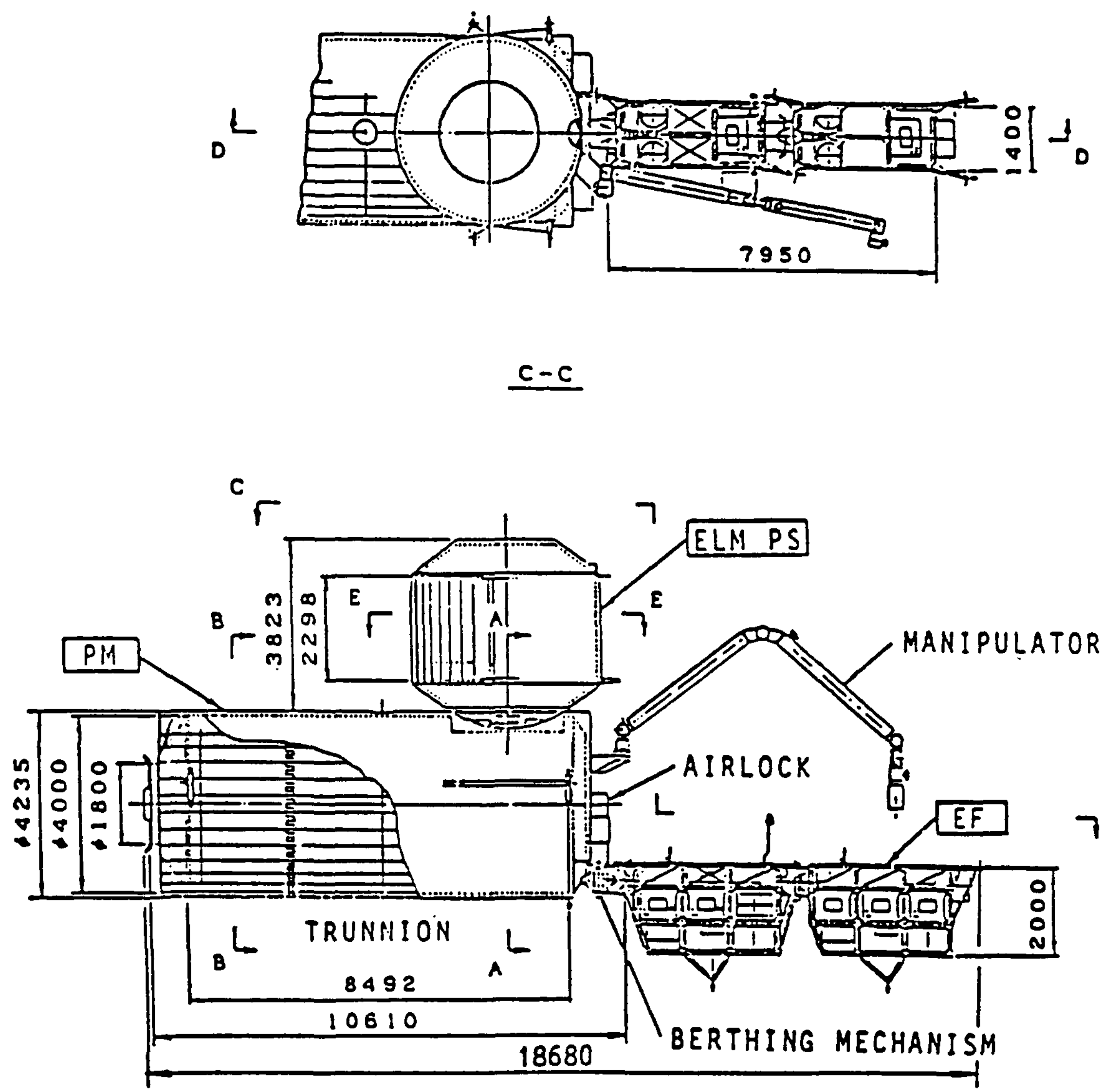

Figure 9, Japanese Experiment Module Reference Configuration from NASDA (1986) dimensions are millimeters ELM PS is the Experiment Logistics Module, Pressurized. EF is the Exposed Facility

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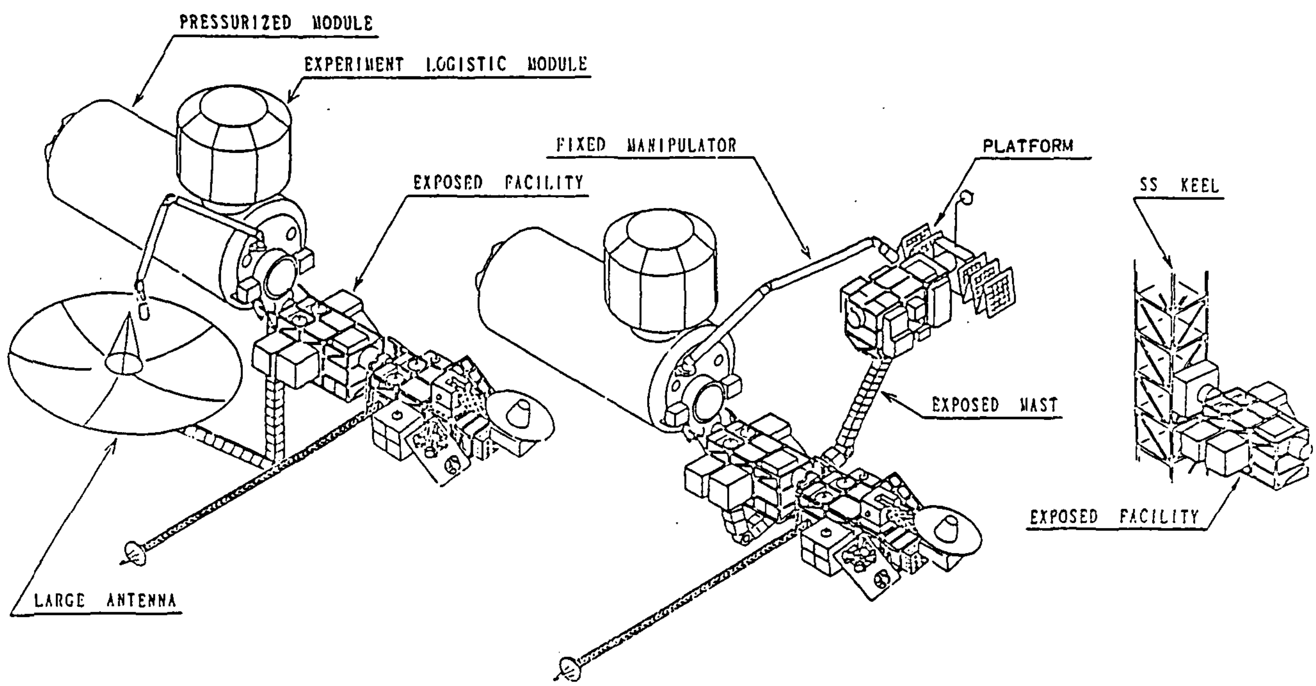

Figure 10, Japanese Experiment Module Growth options from NASDA (1986)

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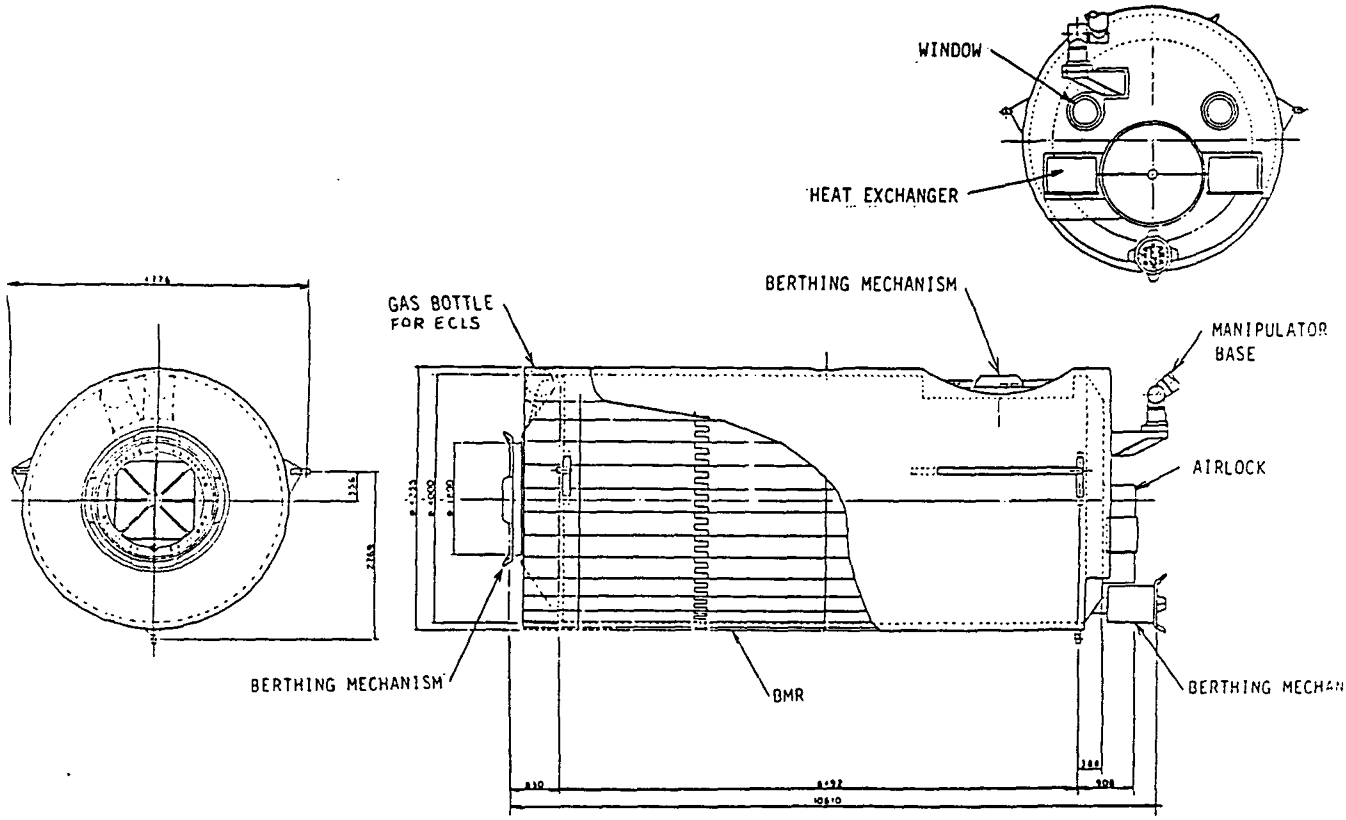

Figure 11, Pressurized Module (JEM) External Configuration from NASDA (1986) Dimensions are in millimeters

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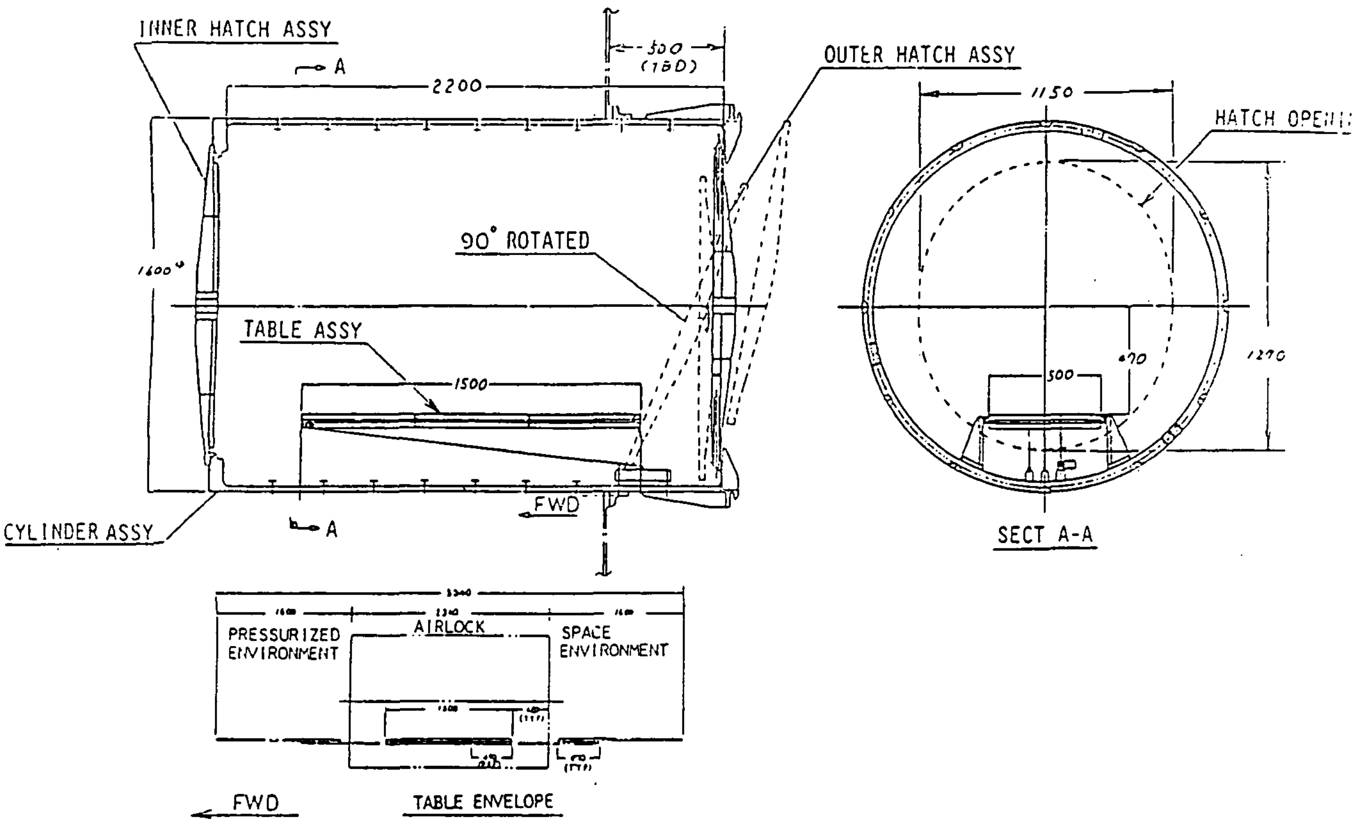

Figure 12, JEM Airlock from NASDA (1986) Dimensions are in millimeters

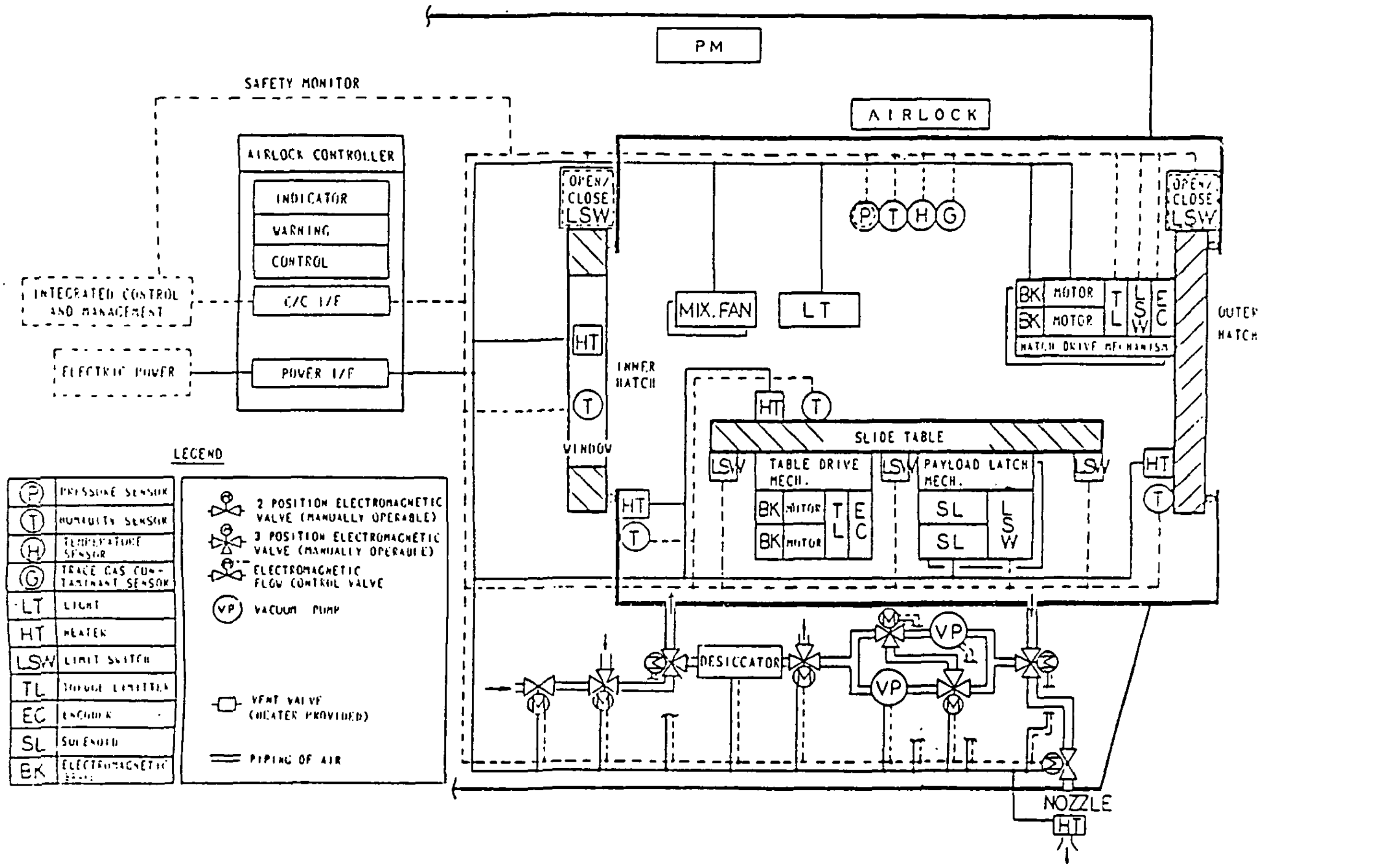

Figure 13. JEM Airlock Schematic from NASDA (1986)

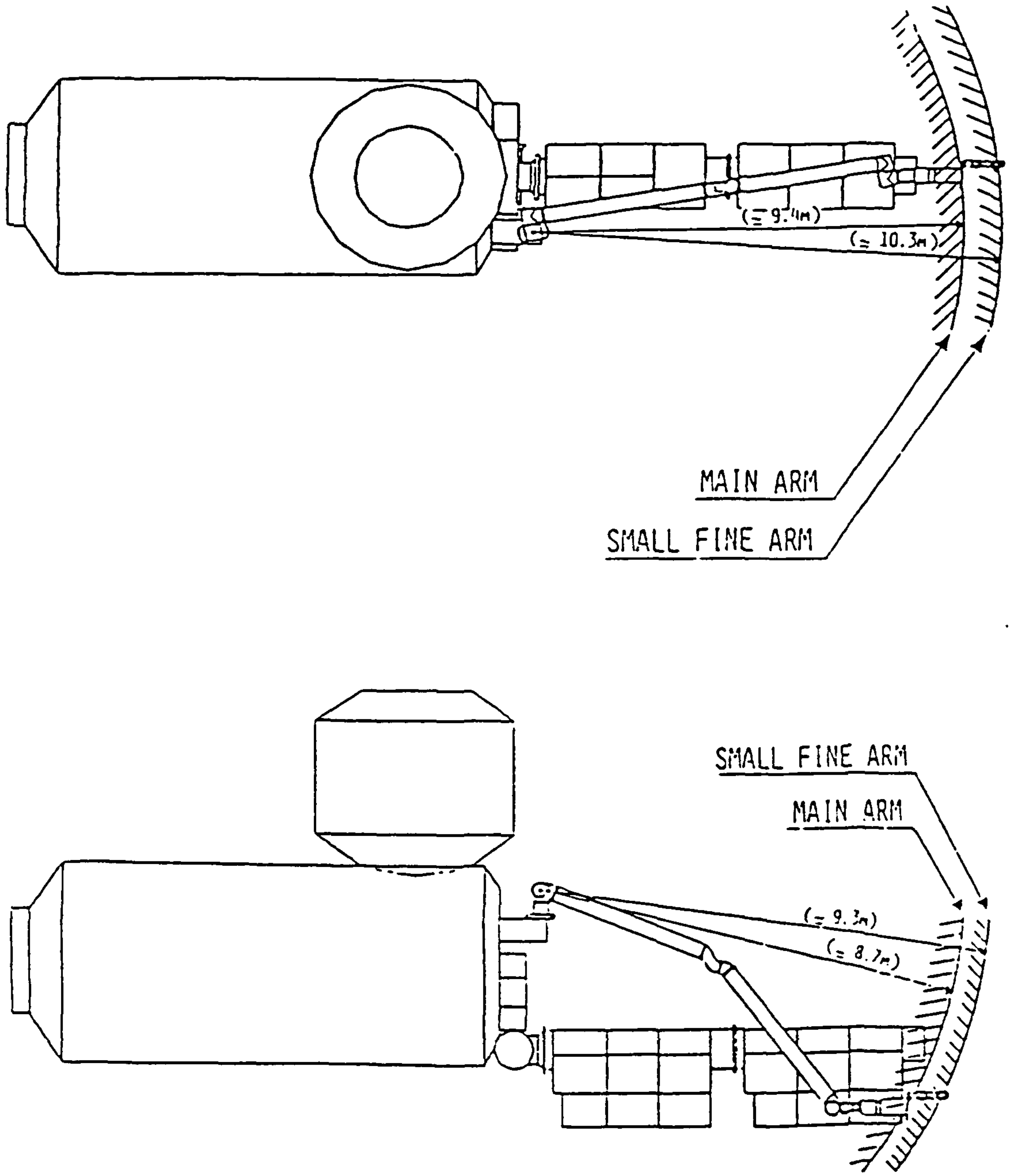

Figure 14, JEM Manipulator Access Areas from NASDA (1986)

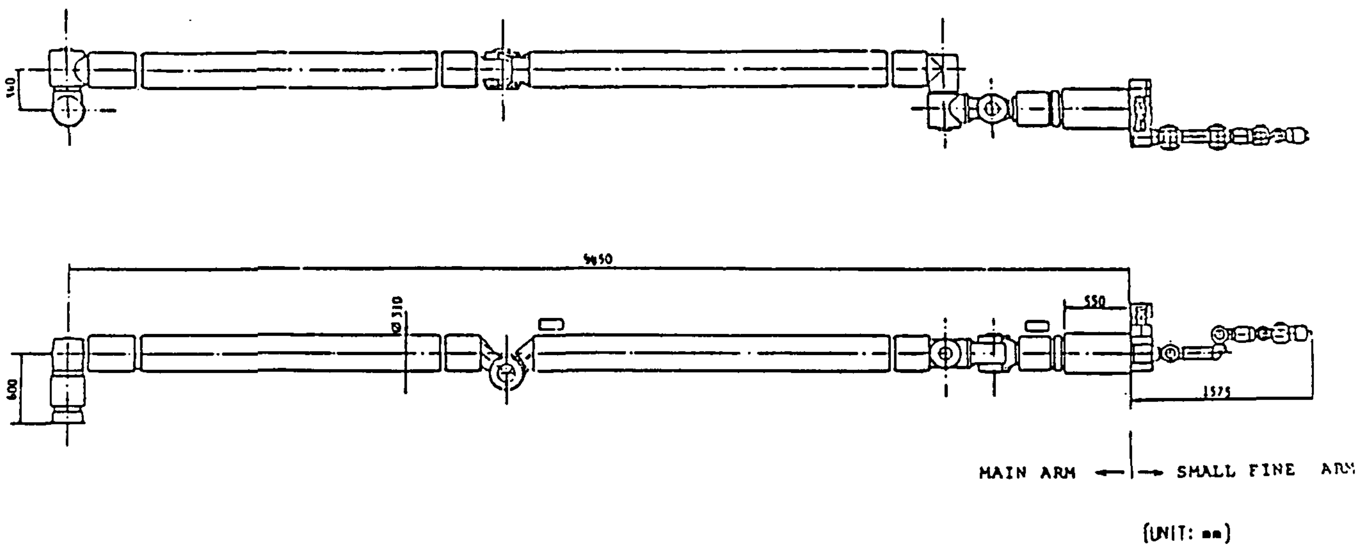

Figure 15, JEM Remote Manipulator System from NASDA (1986) Dimensions are in millimeters

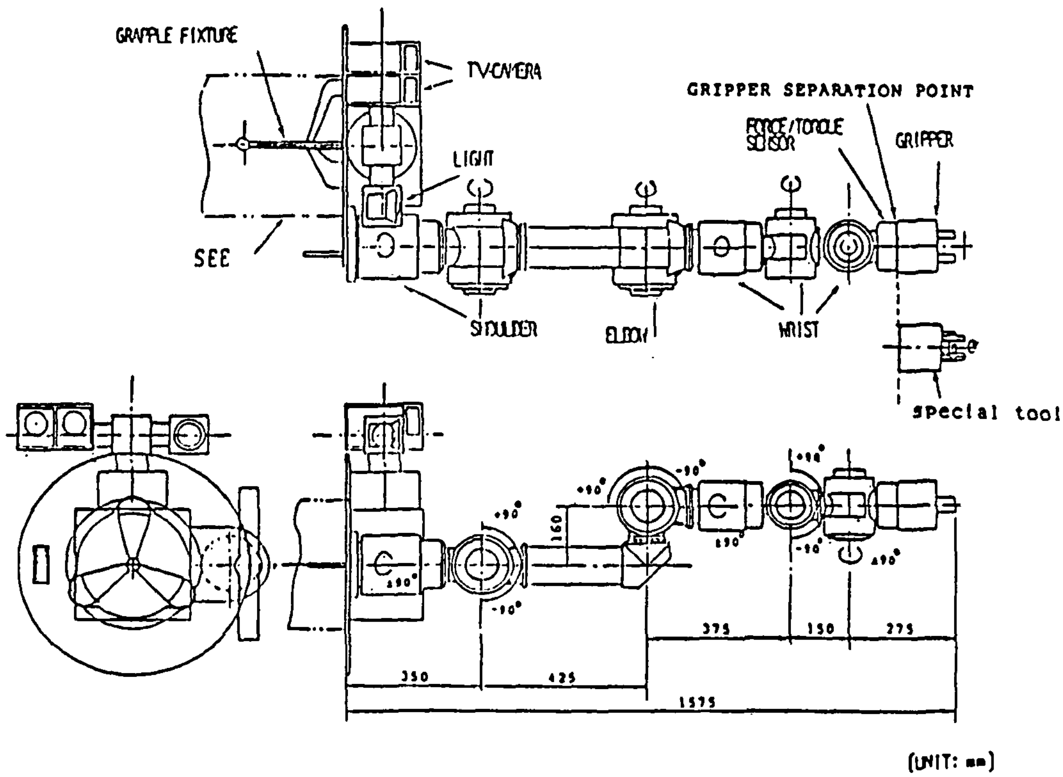

Figure 16, JEM Small Fine Arm Configuration from NASDA (1986) Dimensions are in millimeters

Table 5, JEM Characteristics from NASDA (1986)

(1) Main arm

Arm length:	9,450 mm
Deg. of freedom:	6
Max. tip force:	70 N
Max. tip (wrist) torque:	200 Nm
Max. tip speed:	(No payload) 45 cm/s
(With payload) 4.5 cm/s	
Min. tip speed:	0.45 cm/s
Tip positioning accuracy:	(Manual control) ±30 mm (target)
(Program	control) ± 50 mm/±1 deg
Mass:	400 kg or less

(2) Small fine arm

Arm length:	1.575 mm
Deg. of freedom:	6 + 1 (gripper)
Max. tip force:	30 N
Max. tip (wrist) torque:	4.5 Nm
Max. tip speed:	(No payload) 49 cm/s
(With payload) 4.9 cm/s	
Min. tip speed:	0.49 cm/s
Tip positioning accuracy:	(Bilateral master slave control)
±10 mm	
Gripping force:	TBD N
Mass:	100 kg or less

5.3.1 Pressurized Module and Airlock

The pressurized module is laid out so that it can accept racks essentially identical in size to the US and ESA standard rack (Figure 8). The cylindrical portion of the pressurized module is long enough to hold 8 racks side by side. The module is generally integrated into the Space Station distributed system architecture. A key element in that architecture is the provision for a body mounted radiator on the JEM. Data presented to date has not resolved whether or not there will be a body mounted radiator. The requirement of the MRSR program for holding the sample at a nominal - 40°C is facilitated by such a radiator because it allows cooling to the -40°C range without the electrical power requirements of refrigeration systems that would be needed to reject heat to the active thermal control systems lowest temperature loop, the 35-42°F (1.7 to 5.6°C) water loop. The JEM contains an airlock (Figure 12 and 13) which can transfer experiments between the exposed facility, and the pressurized modules.

5.3.2 Exposed Facility

The exposed facility (Figure 9) is a pair of truss structures with the semicircular outline of a similar truss that fits in the Orbiter payload bay. These truss structures are supplied with a complete set of distributed systems via umbilical connections made up by the manipulators.

5.3.3 JEM Remote Manipulator System (RMS)

The JEM RMS is a general purpose manipulator shown in Figures 14, 15 and 16. The manipulator is sized to service the exposed facility and free flying payloads that might be attached to the exposed facility. The JEM manipulator's reach is not sufficient to reach the transverse boom.

5.4 Columbus Module (ESA)

The Columbus module is similar in structure and function to the US Lab module. It, like the US Lab module, may have a body mounted radiator. It is not considered in this report because MRSR interfaces to it are similar to those of the U.S. Lab module.

5.5 Airlock and Hyperbaric Airlock

The two airlocks are functionally identical in terms of transferring crew and equipment between space and the pressurized modules. The two airlocks are located at the positions indicated on Figures 5 and 6. Each airlock has the capability of transferring a double standard rack 42"x39"x84" and will be able to transfer the processing cabinet defined below into the pressurized modules.

5.7 Mobile Servicing Centre (Canada)

The Mobile Servicing Center has one or two arms which can extend to reach the OMV and retrieve payloads. The arms have a number of possible end effectors including the US Telerobotic servicer (Figures 17 and 18A and B) and Canadian Special Purpose Dexterous Manipulator (Figure 19). These devices, with small dexterous manipulators, can be used to maneuver the EOC into its storage container and extract the SCA from the EOC and transfer it to its external storage container.

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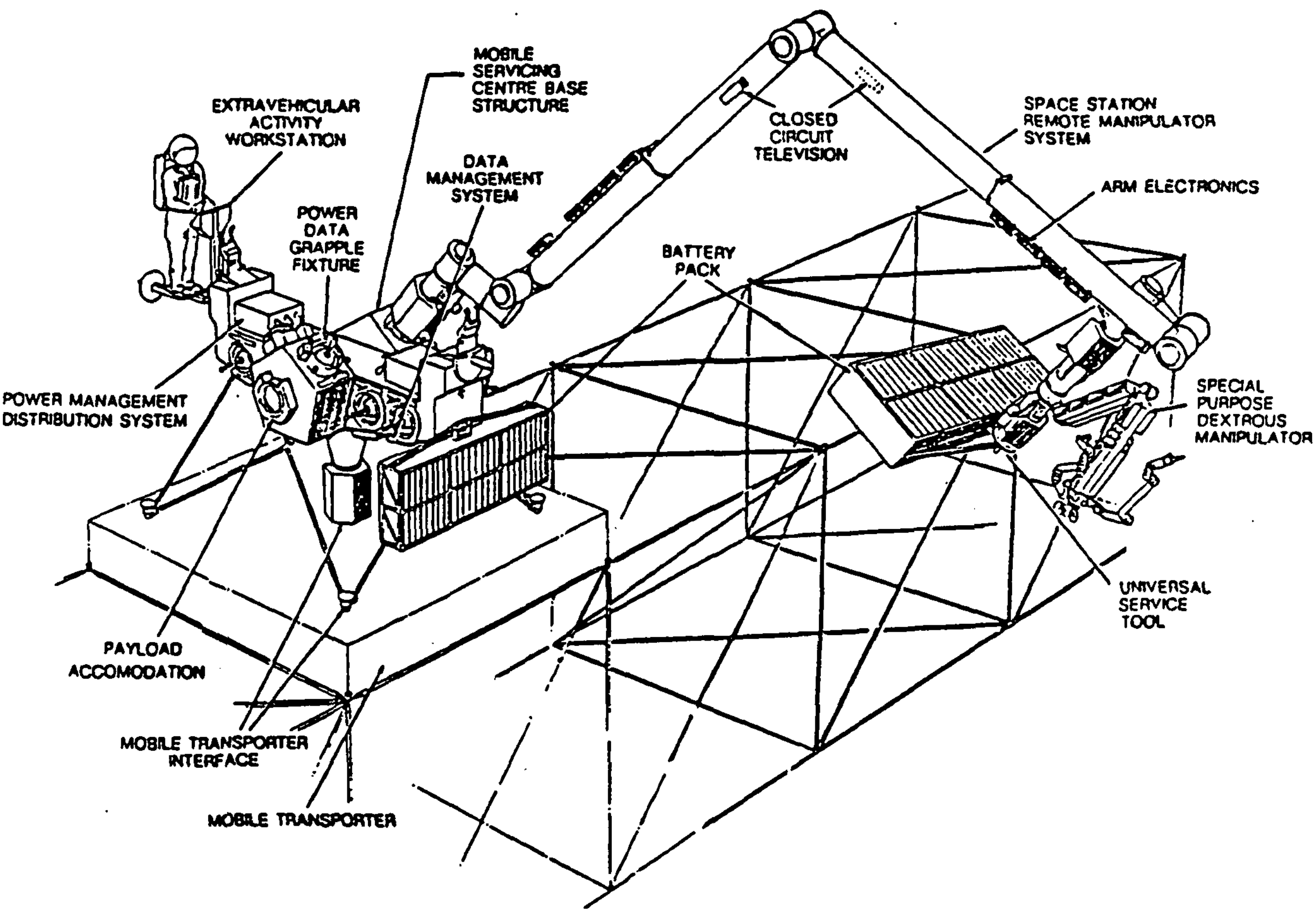

Figure 17, Mobile Servicing Centre from Mobile Servicing Center Def. Package personal communication Brian Erb

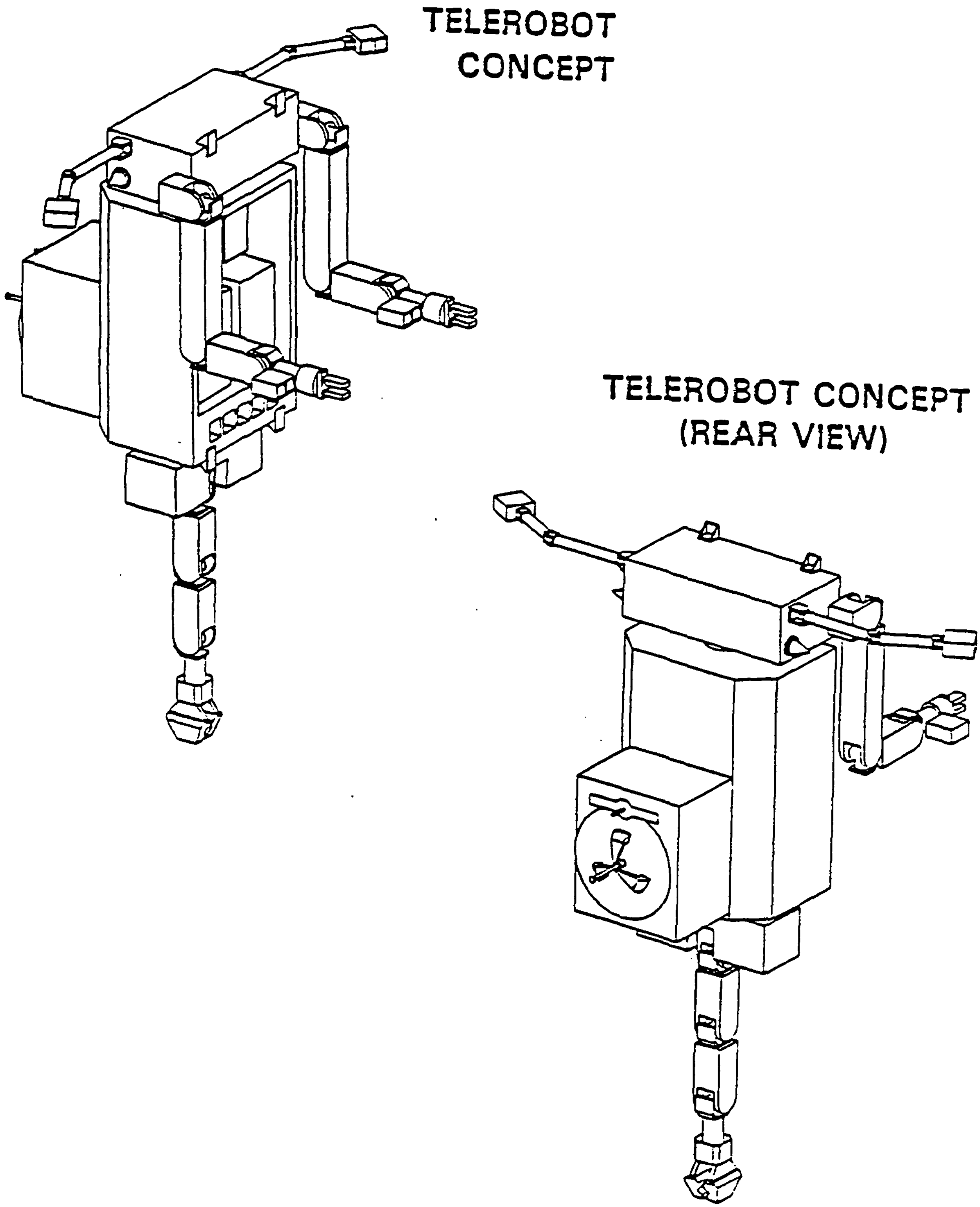

Figure 18A and B, Flight Telerobotic Servicer

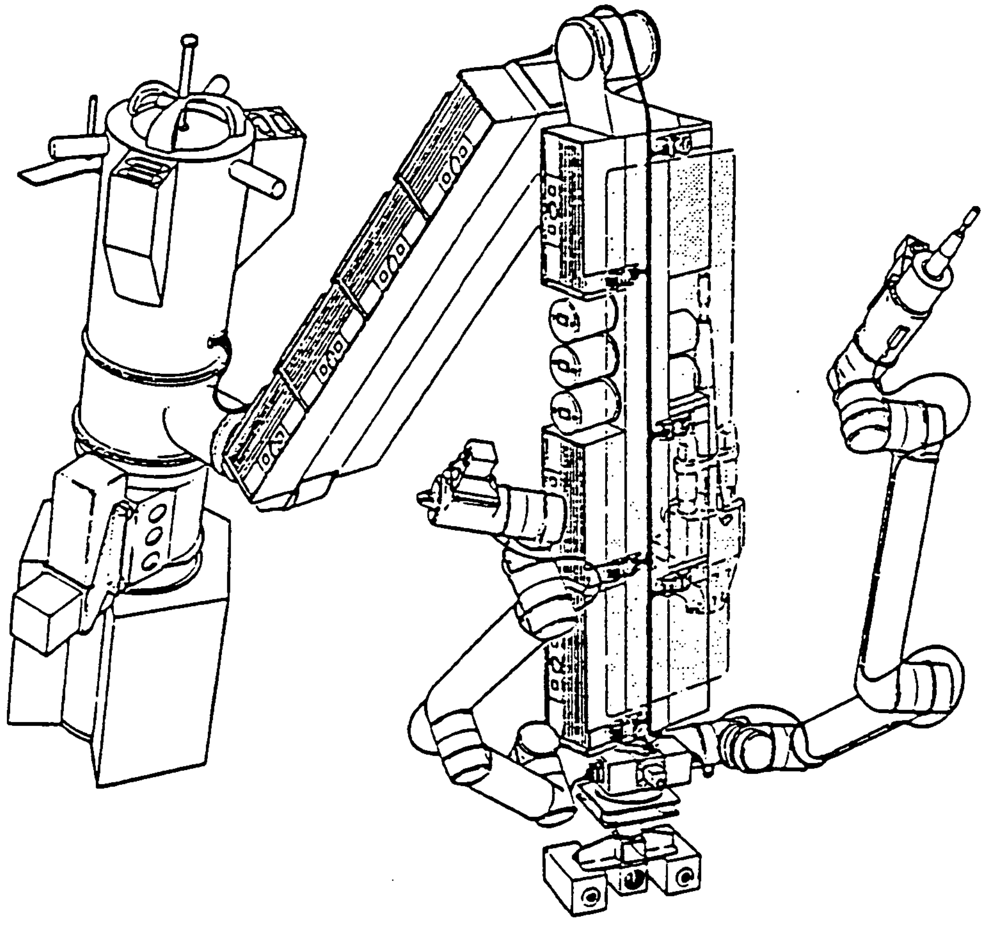

Figure 19, Special Purpose Dexterous Manipulator from Brian Erb (personal communication)

5.8 Definition of Orbital Maneuvering Unit

Figure 20 shows the current concept to the Orbital Maneuvering Unit. The unit is large and mobile enough to retrieve the EOC. The OMV is not a part of the Space Station Program. Rather it is defined as a STS Orbiter based system. The total velocity increment of the OMV with a 100 kg payload is about 1.2 km/sec.

5.9 Biological Isolation Facility

Detailed biological analysis requires on orbit facilities in excess of any anticipated capability of the Phase 1 Space Station or Phase 2 of the current baseline configuration. For the option involving analysis on-orbit a new module will be defined. The Station is scarred to add a module like the biological isolation facility.

6.0 Design Reference Missions

There are three basic types of reference missions considered. The sample can be: 1) repackaged outside the Space Station (DRM 1), 2) taken into an existing module (DRM 2), or 3) taken into a new module specially designed for biological studies (DRM 3). A number of options exist within the first two types of reference missions.

On the outside of the Space Station there are two options:

1) (DRM 1A) Storage of the sample outside the Station prior to return to Earth via the Shuttle Payload Bay. The sample does not come into the Space Station.

2) (DRM 1B) Remove the Sample Return container by EVA or by manipulator and transfer the sample into the Space Station.

There are four paths into the Space Station for a Martian Sample. In addition to the four listed below, there is an airlock proposed for the Columbus Module. However, at the present time, the size and location of this airlock is not established well enough to understand its application to the subject of this study.

1) Via EVA through one of the two airlocks
2) By manipulator transfer through the JEM Airlock
3) By manipulator transfer through an airlock/processing cabinet mounted on a Node Hatch
4) Through an airlock mounted on a new dedicated module.

There are four places to process the sample inside the Space Station. The list of candidate processing locations are:

1) In a rack in the U.S. Lab Module
2) In a rack in the JEM.
3) In a containment area mounted on an airlock attached to a Node hatch.
4) In a containment area with attached airlock in a dedicated module.

In addition the Columbus Module may also be able to support this activity. The current level of definition of this module in the Space Station Baseline Configuration Document

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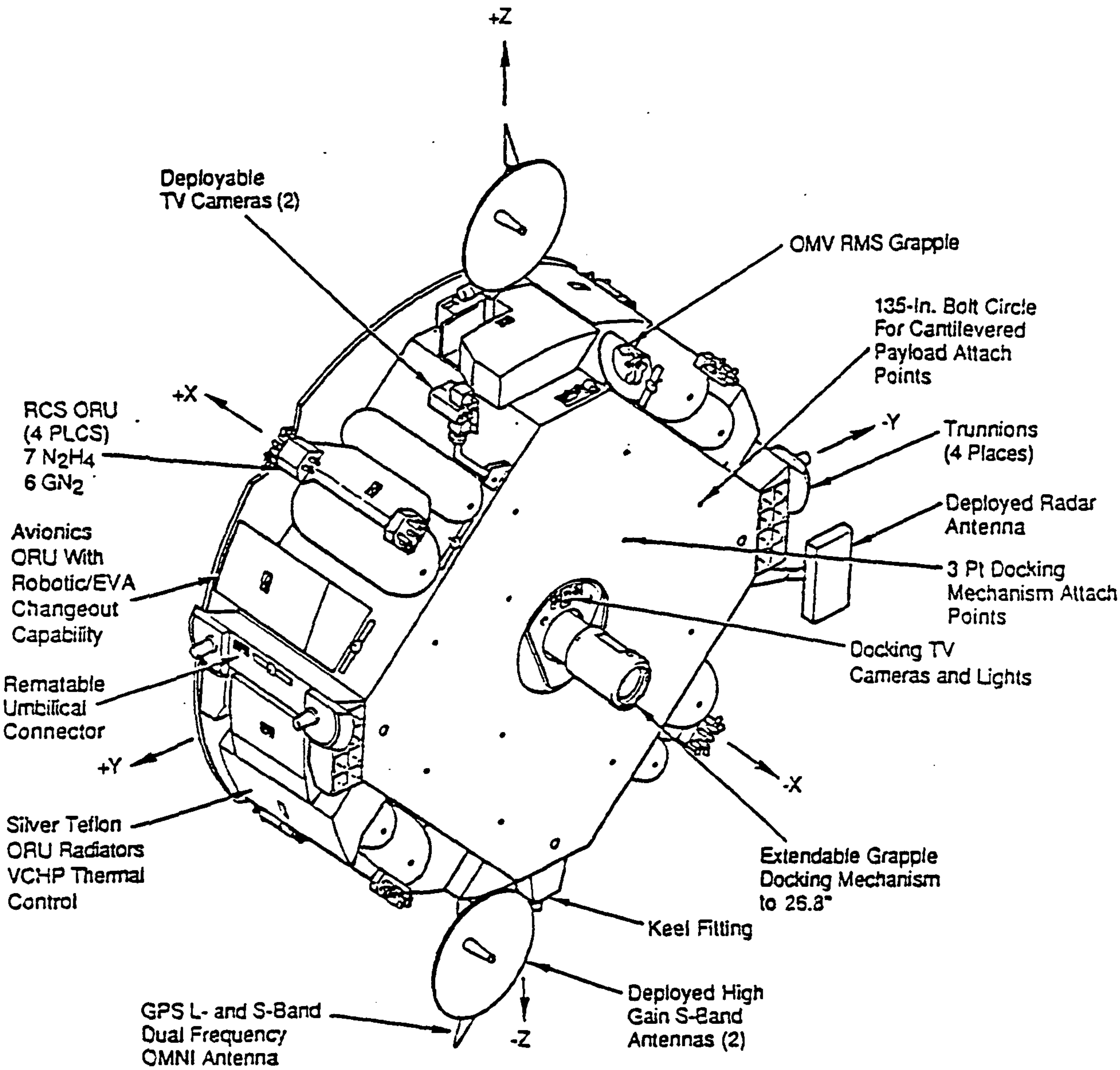


Figure 20, Orbital Maneuvering Unit and Propulsion Module

(BCD) is not adequate to evaluate its suitability. It appears that it will be similar to the US Lab Module and all options involving that module may also apply to the Columbus Module.

There are two levels of processing of the sample inside the Space Station:

1) Opening of the Sample Return Canister and removing one or more subsamples for Earth based analysis.
2) Opening the Sample Return Canister and removing one or more subsamples and then performing sufficient analysis while in orbit to determine that the sample contains no life, or is non-threatening.

The following four sections discuss each one of the above mentioned options. A recommendation is then made, based on the available information and the analysis done to date.

All the possibilities given above result in a variety of combinations. There are a number of combinations which do not make much sense, such as transferring a sample by EVA into the Space Station and then processing it in a modified Node hatch. It is assumed that testing the sample in orbit will require sufficient analytical equipment, not be used for other applications, that a dedicated Mars Sample Processing and Analysis Laboratory would be needed.

After removing the obvious duplicates there still are the 7 options defined in Table 1 falling in 3 major groups. These include:

DESIGN REFERENCE MISSIONS

1A	Repackaging the Sample on Transverse Boom without bringing it into the Station repeat with on JEM exposed facility
2A	Astronaut EVA removal of the repackaged sample from the truss and IVA transfer into the U.S. Lab module via one of the two large airlocks for subsample preparation
2B	Astronaut EVA removal of the repackaged sample from the truss, entry into the Space Station from a large airlock and IVA transfer into the JEM module for subsample preparation
2C	Manipulator removal of the repackaged sample from the JEM pallet into the JEM via the JEM airlock for subsample preparation
2D	Manipulator removal of the repackaged sample from the JEM pallet into the U.S. Lab module via the JEM airlock
2C	Manipulator repackaging on the truss and Manipulator transfer to a Hatch processing facility for subsample preparation
3	Manipulator transfer to a dedicated Module for comprehensive biological testing

6.1 OMV (Orbital Maneuvering Vehicle) Options

An OMV is required to retrieve the EOC in LEO following aerocapture. The OMV can depart from the Station or the Orbiter. Departure from the Orbiter requires a Shuttle launch precisely timed to EOC arrival, an undesirable situation. If the OMV is based at the Station, the Shuttle must only deliver it prior to EOC arrival. A Station based OMV(s) is therefore assumed.

Current plans call for NASA to procure only one OMV with an option for a second. A propulsion/propellant changeout kit, easily replaceable on-orbit, is part of the program, however, (see figure 20). Depending on the orbit of the EOCs, one OMV may not require a propulsion module changeout to go get the second EOC.

If two EOCs arrive within weeks of each other and one OMV does not have enough propellant to go get both, there are a variety of options. Either two OMVs are required at the Station, one OMV must be reloaded with propellants or have its propulsion module changed out, or the Shuttle must change out OMVs or take one OMV up and down within a specific time frame. One OMV with a propulsion module replacement based at the Station appears to be the simplest situation for MRSR and is therefore assumed. Two OMVs based at the station would provide redundancy however.

There are several options for basing the OMV at the Station. The OMV can station keep in the vicinity of the Station, the OMV can rest in a cradle attached to the transient payload fittings on the transverse truss, or the permanent basing fixtures for the OMV, now part of Phase II of the Station, can be prepared and installed.

The permanent fixtures are preferred. Their availability depends on the funding, timing, and other programs that require them. An OMV station keeping is not desired. The difference in ballistic coefficient between the Space Station and the OMV mean that co-orbiting may use considerable propellant. In addition, the desired mode of OMV operations is to have the OMV docked to the Station before removing payloads. If the MRSR program must pay for early OMV docking facilities, a simple cradle on the transverse truss payload fittings may suffice assuming the required approvals can be received. In the absence of good definition of the permanent docking facility, the simple cradle is assumed. Figure 21 shows the OMV being unloaded at the Station.

6.2 Canister Pallet Location, JEM Pallet versus Transverse Truss

A canister pallet, described in section 7.0 (Figure 33), will probably be required for all options. The pallet carries two containers capable of biologically isolating one EOC and one SCA separately. The SCA is removed from the EOC and placed via manipulators in an additional container that did not go to Mars, which can then be handled without fear of biological contamination.

The EOC outside the SCA should be sterile, because of a sterile transfer in Mars orbit, so the container for the EOC is a backup. The SCA exterior may also be sterile, depending on the mechanics of the sterile transfer in Mars orbit. The additional container backs this sterile transfer up and also allows a much thicker metal wall containment, more instrumentation, insulation, etc. than can be practically carried to Mars and back. Thermoelectric refrigeration devices or cooling loops for a cooling coil can also be placed around the SCA without burdening the equipment going to Mars.

Each canister pallet is delivered in the Shuttle payload bay. Each will be removed from the bay and placed on the one of two available positions on transverse beam of the truss on a payload fitting, (see Figure 22) or placed alongside the JEM pallets (Figure 27). Figures 22 through 26 shows a sequence starting with a transverse truss placement of the pallet. Figures 27-30 show the sequence starting from a JEM pallet placement.

The two locations have various advantages and disadvantages. The preferred method of sample handling and transfer uses only the manipulators to remove the SCA from the EOC and place it in a new container. An EVA crewman would serve as a backup.

The JEM pallet location allows convenient use of the JEM manipulator for removing the SCA from the EOC, placing it in a canister, and putting the canister in the JEM airlock for entry into the Station. The JEM manipulator is more appropriately sized for this kind of manipulation. The JEM manipulator is also shirtsleeve eyeball controlled for this application. On the negative side, numerous hand-offs from the JEM manipulator to the Space Station Remote Manipulator System (MRMS) are required, complicating operations. The MRMS must be able to change the side of the truss or face it rests on or it must be located on a face that allows it to hand off to the JEM RMS.

The transverse truss location will have a standard payload attachment fitting and may therefore be more hospitable to transient payloads. However no positions will be available once the dual keel is installed. Removal of the SCA from the EOC out on the main truss will require use of the MRMS with a dexterous end effector of some kind. An EVA crewman will be required on the transverse beam to actually see the transfer operation, not using television. If the JEM airlock is used to bring the SCA into the Station, a handoff, from the MRMS with special end effector to the JEM RMS will be required.

Figure 21, RMS Unloads OMV

Figure 22, RMS Moves Canister Pallet to Transverse Truss Payload Mounting Fixture

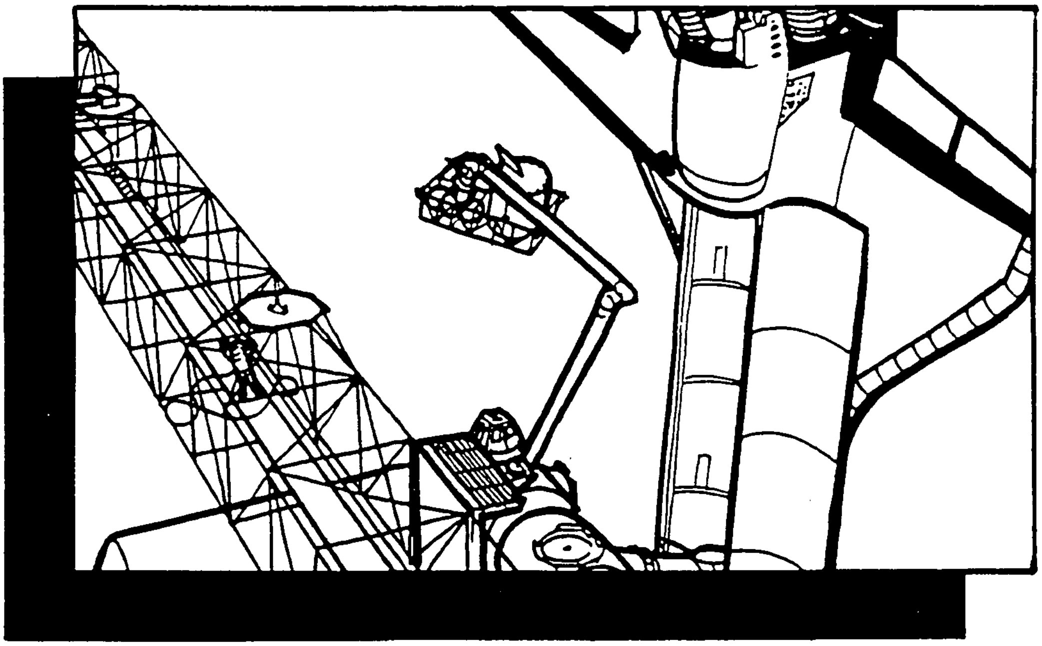


Figure 23, OMV Delivers EOC

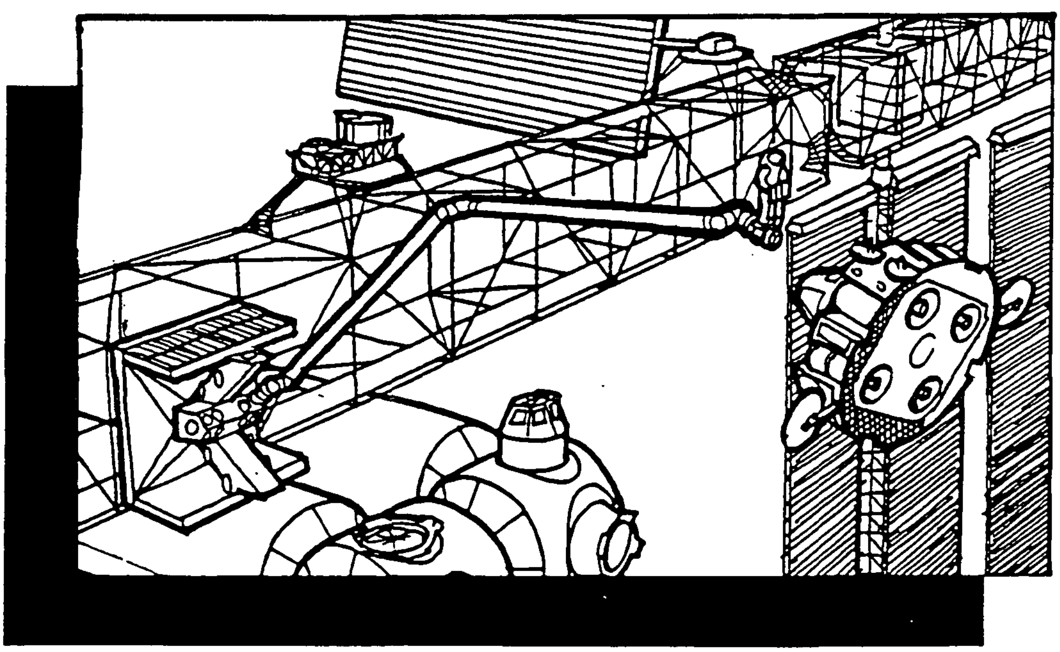


Figure 24, MRMS Places EOC in EOC Canister

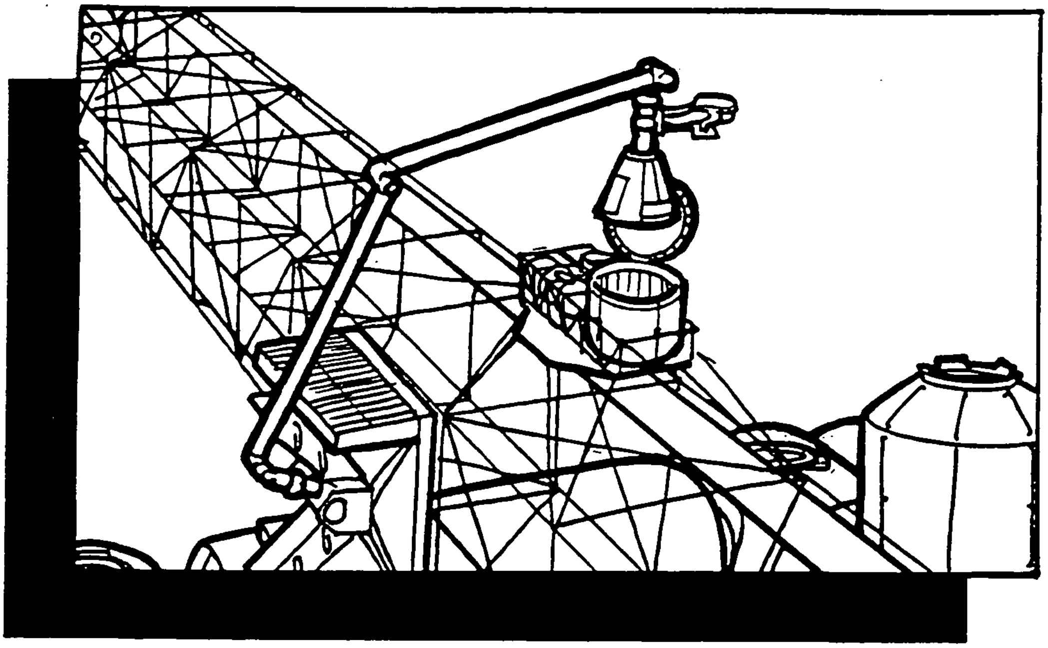
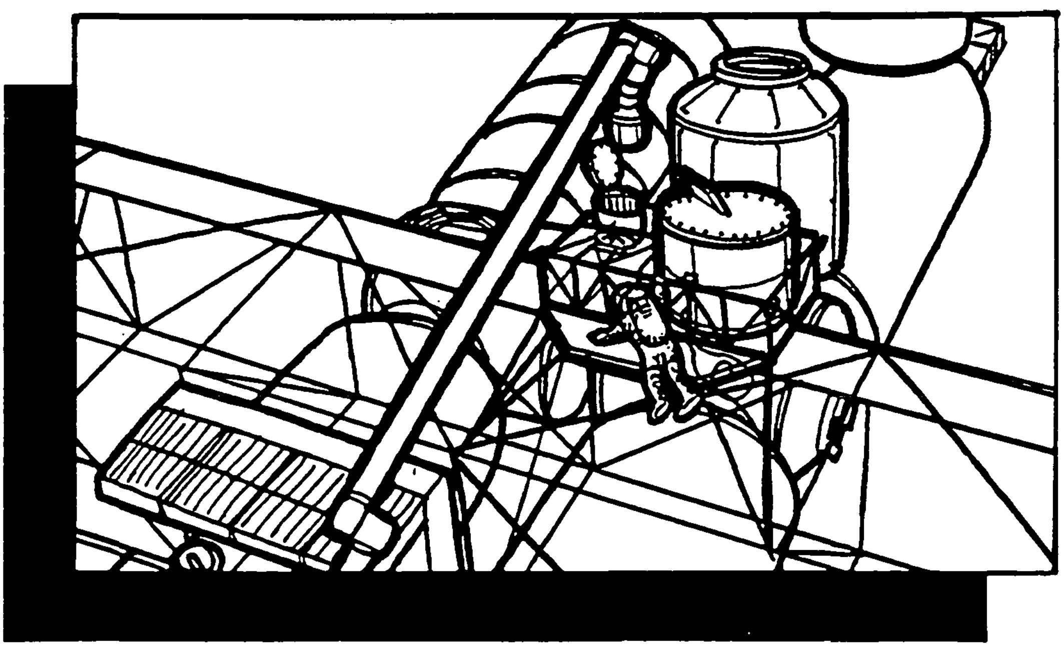


Figure 25, MRMS Places SCA in SCA Canister



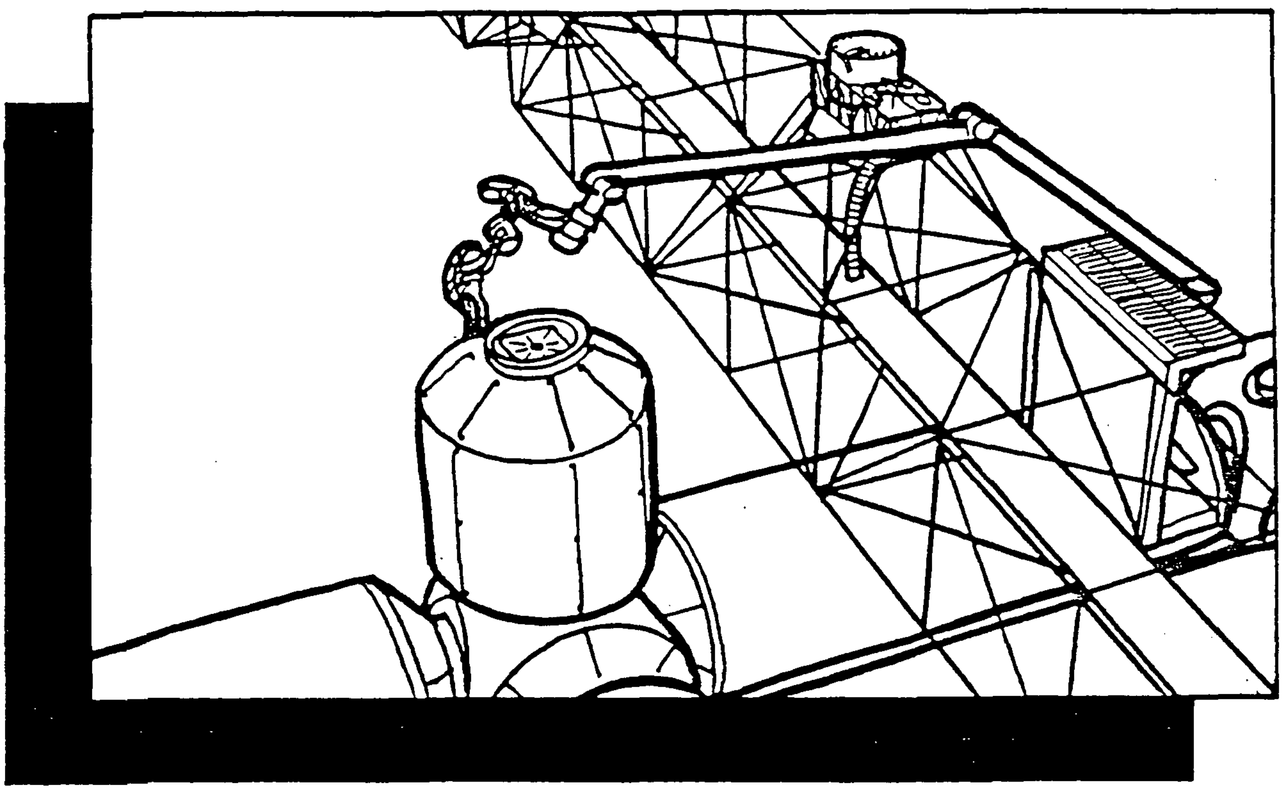


Figure 26, MRMS Moves SCA Canister/Astronaut to Airlock

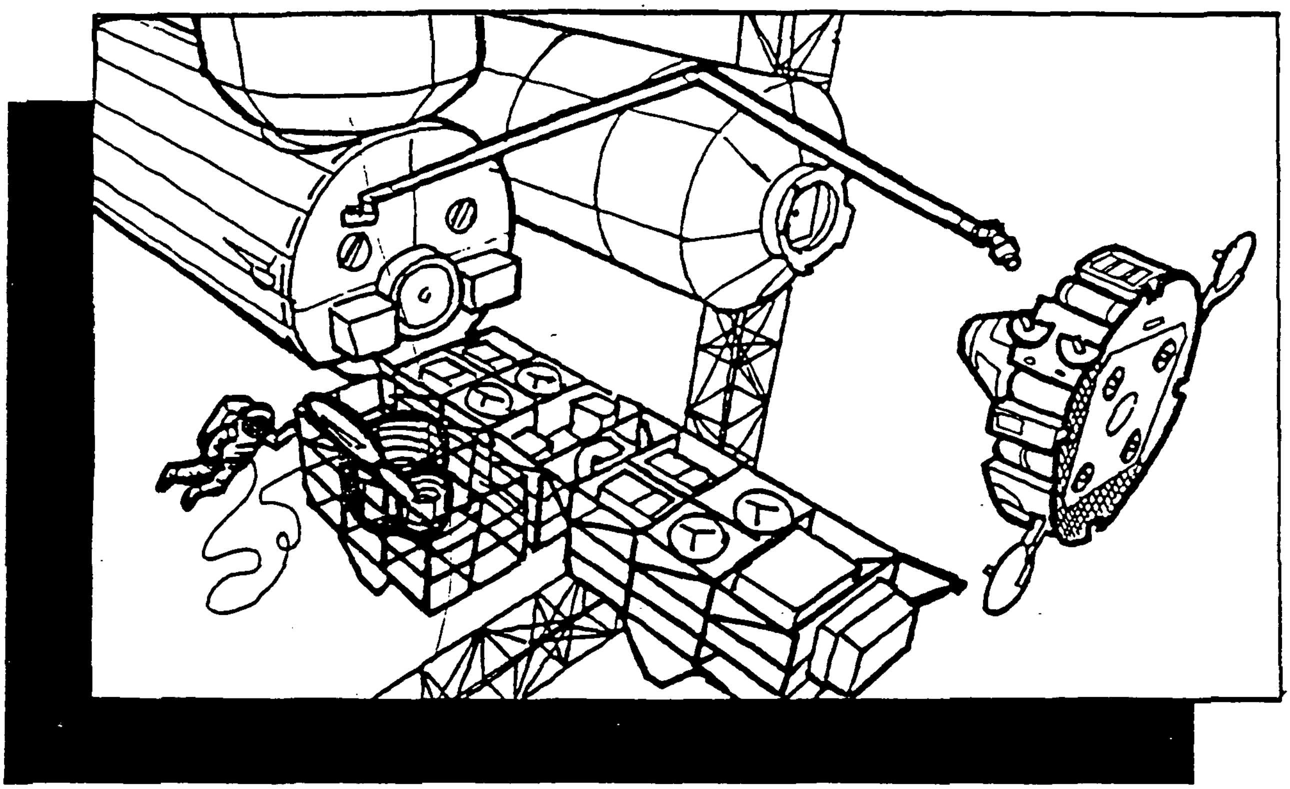


Figure 27, OMV Delivers EOC to JEM Pallet

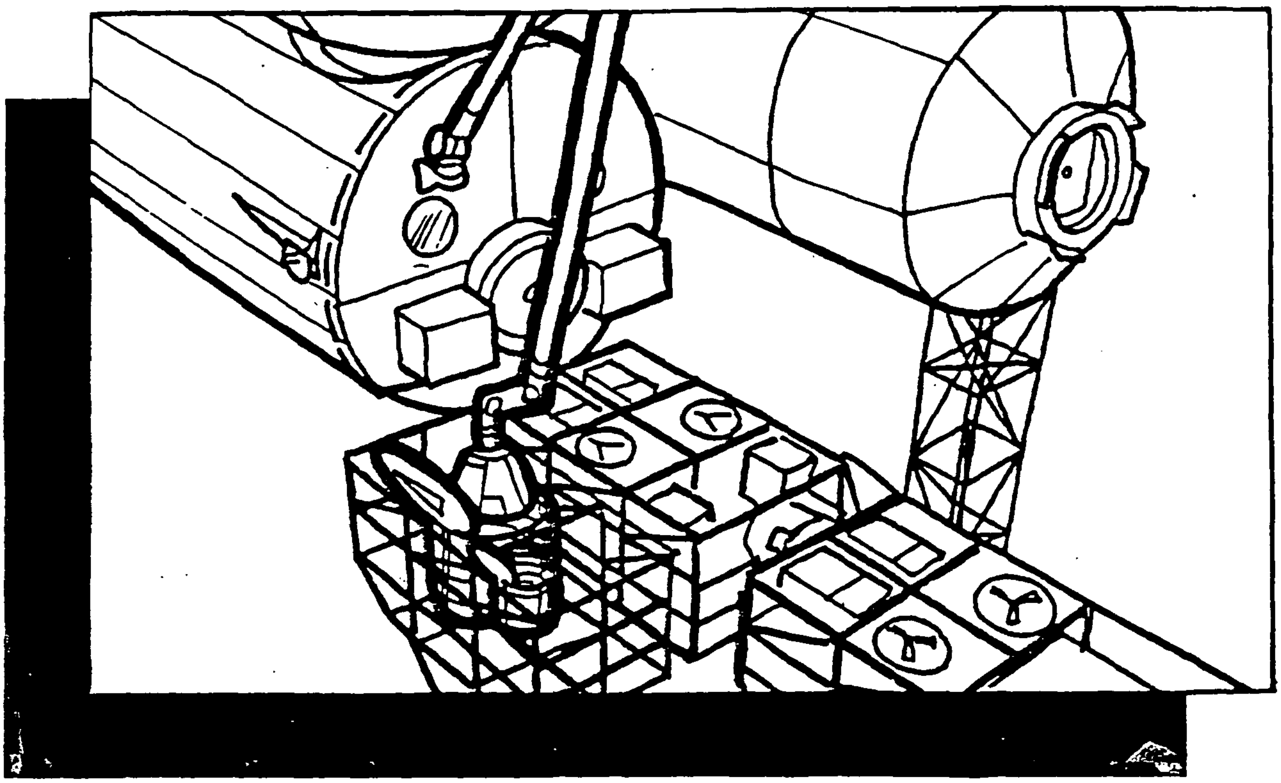


Figure 28, JEM Manipulator Places EOC in EOC Canister

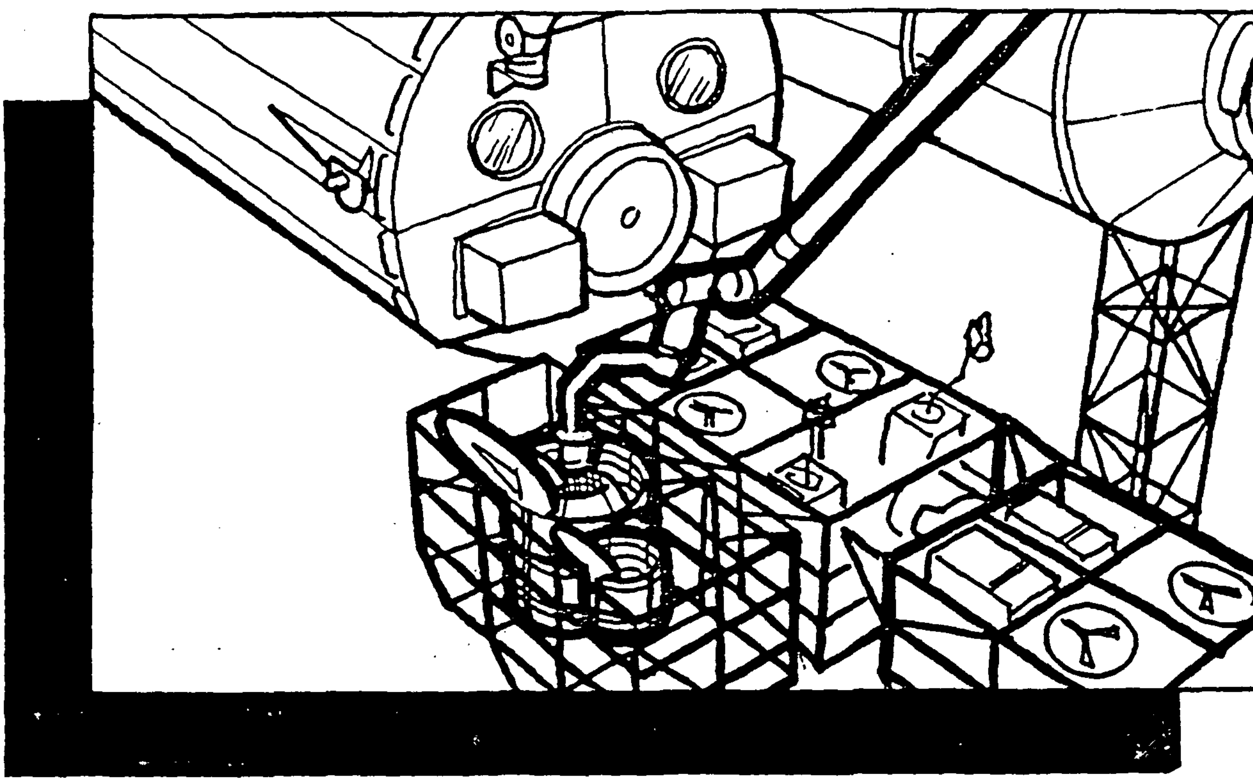


Figure 29, JEM Manipulator Removes SCA from EOC

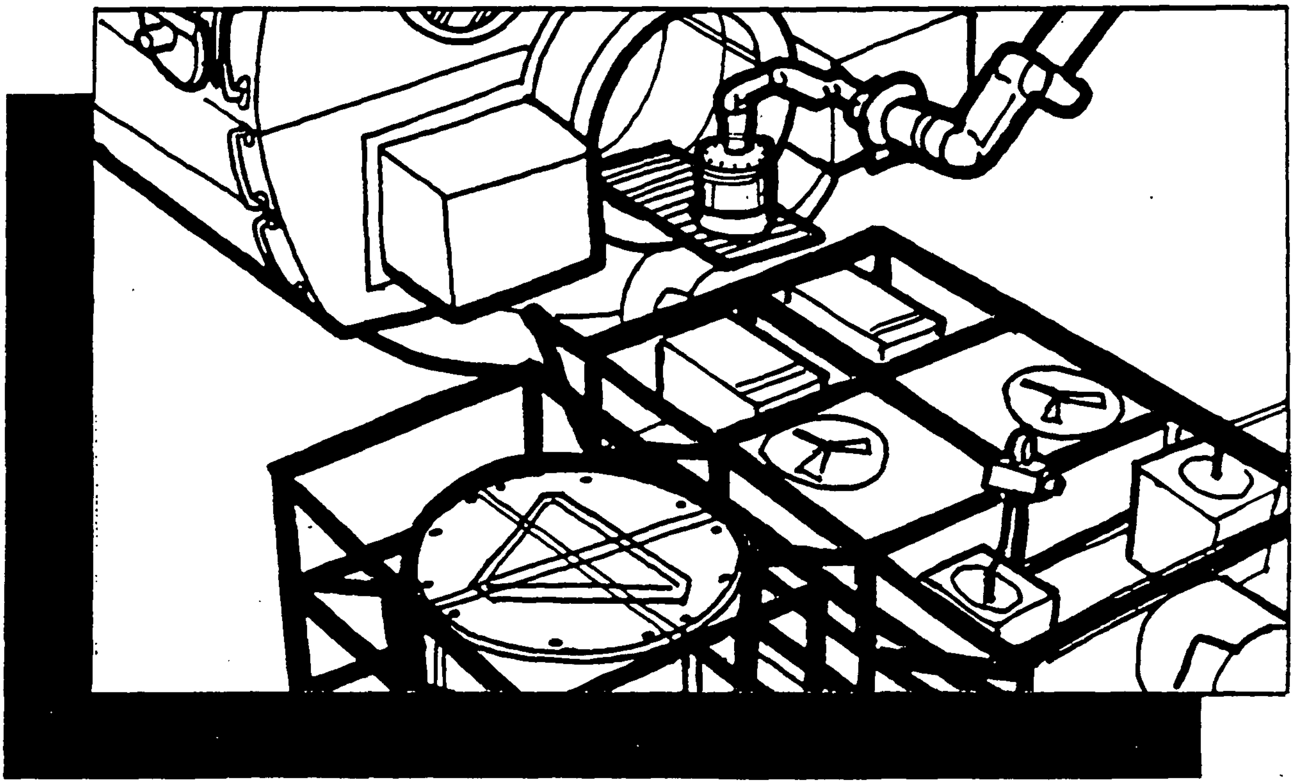


Figure 30, JEM Manipulator Places SCA Canister on Airlock Table

From a safety and mission success standpoint, manipulator repackaging with the JEM manipulator is recommended and the JEM pallet location is therefore recommended. This assumes the JEM pallet can accommodate two canister pallets. The paper, planning, and co-ordination costs of using the JEM will be higher, but Japanese participation in MRSR might involve some overall cost sharing and make the program more secure.

6.3 Arrival of the OMV and EOC at the Space Station

When the EOC aerocaptures into Earth orbit, an OMV will depart the Station to capture it. The EOC will be captured and brought to the vicinity of the Space Station. When the OMV enters the Space Station control zone, control of the OMV will pass from ground controllers to the Space Station. The Space Station crew will be in real time control of the OMV attitude and position as it approaches the Station with the EOC.

Current thought indicates approaches to the Station will be permitted only on the end where the cupolas are located. This allows proximity operations to be carried out under shirtsleeve eyeball control. Figures 23 and 31 show the OMV with the EOC approaching the Station in this manner.

It is also desirable for the Orbiter to be elsewhere during the OMV approach to eliminate the possibility of damaging the Orbiter with an accidental collision.

The preferred sequence is therefore to capture the OMV/EOC with the MRMS and dock the OMV/EOC on the Station truss. The EOC can then be removed from the OMV.

The OMV releases the EOC to the MRMS and it is placed directly in its canister on the canister pallet, if the pallet is on the transverse truss (Figure 24). If the canister pallet is by the JEM pallet, the EOC is handed from the MRMS to the JEM RMS for placement in its canister.

6.4 Manipulator Places EOC and SCA in Canisters

Once the EOC is inside its canister on the canister pallet, a remotely operated locking mechanism engages to lock it in. Several options exist for safing the EOC. The EOC can dump all propellants through opposed thrusters while it is still some distance from the Station, attached to the OMV, it can wait until it is in the can and dump propellants which can then be appropriately vented, or it can be considered safe once the can lid closes, since it will be well sealed.

An electrical connection may be required with the EOC in the can, however, because it must be commanded to release the SCA. The EOC could also be designed to release the SCA via radio telemetry command. A mechanical release, actuated by the manipulator is another possibility.

In any event, once the EOC is locked into its canister, a manipulator, either the JEM RMS or MRMS with special end effector, will grasp the released SCA and place it in its canister (Figure 25). Once the SCA is removed, the EOC canister lid will be commanded to close and seal. The EOC will then be held in isolation until the biological status of the sample is known.

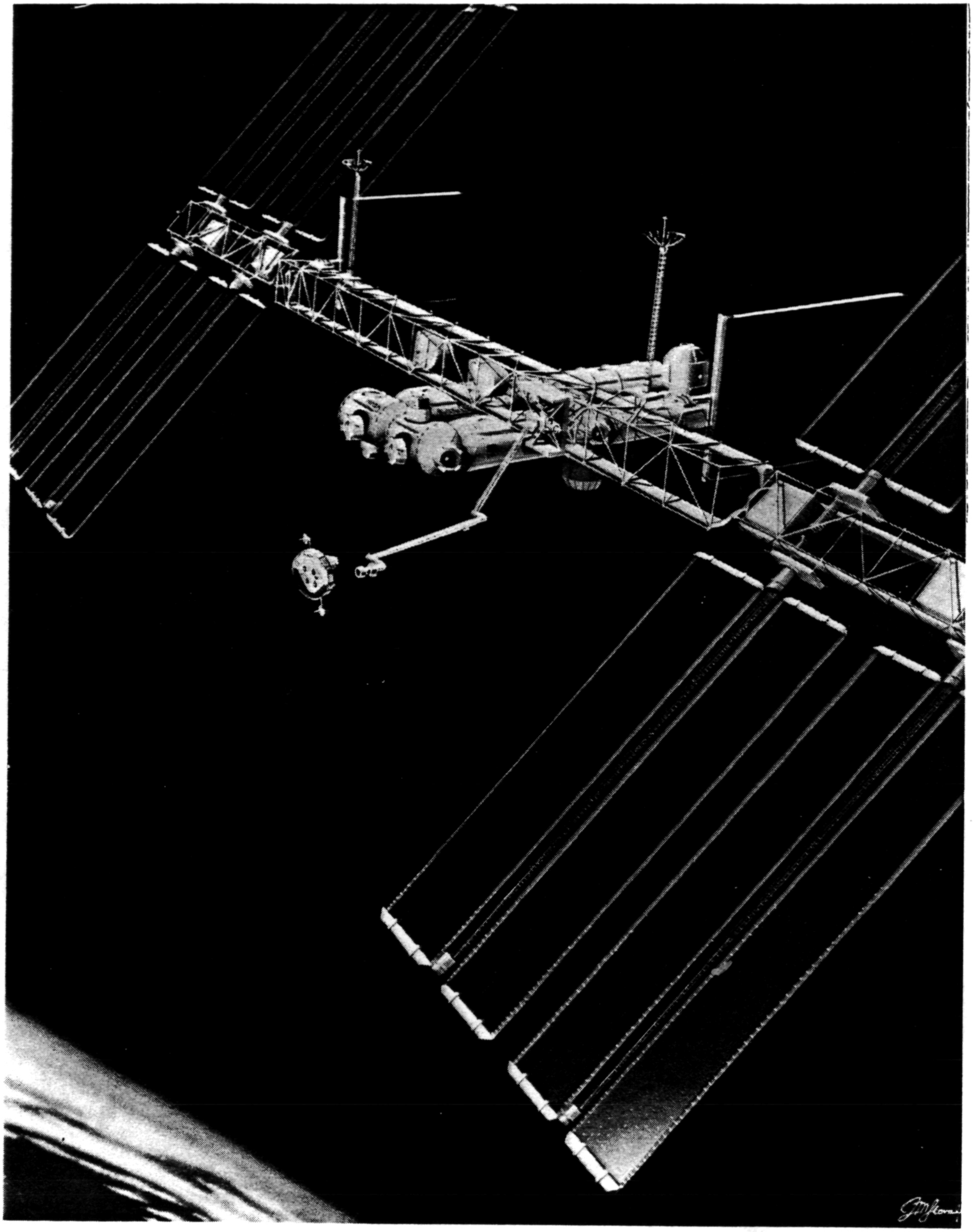


Figure 31, OMV with EOC Approaches Station (Courtesy Space Industries, Inc.)

When the SCA enters its canister, a mechanical locking mechanism will engage, locking it into place. An electrical connection will also make up, allowing measurement of temperature and pressure inside the SCA. The SCA canister lid will then close, sealing the SCA.

The SCA canister will then control the temperature of the SCA, via the movable sun shield, thermoelectric refrigeration devices embedded in the canister walls, or cooling loops in the canister walls, as required. At the moment, it is expected that relatively passive control, such as the movable sun shield, will be all that is required on-orbit. Detailed thermal analysis of the on-orbit, as well as the return to the Earth's surface sequence are needed however to properly define the thermal control equipment.

Once the SCA canister lid is closed, low pressure carbon dioxide will be introduced into the EOC and SCA canisters, while watching pressures inside the SC. This will allow verification of all seals. Redundant vent valves in series can release this pressure when the lids must be opened. Pressure monitoring will allow continuous seal verification. The SCA canister interior pressure will be kept at a pressure substantially below exterior ambient at all times, except when it is to be opened.

Once the seal check is complete, the SCA canister can be transported with safety and assurance of biological containment. The sample material will be doubled sealed behind one light-weight bio-barrier and one heavy steel barrier.

6.5 Transfer Direct to Earth versus Removal of Subsample versus Analysis On-Orbit

Three options exist once the SCA is secure in its canister:

1) The entire canister pallet or just the SCA canister can be returned to Earth without further sample manipulation at the Space Station.

2) The SCA canister can be taken into the Station, a subsample removed in a glove box and sent to Earth. The majority of the sample waits on-orbit.

3) Part of the sample can be analyzed on-orbit. An additional module is needed to provide a high level containment laboratory.

Returning the entire sample (option 1 above) reduces the impact on the Station to a minimum and eliminates the requirement for a zero-g glove box or dedicated laboratory, both of which will be expensive, especially the additional module. It is assumed some increased level of risk of back-contamination will occur if the entire sample is sent back rather than a subsample, but this assumption requires some analysis, beyond the scope of this study.

The questions to be answered are:

1) Is testing of a small subsample adequate?

2) Will opening the sample on-orbit in zero g and removing a subsample involve more risk than just bringing the whole sample directly down, but well contained.

3) Is the risk of a properly handled subsample (a test tube type volume of material) much different from the risk of returning four or five liters of material to Earth.

It is suspected that the risk due to removing a subsample and returning it to Earth is similar to the risk of bringing the entire SCA back, therefore return of the SCA without opening on-orbit is preferred. More study is required to quantify this risk however. The return sequence, and the hardware differences between bringing back a test tube and a large can must be determined in detail.

The focus of this study is on the interfaces with the Space Station of the various options. The external repackaging without entry into the Space Station is a subset of the more complex cases.

Removing a subsample is a much simpler operation than going into a complete analysis on-orbit. As the previous sections show, the hardware required need not be complex.

Analysis, in a biological sense, of the sample on-orbit is predicted to require the majority of a new module because of the space required for equipment. Techniques for zero-g biological analysis and containment must be developed and verified prior to sample arrival. This will be a long and expensive process. Gravity helps biological containment processing in a number of ways. In addition, it must still be shown that the risk of back-contamination is actually less when the sample is processed on-orbit.

6.6 Transfer of the SCA Canister into the Station and holding the Sample on-orbit

Given the decision to bring the sample into the Station there are four paths in:

1) Via EVA through one of the two airlocks
2) By manipulator transfer through the JEM Airlock
3) By manipulator transfer through an airlock/processing cabinet mounted on a Node Hatch
4) Through an airlock mounted on a new dedicated module.

The sample will be inside the SCA which is inside the heavy duty SCA canister on the canister pallet. The pallet will be located on the transverse truss or connected to the JEM pallet. Since the sample is now double sealed it can be safely handled EVA or by bare hand in the Modules.

The SCA canister could be easily removed by an EVA crewman. EVA removal might simplify the design of the pallet and canister, reducing the requirements for automated latch/unlatch of mechanical, electrical and fluid interfaces. On the other hand, an EVA would be required. The EVA option is inherently more flexible and therefore more reliable than the manipulator transfer and associated automatic releases, latches, and electrical and fluid connect/disconnects. Ground preparation and engineering would be reduced for EVA removal. The canister must be designed for EVA handling anyway as a backup to the manipulator transfer. The EVA training and simulation will therefore occur for both cases.

Manipulator transfer into the JEM airlock is the preferred option because the airlock is designed to be supported by the JEM RMS. Use of the JEM airlock will eliminate special manipulator procedures development. Transfer of the SCA from the EOC by the manipulator is considered desirable because it eliminates the possibility of contaminating an EMU. The alternative method of keeping redundant biological barriers between the crewman and the sample is by encasing the EMU in a biological oversuit.

All scenarios bringing the sample into the Space Station and keeping it in a processing cabinet imply a long term electrical power demand to operate the thermoelectric refrigeration system to keep the sample at -40°C. The alternative is to transfer the sample back out by repackaging in the SC/SCA and SCA Canister and replacing the SCA Canister back out on the truss of JEM Exposed Facility.

Use of the dedicated airlock set with integral glove box on a node hatch simplifies the process of transferring the sample since the SCA Canister does not need to move through the interior of the Space Station. The design proposed in Section 9 of this report can eliminate the need for the SCA Canister because SCA's from both EOC can be directly transferred by the Space Station RMS to airlocks equipped with active cooling. The design of the unit keeps two biological barriers between the crew and the possible contaminated exterior of the SC without putting it in another container outside the Station. On the other hand, in the event of a manipulator failure, a crewman in an oversuit would be required to make the transfer and keep two biological barriers intact. The Node hatch mounted facility includes a dedicated radiator to permit on-orbit storage for an indefinite period of time with minimum electrical power demands for the cooling. The airlocks are designed to be rugged enough to safely return both samples in the SCs to Earth by undocking the Node mounted facility and placing the entire unit in the Payload Bay.

The final alternative is to transfer the sample to a complete orbital processing facility. The unit proposed in Section 10 of this report includes a series of both refrigerated and room temperature glove boxes connected to space though an airlock identical to the JEM Airlock. The interior of the glove boxes provides comprehensive analytical facilities to characterize the biological properties of the Martian material and collect all data needed to certify the extent and nature of any biological hazard that the Martian material might pose. The Space Station RMS would transfer the SCA Canisters to the airlock and into the Space Station. The SCA canisters would then be moved within a series of linked refrigerated glove boxes for opening the SCA Canister, SCA and SC. Because the sample would be analyzed on-orbit it is not necessary to send small alloquates of unsterilized material to Earth. The dedicated facility would have a body mounted radiator to allow refrigeration of samples to -40°C temperatures with minimal demands on the Space Station electrical power system.

From a safety and mission success standpoint, the preferred option is use of the dedicated facility. The dedicated integral glove box airlock combination is the next best. The third ranked alternative is manipulator transfer through the JEM airlock, with an EVA backup.

6.7 Location of Rack Mounted Processing Facility (RMPF) Repackaging in the Station

Four options exist:

1) In a rack in the U.S. Lab Module
2) In a rack in the JEM.
3) In a containment area mounted on an airlock attached to a Node hatch.
4) In a containment area with attached airlock in a dedicated module.

Processing a sample in a refrigerated rack in either the U.S. Lab module or the JEM can be accommodated within the general framework of the Space Station's support to scientific experiments within the pressurized volume. The two issues with such an approach are the integrity of the biological isolation, and the assurance that the samples scientific value will not be compromised by on-orbit processing. The process of transferring the sample to the processing rack, opening the sample, and then passing samples back out into the pressurized volume for transfer to Earth is a straight forward variation on techniques used in 1-g facilities which handled lunar samples and biologically dangerous materials. However, performing them in the U.S. Lab or JEM means that the Space Station as a whole is the equivalent of the negatively pressurized rooms enclosing the glove boxes in such facilities. If the sample proves hazardous, it will remain contained in the glove box. The box as a sealed unit can be removed and transferred to Earth much as any other Orbital Replacement Unit.

The use of a cabinet attached to a Node hatch provides: a) improved physical isolation of the sample from the Space Station's pressurized volume over the Standard Rack approach, b) provides less power intensive solutions to maintaining the sample at -40°C by using an integral radiator, and c) allows the transfer to and from Space Station in the unpressurized Orbiter Payload Bay and movement of the cabinet by the RMS rather than the crew. It is assumed this will reduce biological risk. Negative aspects of the concept are the non-standard interface between the crew and the cabinet, and the use of one of the Node hatches which may be used by the Alternate Crew Return Capability (ACRC).

The use of a dedicated Mars Sample Processing Module can provide the best biological isolation of all alternatives for orbital processing because the glove boxes can be isolated by areas to don and doff biological isolation garments and perform decontamination protocols. The biggest advantage is that the entire sample can be held away from the Earth's biosphere until the Martian biota, if any, is characterized and any necessary precautions developed. The negative aspects of the approach are the significant expenses for design, development, testing, and evaluation of the facility and the launch and recovery costs. An additional cost will be a large fraction of Space Station crew time that will be required for the Mars sample biological testing.

In summary, the dedicated facility approach is preferred in a program where small but predictable improvement of biological isolation is deemed worth the cost. Effectively the same level of isolation can be obtained by careful procedural controls using the Node hatch mounted cabinet. However, the level of isolation will not be nearly as apparent to a skeptical public. The internal rack is the least expensive but also the least effective in biological isolation, because its use depends on proper procedures for applying and removing a secession of biological barriers and sterilization of contaminated surfaces. The true risk of biological contamination must be addressed for the entire mission to determine the least risk path. Addressing the Space Station options without looking at direct entry, Shuttle retrieval, and problems at Mars concerning sterile transfer, is inadequate.

6.8 Storage at the Space Station and Loading in the Shuttle

Once the sample has been repackaged in a interior glove box, Node Hatch glove box and airlock, or extensively analyzed in a dedicated module laboratory, it must be stored and then returned to Earth. Four options exist:

Option 1) The SCA canister is reloaded with the sample in the glove box and returned to the exterior, via the same method it came in. The SCA canister is placed on the canister pallet. The canister pallet, with the SCA canister and the EOC canister, is placed in the Shuttle bay and returned to Earth.

Option 2) The SCA canister is reloaded with the sample and stored in the glove box. When the Orbiter is ready to depart, the SCA canister is taken into the mid-deck and stored for the flight down.

Option 3) The SCA canister is reloaded with the sample and stored in the glove box. At the appropriate time, the SCA canister is taken into the ACRC and returned to Earth.

Option 4) The entire assembly holding the Mars Sample, whether glove box, Node hatch mounted unit, or dedicated Module is disconnected from the Space Station distributed systems. The unit is transferred to either a pressurized logistics module, in the case of the glove box or directly to the Payload bay in the case of the Node hatch mounted unit or dedicated analytical facility. The sample is carried to Earth in the payload Bay.

Option 1), return to the pallet for storage may ease the power and cooling requirements the Station must provide to keep the glove box cold. If the sample canister maintains the proper temperature on the pallet with only passive thermal control this will definitely be true. On the other hand, this option involves a manipulator transfer, or EVA to get the canister back on the pallet and hooked up mechanically, electrically, and to the CO_2 line. The requirement to reconnect all this adds to the complexity of the canister pallet, and makes some failure modes more probable. The canister pallet will have to be returned or deorbited at some point however. In the event some form of life is found, additional risk may be incurred by taking the sample out of the glove box, so storage in the box may be desired.

Option 2), storage in the glove box and mid-deck return, has the least risk from a mission success viewpoint. The sample must be thermally controlled in the mid-deck. Preliminary calculations indicate insulation and a little liquid nitrogen could accomplish this without boiling off too much nitrogen. A lot of insulation and a powered refrigeration system is another option. The sample must also be thermally controlled in the payload bay. The cooling power requirement may be less in the payload bay, at least during the on-orbit phase of the flight back. A bigger volume, capable of more insulation, is available in the payload bay. Venting requirements are not as stringent in the payload bay. Larger quantities of freon type refrigerants or liquid nitrogen could be used.

The requirement to survive any possible Shuttle accident without breaching the biological barriers might be laid on the sample. This requirement might well exist, if life is found, whatever its nature. The requirement might also exist if the sample is returned without analysis or subsampling at the Space Station. In the event subsampling or extensive on-orbit analysis indicates no life, the requirement might be waived. It is not clear if this requirement can be met or what is needed to meet it. The worst case accident might be a break-up, explosion, or fire at altitude, followed by a long fall and impact on a hard surface. A great deal of steel, surrounded by crushable material and insulation would be needed to protect the sample. More volume for crushable material and insulation can be provided in the payload bay, but the pressure vessel may also be good protection.

Option 3) would only seem reasonable in the event Martian life was to be brought to the surface without risking contamination of the Orbiter. If this is a real concern, there will be a large group of people opposed to bringing the sample down at all. On the other hand, a ACRC might land more reliably than the Orbiter, if it is modeled along the lines of earlier, simpler spacecraft.

Option 4) is most desirable in the case of the Node hatch mounted unit which is readily made strong enough to contain the sample in the event of an accident to the Orbiter, although it may not be easy to maintain the integrity of the contaminated volume inside the glove box. Transfer inside a glove box is far from optimal because movement of the large cabinet to the pressurized Logistics Module adds numerous opportunities to breach the biological barriers around the sample. The glove box also would require separate cooling facilities to maintain the sample at the required temperature. The dedicated module can be made strong enough to maintain biological isolation in the event of an Orbiter accident. However, the module might be better used to conduct biological investigations at the Space Station after decontamination and clean up of any Martian material.

6.9 Sequences for Design Reference Missions

The following brief sequences describe the various design reference missions. The sequences are highly redundant, so some are described in terms of differences with others. In addition to the options discussed direct entry, and shuttle retrieval without the station are good possibilities but were beyond the scope of this study.

6.9.1 Repackaging the Sample without bringing it into the Station (DRM1A and DRM1B)

Two types of locations can be used for external repackaging, the two current, defined payload attachment fittings on the transverse truss or the JEM pallet. These design reference missions require the political decision to be made that the entire Mars sample may be brought to Earth prior to analysis.

The basic requirement is that the SCA be repackaged in a container that provides biological containment, thermal control, crash protection, and ease of handling for the trip down.

6.9.1.1 DRM 1A, the scenario for repackaging the sample on the Transverse Truss Payload Fitting without bringing it into the Station is as follows:

1) Orbiter arrives with two canister pallets and OMV/extra propulsion module/cradle
2) MRMS places two canister pallets and OMV/module/cradle on the two currents defined transverse truss payload fittings and a third as yet undefined fitting.
3) Power/data connections and mechanical latches are engaged, preferably remotely, with EVA backup
4) Orbiter departs
5) OMV departs for first EOC retrieval
6) OMV returns with EOC
7) MRMS grapples OMV/EOC and places OMV in docking cradle
8) MRMS takes EOC from OMV and places it in EOC canister
9) EOC canister locks EOC in
10) MRMS picks up special end effector and grabs SCA
11) EOC commanded to release SCA to MRMS/end effector
12) EOC canister lid shuts
13) RMS removes SCA from EOC

14) MRMS/end effector places SCA in SCA canister
15) SCA canister locks SCA in and makes electrical connection
16) SCA canister lid commanded shut and sealed
17) CO_2 Pressure delivered to SCA and EOC canisters to check seals
18) MRMS/end effector changes out propulsion module on OMV
19) OMV departs
20) Repeat 6) through 16) for second EOC
21) Orbiter arrives
22) MRMS places OMV/module/cradle in payload bay
23) MRMS places one canister pallet in payload bay
24) Orbiter departs
25) Orbiter arrives
26) MRMS places second canister pallet in payload bay
27) Orbiter departs

6.9.1.2 DRM 1B repackaging the sample near the JEM pallet without bringing it into the Station

1) Orbiter arrives with two canister pallets and OMV/extra propulsion module/cradle
2) MRMS places OMV/module/cradle on one Transverse Truss Payload Fitting
3) MRMS takes each canister pallet out of the bay and hands them to the JEM RMS
4) JEM RMS places each canister pallet in turn by the JEM pallet
5) Power/data connections and mechanical latches are engaged, preferably remotely, with EVA backup
6) Orbiter departs
7) OMV departs for first EOC retrieval
8) OMV returns with EOC
9) MRMS grapples OMV/EOC and places OMV in docking cradle
10) MRMS takes EOC from OMV and hands it to JEM manipulator
11) JEM manipulator places EOC in EOC canister
12) EOC canister locks EOC in
13) JEM manipulator grabs SCA
14) EOC commanded to release SCA to JEM manipulator
15) MRMS removes SCA from EOC
16) EOC canister lid shuts
17) JEM manipulator places SCA in SCA canister
18) SCA canister locks SCA in and makes electrical connection
19) SCA canister lid commanded shut and sealed
20) CO_2 Pressure delivered to SCA and EOC canisters to check seals
21) MRMS/end effector changes out OMV propulsion module
22) OMV departs for second EOC
23) Repeat 8) through 19) for second EOC and second canister pallet
24) Orbiter arrives
25) MRMS places OMV/module/cradle in payload bay
26) JEM manipulator hands one canister pallet to MRMS
27) MRMS places one canister pallet in payload bay
28) Orbiter departs
29) Orbiter arrives
30) JEM manipulator hands second canister pallet to MRMS
31) MRMS places second canister pallet in payload bay
32) Orbiter departs

6.9.2 DRM 2A, astronaut EVA removal of repackaged sample from truss and IVA transfer into the U.S. Lab module via one of the two large airlocks for subsample preparation.

The SCA canister is brought in the Station by an astronaut via either the Airlock or Hyperbaric Airlock. It is assumed for purposes of this study that the subsample preparation will be done in a dedicated refrigerated glove box operating with a derivative of current sample handling procedures used for lunar samples and Antarctic meteorites, and biological containment procedures derivative of the old Lunar Receiving Lab (LRL). A candidate design is proposed for the processing facility to establish its weight and interfaces for the purposes of trade studies.

1) Orbiter arrives with two canister pallets and OMV/extra propulsion module/cradle
2) MRMS places two canister pallets and OMV/module/cradle on three Transverse Truss Payload Fittings
3) Power/data connections and mechanical latches are engaged, preferably remotely, with EVA backup
4) Orbiter departs
5) OMV departs for first EOC retrieval
6) OMV returns with EOC
7) MRMS grapples OMV/EOC and places OMV in docking cradle
8) MRMS takes EOC from OMV and places it in EOC canister
9) EOC canister locks EOC in
10) MRMS picks up special end effector and grabs SCA
11) EOC commanded to release SCA to MRMS/end effector
12) MRMS removes SCA from EOC
13) EOC canister lid shuts
14) MRMS/end effector places SCA in SCA canister
15) SCA canister locks SCA in and makes electrical connection
16) SCA canister lid commanded shut and sealed
17) CO_2 Pressure delivered to SCA and EOC canisters to check seals
18) EVA astronaut comes out of Airlock and rides MRMS to canister pallet. Second astronaut waits at Airlock
19) EVA astronaut clips a line on to the SCA canister
20) Canister pallet commanded to release SCA canister
21) EVA astronaut takes SCA canister by handle and rides MRMS to Airlock
22) EVA astronaut enters Airlock and pressurizes
23) Suited astronauts enter the donning doffing area
24) A waiting IVA astronaut takes possession of the SCA canister
25) The IVA astronaut takes the SCA canister to the Processing Cabinet
26) With the aid of a second IVA astronaut, the SCA canister is placed in the processing cabinet pass-through airlock
27) The gas in the pass though airlock is purged with CO_2
28) The inner hatch of the pass through is opened and the SCA is transferred into the processing cabinet which has been chilled and filled with CO_2
29) The SCA and SCA canister is stripped off and placed in its chilled holding container
30) The SC is mounted in a refrigerated jacket connected with quick disconnects to the processing cabinet refrigeration system
31) The SC is opened

32) A tube is removed, the SC is resealed and the tube is mounted in the sample tube opener-extruder
33) The ends of the tube are removed
34) A subsample is extruded into a subsample transfer vial
35) The preceding steps are repeated until a satisfactory subsample is processed
36) The vials are loaded into an insulated and actively cooled transfer container.
37) An Orbiter is ready to depart the Station
38) The subsample transfer container is disconnected from the active cooling system

(Note: although the loading of the samples may be nominally a sterile process, the fact that the transfer is sterile can not be proved thus samples will be sterilized before transfer)

39) The subsample transfer container is placed in the pass-through airlock.
40) The heat sterilization cycle is run
41) The subsample transfer container is removed from the sterilizer and reconnected to an active cooling system
42) The subsample and associated cooling system are transferred to the waiting shuttle and are carried in the Mid-deck.
43) The Orbiter departs
44) MRMS changes out propulsion modules in OMV
45) OMV departs for second EOC
46) OMV returns with second EOC
47) MRMS grapples OMV/EOC and places OMV in docking cradle
48) MRMS takes EOC from OMV and places it in EOC canister
49) EOC canister locks EOC in
50) MRMS picks up special end effector and grabs SCA
51) EOC commanded to release SCA to MRMS/end effector
52) EOC canister lid shuts
53) MRMS/end effector places SCA in SCA canister
54) SCA canister locks SCA in and makes electrical connection
55) SCA canister lid commanded shut and sealed
56) CO_2 Pressure delivered to SCA and EOC canisters to check seals

Earth analysis concludes subsamples contain no dangerous organisms

57) Orbiter arrives
58) MRMS places OMV/module/cradle in payload bay
59) SC is replaced in SCA. SCA is placed is SCA canister
60) SCA canister is removed from glove box and transferred to Orbiter mid-deck
61) Orbiter departs
62) Orbiter arrives
64) MRMS places second canister pallet with unopened second sample in payload bay
65) MRMS places first canister pallet in payload bay
66) Orbiter departs

Earth analysis concludes subsamples contain dangerous organisms

67) SC is replaced in SCA. SCA is placed in SCA canister.
68) SCA canister is sealed and maintained in glove box indefinitely
or
69) SCA canister, is transferred into the cabinet pass-through airlock and the outside is heat sterilized
70) SCA is transferred to the canister pallet on the truss and held there until a satisfactory procedure is developed to transfer the sample to Earth.

6.9.3 Astronaut EVA removal of repackaged sample from truss, entry into the Space Station from a large airlock and IVA transfer into the JEM module for subsample preparation

This design reference mission is identical to the previous design reference mission, differing only in the location of the processing facility. The same double standard rack processing facility can be placed in the JEM as can be placed in the U.S. Lab Module. The sequence of operations is identical to those that would take place in the U.S. Lab Module,

6.9.4 DRM 2C, manipulator removal of repackaged sample from JEM pallet into JEM via JEM airlock for subsample preparation

This design reference mission is a derivative of the previous design reference mission with the key difference being the path into the Space Station. A review of the current baseline for the U.S. and Japanese Modules indicates that the JEM Airlock seems completely adequate in terms of size, pressurization, depressurization rates, and position of the Space Station to support the sample transfer. The airlock is designed to be supported on the space side by the JEM RMS.

In the baseline JEM design there is an antenna mounting on the outboard, or port side which may interfere with mounting the pallet. The JEM growth options include the exposed mast, an attachment point for satellites and the Flight Telerobotic Servicer. The mast as depicted has two degrees of freedom of motion, that is it simply pivots around a non-rotating wrist joint. The current design of this mast appears to be inconsistent with the placement of the stinger between the JEM and the Columbus module.

1) Orbiter arrives with two canister pallets and the OMV/extra propulsion module/cradle
2) MRMS places OMV/module/cradle on one Transverse Truss Payload Fitting
3) MRMS takes each canister pallet out of the bay and hands them to the JEM manipulator
4) JEM manipulator places each canister pallet in turn by the JEM pallet
5) Power/data connections and mechanical latches are engaged, preferably remotely, with EVA backup
6) Orbiter departs
7) OMV departs for first EOC retrieval
8) OMV returns with EOC
9) MRMS grapples OMV/EOC and places OMV in docking cradle
10) MRMS takes EOC from OMV and hands it to JEM manipulator
11) JEM manipulator places EOC in EOC canister
12) EOC canister locks EOC in

13) JEM manipulator grabs SCA
14) EOC commanded to release SCA to JEM manipulator
15) MRMS remove, SCA from EOC
16) EOC canister lid shuts
17) JEM manipulator places SCA in SCA canister
18) SCA canister locks SCA in and makes electrical connection
19) SCA canister lid commanded shut and sealed
20) CO_2 Pressure delivered to SCA and EOC canisters to check seals
21) JEM manipulator grabs SCA canister
22) Canister pallet commanded to release SCA canister
23) JEM manipulator places SCA canister on JEM airlock table
24) Airlock table makes mechanical connection with SCA canister
25) The airlock table is retracted, the hatch is closed, and the airlock repressurized by an astronaut at the JEM control station
26) A waiting IVA astronaut takes possession of the SCA canister
27) The IVA astronaut takes the SCA canister to the processing cabinet
28) With the aide of a second IVA astronaut, the SCA canister is placed in the processing cabinet pass-through airlock
29) The gas in the pass though airlock is purged with CO_2
30) The inner hatch of the pass through is opened and the SCA is transferred into the processing cabinet which has been chilled and filled with CO_2
31) The SCA and SCA canister is stripped off and placed in its chilled holding container
32) The SC is mounted in a refrigerated jacket connected with quick disconnects to the processing cabinet refrigeration system

(Note: at this point in time the samples thermal condition is stabilized)

33) The SC is opened
34) A tube is removed, the SC is resealed and the tube is mounted in the sample tube opener-extruder
35) The ends of the tube are removed
36) A subsample is extruded into a subsample transfer vial
37) The preceding steps are repeated until a satisfactory subsample is processed
38) The vials are loaded into an insulated and actively cooled transfer container.
The subsample is now ready and waits for an opportunity to transfer the sample to Earth in the Shuttle. Once a Shuttle is ready to return to Earth the following takes place.
39) The subsample transfer container is disconnected from the active cooling system

(Note: although the loading of the samples may be nominally a sterile process, the fact that the transfer is sterile can not be proved thus samples will be sterilized before transfer)

40) The subsample transfer container is placed in the pass-through airlock
41) The heat sterilization cycle is run
42) The subsample transfer container is removed from the sterilizer and reconnected to an active cooling system
43) The subsample and associated cooling system are transferred to the waiting Orbiter and are carried in the mid-deck.
44) The Orbiter departs

45) MRMS changes out the propulsion module in the OMV
46) The OMV departs for the second EOC
47) OMV returns with second EOC
48) MRMS grapples OMV/EOC and places OMV in docking cradle
49) MRMS takes EOC from OMV and hands it to JEM manipulator
50) JEM manipulator places EOC in EOC canister
51) EOC canister locks EOC in
52) JEM manipulator grabs SCA
53) EOC commanded to release SCA to JEM manipulator
54) EOC canister lid shuts
55) JEM manipulator places SCA in SCA canister
56) SCA canister locks SCA in and makes electrical connection
57) SCA canister lid commanded shut and sealed
58) CO_2 Pressure delivered to SCA and EOC canisters to check seals

Earth analysis concludes subsamples contain no dangerous organisms

59) Orbiter arrives
60) MRMS places OMV/module/cradle in payload bay
61) SC is replaced in SCA. SCA is placed is SCA canister
62) SCA canister is removed from glove box and transferred to Orbiter mid-deck
63) Orbiter departs
64) Orbiter arrives
65) JEM manipulator hands first and second canister pallets to MRMS
66) MRMS places first and second canister pallets with unopened second sample in payload bay
67) Orbiter departs

Earth analysis concludes subsamples contain dangerous organisms

68) SC is replaced in SCA. SCA is placed in SCA canister.
69) SCA canister is sealed and maintained in glove box indefinitely

or

70) SCA canister, is transferred into the cabinet pass-through airlock and the outside is heat sterilized
71) SCA is transferred to the canister pallet on the truss and held there until a satisfactory procedure is developed to transfer the sample to Earth.

6.9.5 DRM 2D manipulator removal of repackaged sample from JEM pallet into U.S. Lab module via JEM airlock

This design reference mission is identical to the previous one except for the fact that the processing double standard rack is located in the JEM instead of the Lab Module. The sequence of steps is identical to that for previous mission.

6.9.6 DRM 2E manipulator repackaging on truss and Manipulator transfer to a hatch processing facility for subsample preparation

1) Orbiter arrives with the hatch processing facility and the OMV/extra propulsion module/cradle
2) MRMS places OMV/module/cradle on one transverse truss payload fitting

3) MRMS takes the hatch processing facility out of the bay on mounts it on a node, IVA crewman makes up connections
4) Power/data connections and mechanical latches are engaged, preferably remotely, with EVA backup

At this point the Space Station is ready to receive a sample.

1) Orbiter arrives with two canister pallets
2) MRMS places two canister pallets on two transverse truss payload fittings
3) Power/data connections and mechanical latches are engaged, preferably remotely, with EVA backup
4) Orbiter departs
5) OMV departs for first EOC retrieval
6) OMV returns with EOC
7) MRMS grapples OMV/EOC and places OMV in docking cradle
8) MRMS takes EOC from OMV and places it in EOC canister
9) EOC canister locks EOC in
10) MRMS picks up special end effector and grabs SCA
11) EOC commanded to release SCA to MRMS/end effector
12) MRMS removes SCA from EOC
13) EOC canister lid shuts
14) MRMS/end effector places SCA in SCA canister
15) SCA canister locks SCA in and makes electrical connection
16) SCA canister lid commanded shut and sealed
17) CO_2 Pressure delivered to SCA and EOC canisters to check seals
18) EVA astronaut comes out of airlock and rides MRMS to canister pallet. Second astronaut waits at airlock
19) EVA astronaut clips on to SCA canister
20) Canister pallet commanded to release SCA canister
21) EVA astronaut takes SCA canister by handle and rides MRMS to dedicated hatch processing facility
22) Astronaut clips SCA canister to extended airlock table at hatch processing facility and makes mechanical connection between SCA canister and table
23) The table retracts with the SCA canister and the outer door closes
24) The hatch is closed and the airlock repressurized by an astronaut at a control station

(Note: the passive cooling system is capable of keeping the sample at a temperature of less than -40°C in the airlock thus the remaining steps may occur when the IVA schedule permits)

25) An astronaut working though the processing cabinet gloves opens the airlock and detaches the SCA tether and removes the SCA from the airlock. The processing cabinet has been chilled and filled with CO_2.
26) The SCA is stripped off and placed in its chilled holding container
27) The SC is mounted in a refrigerated jacket connected with quick dis-connects to the processing cabinet refrigeration system.

(Note: at this point in time the samples thermal condition is stabilized)

28) The SC is opened
29) A tube is removed, the SC is resealed and the tube is mounted in the sample tube opener-extruder
30) The ends of the tube are removed
31) A sample is extruded into a subsample transfer vial
32) The preceding steps are repeated until a satisfactory subsample is processed
33) The vials are loaded into a insulated and actively cooled transfer container
34) The Orbiter is ready to depart the Station
35) The subsample transfer container is disconnected from the active cooling system

(Note: although the loading of the samples may be nominally a sterile process, the fact that the transfer is sterile can not be proved thus samples will be sterilized before transfer)

36) The subsample transfer container is placed in the pass through airlock.
37) The heat sterilization cycle is run
38) The subsample transfer container is removed from the sterilizer and reconnected to an active cooling system
39) The subsample and associated cooling system are transferred to the waiting shuttle and are carried in the mid-deck.
40) The Orbiter departs
41) MRMS changes out propulsion modules in OMV
42) OMV departs for second EOC
43) OMV returns with second EOC
44) MRMS grapples OMV/EOC and places OMV in docking cradle
45) MRMS takes EOC from OMV and places it in EOC canister
46) EOC canister locks EOC in
47) MRMS picks up special end effector and grabs SCA
48) EOC commanded to release SCA to MRMS/end effector
49) EOC canister lid shuts
50) MRMS/end effector places SCA in SCA canister
51) SCA canister locks SCA in and makes electrical connection
52) SCA canister lid commanded shut and sealed
53) CO_2 Pressure delivered to SCA and EOC canisters to check seals

Earth analysis concludes subsamples contain no dangerous organisms

54) Orbiter arrives
55) MRMS places OMV/module/cradle in payload bay
56) SC is replaced in SCA. SCA is placed is SCA canister
57) SCA canister is removed from glove box and transferred to Orbiter mid-deck
58) Orbiter departs
59) Orbiter arrives
60) MRMS places second canister pallet with unopened second sample in payload bay
61) MRMS places first canister pallet in payload bay
62) Orbiter departs

Earth analysis concludes subsamples contain dangerous organisms

63) SC is replaced in SCA. SCA is placed in SCA canister.
64) SCA canister is sealed and maintained in glove box until a sterilization procedure is proven
65) SCA canister on truss is kept on the canister pallet until a sterilization procedure is proven

6.9.7 DRM 3 Manipulator transfer to a dedicated Module for comprehensive biological testing

This design reference mission is far and away the most expensive since it requires the addition of a major laboratory module to the Space Station.

1) Orbiter arrives with two canister pallets and two OMVs
2) MRMS places two canister pallets and OMVs/cradle on three transverse truss payload fittings
3) Power/data connections and mechanical latches are engaged, preferably remotely, with EVA backup
4) Orbiter departs
5) OMV departs for first EOC retrieval
6) OMV returns with EOC
7) MRMS grapples OMV/EOC and places OMV in docking cradle
8) MRMS takes EOC from OMV and places it in EOC canister
9) EOC canister locks EOC in
10) MRMS picks up special end effector
11) EOC commanded to release SCA to MRMS/end effector
12) MRMS removes SCA from EOC
13) EOC canister lid shuts
14) MRMS/end effector places SCA in SCA canister
15) SCA canister locks SCA in and makes electrical connection
16) SCA canister lid commanded shut and sealed
17) CO_2 Pressure delivered to SCA and EOC canisters to check seals
18) EVA astronaut comes out of the airlock translates to the MRMS and rides MRMS to canister pallet. Second astronaut waits at airlock
19) EVA astronaut clips line on to the SCA canister
20) Canister pallet commanded to release SCA canister
21) EVA astronaut takes SCA canister by handle and rides MRMS to dedicated hatch processing facility
22) Astronaut clips SCA canister to the extended table on Processing Facility Airlock and makes mechanical connection between SCA canister and table
23) The table is retracted and outer door closes
24) The airlock is repressurized by an astronaut at a control station

(Note that the passive cooling system is capable of keeping the sample at a temperature of less than -40°C in the airlock thus the remaining steps may occur when the IVA schedule permits)

25) An astronaut working though the gloved end processing cabinet gloves opens the airlock and detaches the SCA tether and removes the SCA from the airlock. The processing cabinet which has been chilled and filled with CO_2.

26) The sample is transferred to one of the refrigerated cabinets on either side of the facility.
27) The SCA is stripped off and placed in its chilled holding container
28) The SC is mounted in a refrigerated jacket connected with quick disconnects to the processing cabinet refrigeration system. The SC and attached hoses are replaced in the airlock.

(Note: at this point in time the samples thermal condition is stabilized)

29) The SC is opened
30) A tube is removed, the SC is resealed and the tube is mounted in the sample tube opener-extruder
31) The ends of the tube are removed
32) The biological analysis protocol is run. Many steps and much time will be involved in this protocol. See DeVincenzi and Bagby, 1981 for an example.

Analysis concludes subsamples contain no dangerous organisms

33) Orbiter arrives
34) MRMS places OMV in payload bay
35) SC is replaced in SCA. SCA is placed in SCA canister
36) SCA canister is removed from glove box and transferred to Orbiter mid-deck
37) Orbiter departs
38) Orbiter arrives
39) JEM manipulator hands second canister pallet to MRMS
40) MRMS places second canister pallet with unopened second sample in payload bay
41) Orbiter departs

Analysis concludes subsamples contain dangerous organisms

42) SC is replaced in SCA. SCA is placed in SCA canister.
43) SCA canister is sealed and maintained in glove box indefinitely

or

44) SCA canister, is transferred into the cabinet pass-through airlock and the outside is heat sterilized
45) SCA is transferred to the canister pallet on the truss and held there until a satisfactory procedure is developed to transfer the sample to Earth.

7.0 Canister Pallet Definition

The canister pallet (Figure 32 and 33) will probably be required in all the previously discussed scenarios. The pallet carries two canisters in which the EOC and SCA will be placed and sealed. The scenarios range from bringing it back without analysis or subsampling on-orbit to a complete biological analysis on-orbit. The conceptual design in the following is slanted more towards the return without on-orbit analysis case, but this is a back-up situation for all the more complicated cases.

The location of the pallet by the JEM pallet or on the attachment points on the transverse boom will result in differences in where the power/data umbilical is hooked up, and the latching mechanism.

7.1 Requirements

The following guidelines were used to conceptually design the canister pallet and the SCA and EOC canisters.

1) The SCA must be kept below -40° Celsius from the time it is handed off from the OMV until it is in a laboratory on Earth. While passive cooling may be adequate on-orbit, active cooling will probably be required while the sample is in the payload bay or the mid-deck. The SCA itself cannot easily afford the mass penalty of thermo-electric units, a small compressor unit, or cooling loops for liquid nitrogen.

2) The SCA must be sealed in a new container upon arrival at the Space Station to back up the primary biological seal prepared at Mars. This new seal must be verifiable at all times.

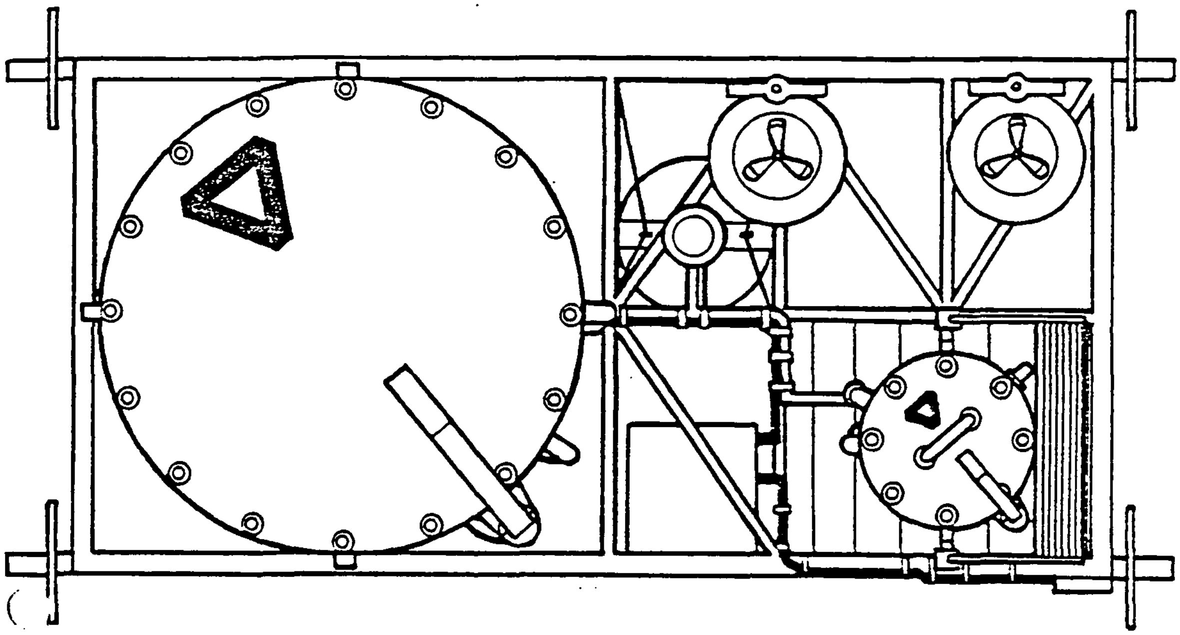
3) The EOC must also be sealed in a biobarrier upon arrival at the Space Station in the event of a failure in the sterile transfer process at Mars.

4) Resealing of the EOC and SCA without EVA is preferred. EVA can serve as a backup.

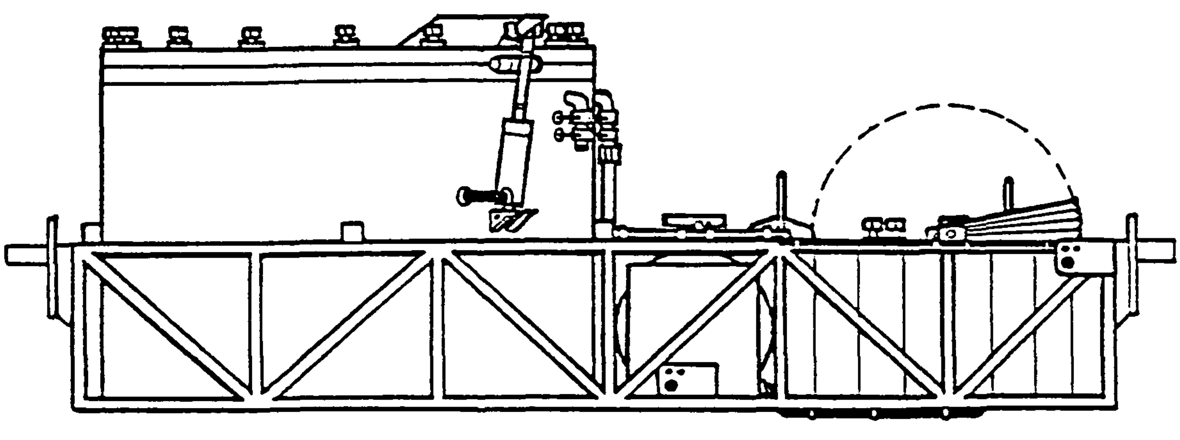
5) Two independent biological barriers must be kept between humans and the sample at all times.

6) The SCA canister must be capable of heat sterilization on the exterior to 200°C for 10 minutes without sample temperatures rising above -10°C. These are assumed numbers but should be in the right range. Heat sterilization must not destroy or degrade SCA canister instrumentation, seals, thermal control systems, etc.

7) In the event of an entry or landing accident in the Orbiter the SCA canister must not be breached. The SCA canister must survive an impact and a temperature/time specification without breach of the biological containment. Work is needed to determine this specification.



Top View



Side View
Figure 32, Canister Pallet Top and Side Views

Figure 33, Cannister pallet subsystems

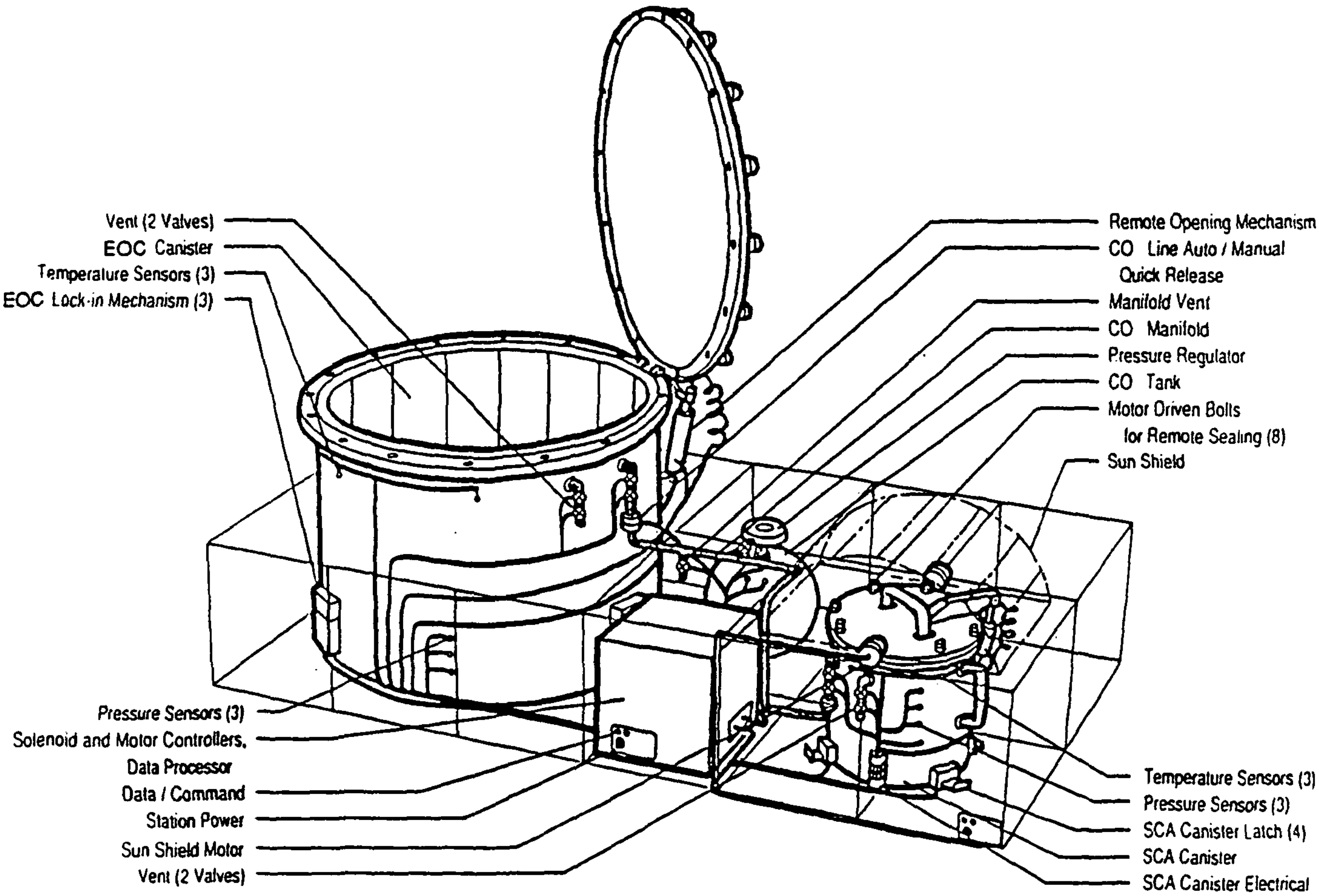


Figure 33, Cannister pallet subsystems

7.2 Conceptual Design of the Canister Pallet

Figures 32 and 33 show a conceptual design of the canister pallet. The design consists of two canisters with automatic closing and sealing mechanisms mounted on a small shuttle pallet. The mechanisms are all assumed to be electrically driven.

In addition to the two canisters, a pressure vessel containing a small quantity of carbon dioxide is included on the pallet. Once the canisters are closed, valves will be opened to allow low pressure CO_2 in the canisters. The pressure inside the SC is nominally 10 millibars (0.145 psi) CO_2 and trace gases acquired on the Martian surface. The pressure in the canister holding the SCA will be in the range of 50 to 100 millibars (1 or 2 psi), enough to check the seals of the canister to the exterior and of the SCA. Once the gas has entered the chamber, the pressure time history, both inside the SCA, and in the canister that contains it will be recorded to check the seals.

Since the SCA may be subjected to higher pressures later, when the exterior seal is broken, the pressure in the canister may be run up if desired to see if the interior seal will hold.

The valves are nominally remotely controlled solenoids, but may be manually operated. Valves into the SCA canister and EOC canister are redundant, normally closed.

A small computer solenoid controller analog to digital converter is shown on the pallet. To reduce the number of wires and to allow less costly ground checkout and test, the power controllers, analog to digital converters, and a small computer are all assumed to be mounted on the pallet. This allows all the hardware and software for the pallet to be integrated and tested on Earth. The electrical interface with the Space Station will therefore be a single data bus and a power connection. The Space Station software will only be required to display data, transmit it to Earth, and send manually executed commands. All other software will be on the pallet. The small processor will monitor and alarm all parameters of interest and will automatically command any active temperature control that is required, such as moving the sun shade.

Electrical mechanisms shown in the sketch include:

1) Opening and closing mechanism for the EOC canister lid and the SCA canister lid - envisioned to be a motor driven rod arrangement.

2) Sealing mechanisms - envisioned as a series of motor driven bolts, capable of being torqued down with a wrench if necessary.

3) EOC latching mechanism - three required to latch the EOC into the EOC canister.

4) SCA latching mechanism - one needed to latch the SCA into the SCA canister

5) SCA canister latching mechanism - two to four needed to latch the SCA canister onto the canister pallet

6) SCA canister dual redundant vent valves - capable of venting the canister when it must be opened. In the event of a bad seal, the canister would be vented, opened, and reclosed.

7) EOC canister dual redundant vent valves - same as above

8) SCA canister dual redundant CO_2 feed valves - allow CO_2 from the manifold into the canister.

9) EOC canister dual redundant CO_2 feed valves - same as above

10) SCA canister CO_2 line hook-up, automatic/manual quick release

11) EOC canister CO_2 line hook-up, automatic/manual quick release

12) SCA canister electrical hook-up, exterior - automatically makes and breaks a multi-pin connector that connects all SCA canister instrumentation and mechanisms to the pallet. Must be automatic make if SCA canister is to be returned to the pallet without EVA.

13) CO_2 manifold vent solenoid

14) CO_2 manifold feed solenoid

15) CO_2 pressure regulator control

16) Sun shade motor - or other more complicated thermal control as required.

17) SCA canister interior electrical connection with the SCA - must make automatically if the SCA is to be placed in the SCA canister without EVA.

The following instrumentation is shown in the sketch:

1) SCA canister triple redundant pressure sensors

2) SCA canister triple redundant temperature sensors

3) SC temperature sensors

4) SC pressure sensors

5) EOC canister triple redundant pressure sensors

6) EOC canister triple redundant temperature sensors

7) CO_2 tank pressure sensor

8) CO_2 tank temperature sensor

9) CO_2 manifold pressure sensor

10) Mechanism position feedbacks as required for the list above

7.3 Thermal Analysis

A true thermal analysis of the sample resting on the truss is beyond the scope of this effort. The thermal characteristics of the SC, SCA, and sample canister must all be known, as well as the precise location, calender dates, etc., in general, a level of detail not available. In addition to the analysis on the truss, the design must also consider the problems of returning to Earth either in the payload bay or in the mid-deck. The SCA canister, etc. must be designed to maintain temperature in this environment. All this requires a level of detail not yet determined in the program. Some estimates of cooling requirements may be made however, based on comparison with true analysis on other devices, and from rough calculations.

The sample must remain at temperatures below -40°C. To avoid warming of the sample, heat loads on the sample container need to be minimized.

The principal thermal loads on the sample container are incident radiation from the sun, Earth albedo, which is a fraction of the solar radiation in the same spectral band as the solar radiation, and heat rejection into the deep space.

To determine the transient thermal response of the sample in the container, a detailed thermal analysis needs to performed. It is possible that a sufficient fraction of the container surface area is away from the sun and facing the deep space, so that the net thermal effect is little change in sample temperature. This passive temperature control can be further enhanced with the appropriate surface coating of the container exterior walls. Low solar absorbance (α) and high infrared emittance (ϵ) coatings will ensure that the equilibrium temperature on the sunlit surfaces is low and even lower on the surfaces facing the deep space. The α/ϵ ratio is the measure of the radiation equilibrium temperature of an adiabatic surface in vacuum. Lower ratios give lower temperatures. Surface coatings with various α/ϵ ratios are widely available in the aerospace industry.

The interior of the container can be lined with a high thermal conductivity metal, such as aluminum, to facilitate the equalization of the temperatures in the interior. Possibly, thermal insulation can be provided at the container walls to slow the temperature response.

Analysis of Space Station truss members suggests that the average temperature on the truss is <-40° Celsius. The temperature can rise to above freezing during certain times of the year when the precession of the Space Station-orbit and the Earth's relation to the Sun result in an orbit which sees the Sun for long periods.

In case the thermal analysis of the box indicates that the passive thermal control is not sufficient to keep the sample at -40°C, active or semi-active devices might have to be considered.

One such device could be a moveable sun shade, which can be positioned by a stepping motor to block direct sunlight. The stepping motor can be controlled with a solar sensor. The distance of the shade should be large enough, so that the radiation view factors of most of the container surfaces toward the deep space can be maximized.

Another temperature control device would be an insulation blanket, consisting of a few layers of reflective shields which could be used as a thermal cover on those surfaces of the container which are exposed to solar and albedo radiation to impede heat flow.

7.4 Flight Support Equipment and Transfer to Earth

The canister pallet is estimated to be similar to a truss type pallet developed by the Marshall Space Flight Center (Ref. 14). The truss is called the COPE (capacity of opportunity payload experiment). The COPE truss is a beam, 48 x 24 x 73 inches with a mass of 386 kgms (850 lbm), capable of carrying a payload of 1,240 kgms (2,730 lbm). The COPE truss rides in the payload bay on four trunion fittings.

On the flight up, no connections other than the trunions between the Orbiter and the pallet are envisioned to be required.

On the flight down, if the SCA canister is carried on the truss, power and data connections to the processor/power controller will be required. Active thermal control may be needed, but will be provided by the pallet, given power from the Orbiter.

On the flight down, if the SCA canister is carried in the mid-deck, provisions to stow it in the mid-deck will be required.

7.5 Weight Estimates

Item/Basis of Calculation — **Weight (lbs.)**

1) Truss — 850

48 x 24 x 73 inches with a mass of 850 lbm, capable of carrying a payload of 1,240 kgms 2,730 lbm. Reference 14

2) SCA Canister, metal walls and lid — 660 (246 if r=13inches) r

The canister mass = 2* *r*t*(h + r)* den, where:

r = radius of canister = 15 inches
h = height of canister = 16 cm
t = thickness of walls = 1 inches
den = density of wall material
= 7.85 kg/cc for high strength steel

The dimensions of the canister are set by the canister it must contain in a compact fashion. The wall thickness of the can will likely be determined by crash considerations; that needed to contain and protect the sample in the event of a Shuttle accident. A thick high strength steel in the interior with insulation capable of handling high thermal loads on the exterior may work for most cases without penalizing the whole system much. To handle surface impact, some type of crushable outer container may also be needed. This could be an additional container, only used during the ride down.

3) SCA Canister Mechanisms, estimate — 220

4) EOC Canister, metal walls and lid — 1851

The canister mass = 2* *r*t*(h + r) *den, where:

r = radius of canister = 80 cm
h = height of canister = 134 cm
t = thickness of walls = 1 cm
den = density of wall material
= .00785 kg/cc for high strength steel

5) Carbon Dioxide Bottle — 11

6) Data Processor/power controller — 22

Total (less truss) — 2,764

Total (with truss) — 3,614

7.6 Interfaces with the Space Station (Hooks, Scars, and Other Provisions)

The Space Station must mechanically connect to the pallet, provide it electrical power, and give the crew and the ground the ability to communicate with it.

7.6.1 Electrical Power Interface

The pallet will be provided with electrical power from the Space Station where it is located on the transverse truss or beside the JEM pallet.

This power will nominally be a standard Station power, 208 volts AC at 20 kilohertz. This power will be transformed as required on the pallet to power mechanisms and electronics. If the thermal control can indeed be done passively, the average power requirement will be on the order of a few hundred watts to run the processor and other electronics. Peak load might be as high as a kilowatt when certain closing mechanisms are operating.

If active thermo-electric devices are used for cooling power requirements may go up in the range of several kilowatts.

The desired actual interface is a plug-in connector capable of manual and automatic make and break. It is desirable that this interface be at the location of the pallet on the structure such that the pallet can be placed on the structure and connected automatically without EVA required. EVA connection would be the back-up for automation problems.

7.6.2 Data and Commands

The data processing for the pallet can be handled in several ways.

1) All the processing, power controllers, and other electronic equipment could be located in the pressurized module. All data processing is done within the Space Station computer. This allows easy servicing and maintenance on-orbit. It does require a large number of wires running from the pallet to the pressurized volume, and complicates installation and checkout.

2) Same as 1) except the computer and other hardware can be rack mounted in the Space Station, brought up especially for this task. Only power, communications hook-ups, and feed throughs to the exterior are required.

3) All the processing, power controllers, etc. could be located on the pallet in a local controller with multiplexer-demultiplexer and an embedded data processor. It would add an additional orbital replaceable unit to the pallet and possibly require some thermal control, but it could be integrated and tested on the ground. Interface with the Space Station networks would be limited to sending commands and storing and displaying data at a control station. The Space Station Attach Payload SDP would be used for this.

4) The power processing and data processing could be split between the attached payload SDP and the local controller on the pallet. Some software and hardware could reside in both locations as seems most convenient at the time. Data would be stored on a mass storage unit with the Attached Payload SDP as would top level commands.

Due chiefly to the ease of integration and testing, the fourth option, with the processor and most other hardware on the pallet and data storage and top level commands on the attach payload SDP, is chosen as a baseline.

For this option, the Space Station must provide a port into the computer and the ability to display data to the crew on-board, and send it to the ground, and allow the crew and the ground to send commands to the pallet.

Two EOCs, SCAs, and canister pallets may be at the Station at one time so all the data/commands/power requirements below should be multiplied by two for two missions flown at the same opportunity.

Data Requirements

Thirty-nine data items are listed below. Software will be required to display each item and send some or all of the items to the ground for display.

SCA Internal Temp. 1
SCA Internal Temp. 2
SCA Internal Pressure 1
SCA Internal Pressure 2
SCA Canister Internal Pressure 1
SCA Canister Internal Pressure 2
SCA Canister Internal Pressure 3
SCA Outer Wall Temp. 1
SCA Outer Wall Temp. 2
SCA Outer Wall Temp. 3
EOC Canister Internal Pressure 1
EOC Canister Internal Pressure 2
EOC Canister Internal Pressure 3
EOC Canister Internal Temp. 1
EOC Canister No.1 Vent Valve Position (Open/Closed)
EOC Canister No.2 Vent Valve Position (Open/Closed)
SCA Canister No.1 Vent Valve Position (Open/Closed)
SCA Canister No.2 Vent Valve Position (Open/Closed)
EOC Canister No.1 Pressurize Valve (Open/Closed)
EOC Canister No.2 Pressurize Valve (Open/Closed)
SCA Canister No.1 Pressurize Valve (Open/Closed)
SCA Canister No.2 Pressurize Valve (Open/Closed)
CO_2 Manifold Valve (Open/Closed)
CO_2 Manifold Pressure (Downstream of Regulator)
CO_2 Manifold Vent Valve (Open/Closed)
CO_2 Bottle Pressure Regulator Position
CO_2 Bottle Internal Pressure
CO_2 Bottle Internal Wall Temperature
Canister Pallet Latch No. 1 (Latched/Unlatched)
Canister Pallet Latch No. 2 (Latched/Unlatched)
Canister Pallet Latch No. 3 (Latched/Unlatched)
Canister Pallet Latch No. 4 (Latched/Unlatched)
EOC Latch In, No.1 (Latched/Unlatched)
EOC Latch In, No.2 (Latched/Unlatched)
EOC Latch In, No.3 (Latched/Unlatched)

SCA Canister Latch On, No.1 (Latched/Unlatched)
SCA Canister Latch On, No.2 (Latched/Unlatched)
SCA Canister Latch On, No.3 (Latched/Unlatched)

Command Requirements

Twenty seven low level command items are listed below. The Station software must allow the following commands to be sent to the pallet, to be executed by the processor and hardware on the pallet.

SCA Canister Temperature Control (Auto/Manual)
SCA Canister Temperature Thermostat Set (TBD °C)
Sun Shade Position - (1,2,3,4,5,6)
EOC Canister No.1 Vent Valve Power (On or Open/Off or Closed)
EOC Canister No.2 Vent Valve Power (On or Open/Off or Closed)
SCA Canister No.1 Vent Valve Power (On or Open/Off or Closed)
SCA Canister No.2 Vent Valve Power (On or Open/Off or Closed)
SCA Canister Vent Valve Power Safety (On/Off)
(switch in sequence to prevent inadvertent vent)
EOC Canister Pressurize No.1 Valve Power (On or Open/Off or Closed)
EOC Canister Pressurize No.2 Valve Power (On or Open/Off or Closed)
SCA Canister Pressurize No.1 Valve Power (On or Open/Off or Closed)
SCA Canister Pressurize No.2 Valve Power (On or Open/Off or Closed)
CO_2 Manifold Valve Power (On or Open/Off or Closed)
CO_2 Manifold Vent Valve (Open/Closed)
CO_2 Bottle Pressure Regulator Position
SCA Canister Lid (Open/Close)
EOC Canister Lid (Open/Close)
Canister Pallet Latch No. 1 (Latch/Unlatch)
Canister Pallet Latch No. 2 (Latch/Unlatch)
Canister Pallet Latch No. 3 (Latch/Unlatch
Canister Pallet Latch No. 4 (Latch/Unlatch)
EOC Latch In, No.1 (Latch/Unlatch)
EOC Latch In, No.2 (Latch/Unlatch)
EOC Latch In, No.3 (Latch/Unlatch)
SCA Canister Latch On, No.1 (Latch/Unlatch)
SCA Canister Latch On, No.2 (Latch/Unlatch)
SCA Canister Latch On, No.3 (Latch/Unlatch)

7.6.3 Mechanical Interface Requirements

Four latch connectors may be needed to connect the pallet to Space Station structure. In the two locations of interest, beside the JEM pallet, and on the transverse truss, standard connectors will certainly be used. At the moment these connectors are not defined.

Table 7, Interfaces for Canister Pallet

EXTERNAL

DATA MANAGEMENT SYSTEM

Interface to SS DMS is 1553 serial bus	
Internal interface to Pallet mounted M/DM	
Temperature sensors	9
Pressure Sensors	10
Valve and Solenoid Drivers	24
Motor Speed and Current Sensors	0

POWER

208 VAC 20,000 hz (switched)	
Peak Power usage (w)	1,000 (estimate)
Average Power Usage (w)	300 (estimate)

THERMAL CONTROL SYSTEM

Passive

FLUIDS SYSTEM

Waste Gas (for CO_2 dewar)

FLUIDS SYSTEM

Carbon Dioxide (high purity)
Waste Gas (for LN2 dewar)

8.0 U.S. Lab, JEM or Columbus Module Rack Mounted Processing Facility (RMPF)

The rack mounted processing facility is a biologically isolated area where an astronaut working IVA can open the SC and SCA and remove a small sample to be shipped to earth separate from the rest of the sample. That small sample can be analyzed to determine the biological nature of the Martian material. Design Reference Mission 2 A through D are a series of compromises to allow the bulk of the Mars sample to be held on-orbit while a small amount of unsterilized material is transferred to Earth to define the extent and type of biological hazard. The principle component of the Mars sample processing system within the Space Station is a refrigerated Rack Processing Facility. Figure 19 shows the cabinet.

8.1 Requirements

The principal requirements for the Rack Mounted Processing Facility are: 1) that it fit in 1 double standard rack, 2) it be able to sterilize the exposed surface of any material passed out of the cabinet, 3) that the cabinet support biological isolation of the Mars sample with a two fault tolerant system, and 4) that it be able to hold the bulk of the Mars sample in the canister, one or two sample vials, and biological testing alloquates at a temperature of less than -40°C.

The Rack mounted facility is far too small to allow detailed analysis of the samples. Study of the sample will be limited to visual examination, possibly through a microscope. The analysis protocol of DeVincenzi and Bagby (1981) requires a combination of microscopes, analytical instruments and challenge cultures too complex to put in only one or two racks. The smallest facility that could perform on-orbit analysis is described in section 10 of this report.

8.2 Conceptual Design

The cabinet conceptual design fits the equivalent of a sample cabinet used to process the Apollo Lunar Samples in the Lunar Receiving Laboratory, Antarctic meteorites at the Johnson Space Center or biological materials. The cabinet design is shown in Figure 34A and 34B. A schematic for the design is shown in Figure 35.

The cabinet consists of the following components:

1) Cooled processing volume - The chamber is sized to allow movement of the SCA canister (the largest piece of equipment that passes in and out of the chamber). The chamber is cooled by a cold plate at the back with a small fan to maintain active circulation since convective transfer in the chamber will be ineffective in micro-g

2) Four glove ports - the gloves will be laminated with successive layers from the hand surface of: punctures resistant cloth, a thin vapor/biological barrier, insulation, a second vapor/biological barrier, and an outer puncture resistant layer. In practice the gloves will be encased in a teflon overglove as is current practice with lunar samples.

3) Pass-though airlock and sterilizer - The insulated chamber will have insulated gas tight doors between the cabin and the airlock, and the airlock and the processing volume. The airlock will have a coldplate and fan, and a electric heating element. The chamber heater will be sized to heat the exterior surface of the SC to 200 C for 10 minutes (these numbers are estimates) for biological sterilization, and then cool it before the interior warms up.

4) Cooled holding chamber for the SC - This chamber will have a coldplate to maintain temperature of the chamber in the required varge.

5) Uninsulated chamber for the SCA Canister and the SCA - This chamber holds the SCA Canister and SCA while the SC is being removed and then serves as the on-orbit storage point for the SCA.

6) Quick disconnects (QDs) - pass refrigerant to the SC and the subsample containers.

7) -40°C refrigeration system, with a working fluid to be defined - The thermoelectric unit rejects heat to the Internal Thermal Control Systems 42°F water cooling loop.

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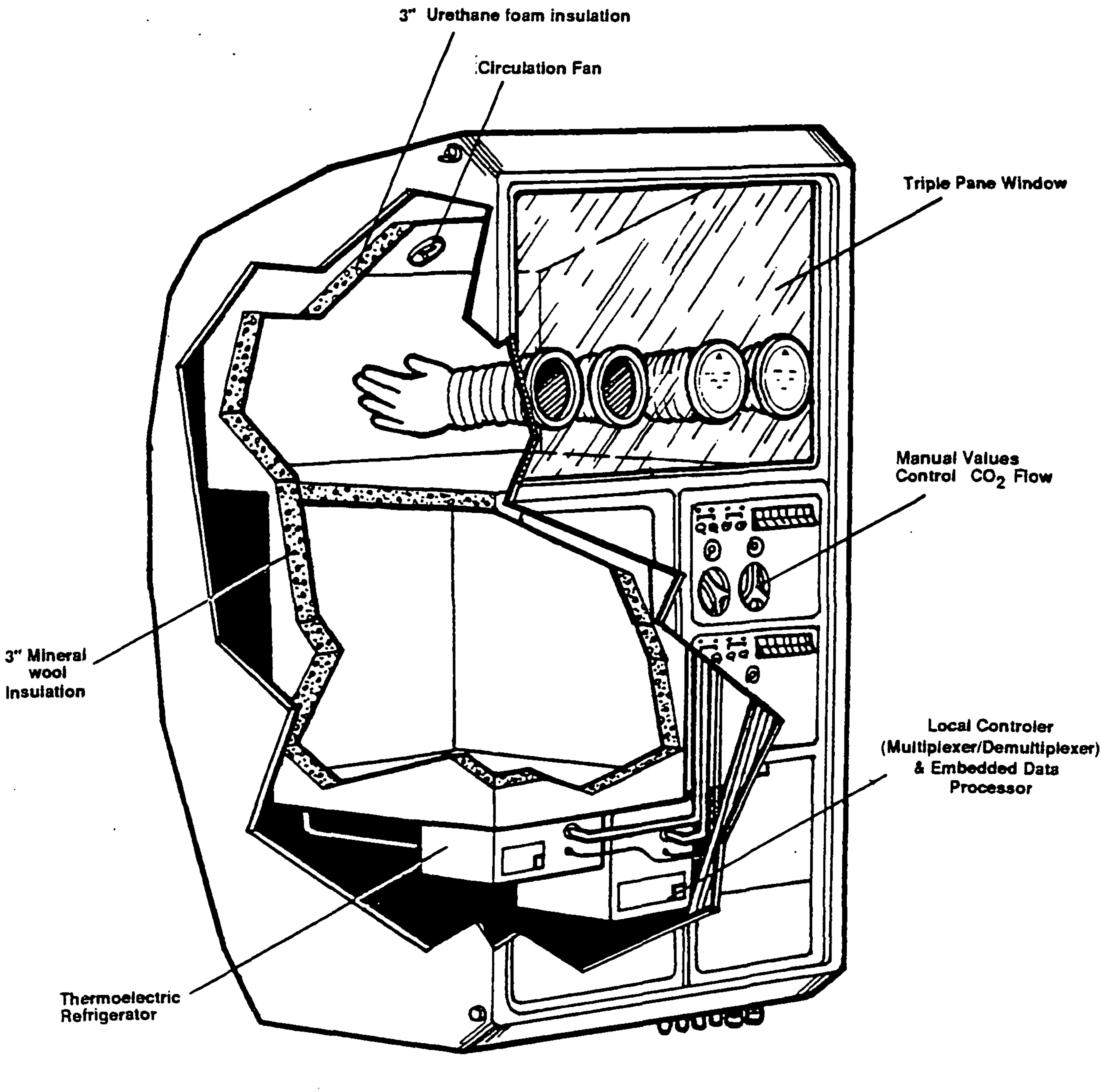

Figure 34A, Rack Mounted Processing Facility

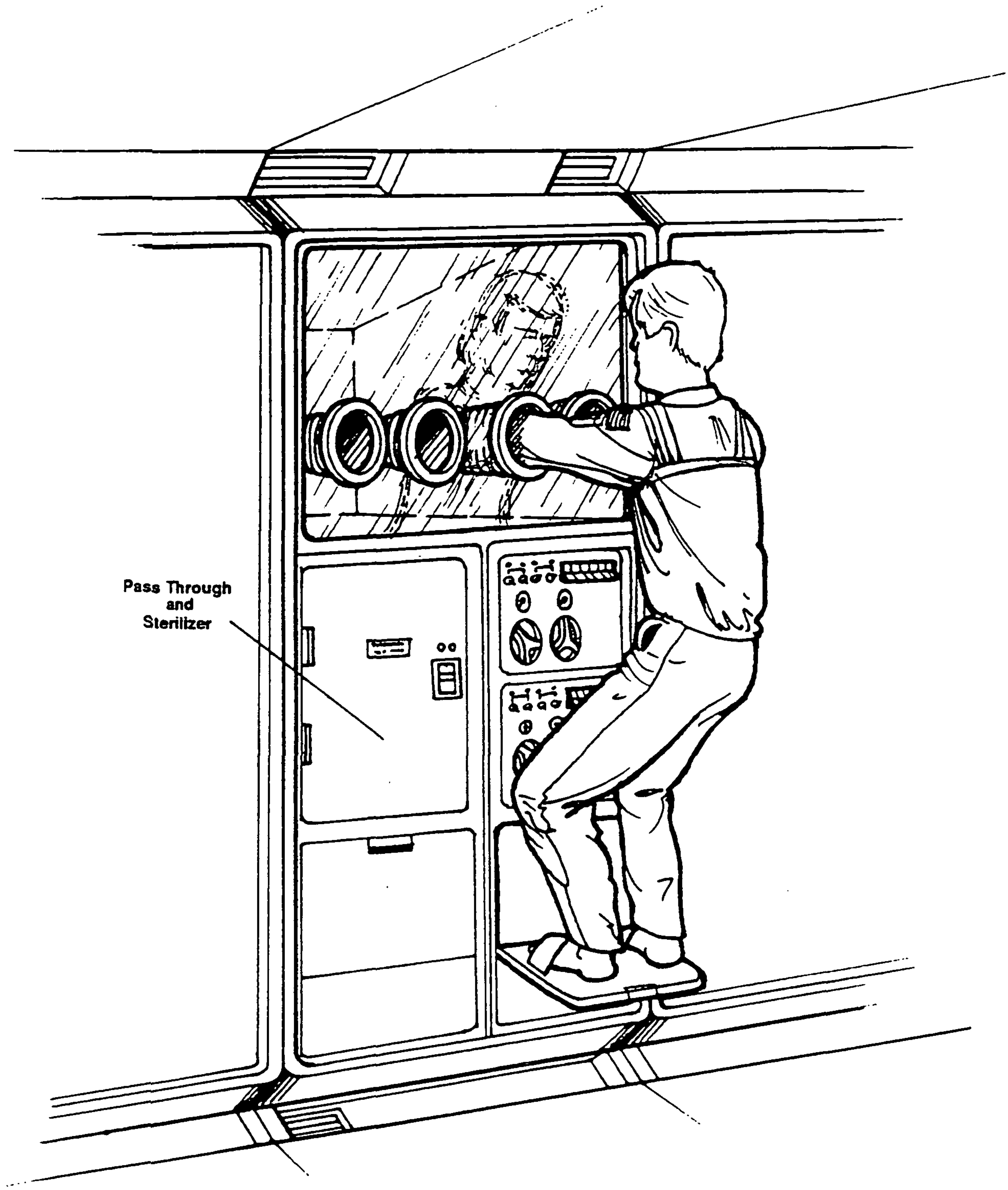

Figure 34B, Rack Mounted Processing Facility

8) Cabin atmosphere composition measurement system with sensors to measure humidity and O_2 in a stream of gas extracted from the cabin by a small pump.

9) Control panel to control the flow of CO_2 into the various chamber and to turn on and off the sterilizer and cooling equipment and display critical data.

10) A local controller with multiplexer/demultiplexer connected to all sensors and a embedded data processor to process the data and control the pumps fans and the thermoelectric refrigerator. The local controller would be attached with a serial data link to one of the Standard Data Processor (SDP) serving the internal payloads. The control panels or the rack work through the local controller. The Mass Storage unit with that SDP would store any large volume of sensor data that must be preserved. The standard local controller is oversized for controlling this single rack, however no smaller unit has been defined in the Space Station DMS architecture.

11) Crew aides will be required to allow the crewman to work in the gloves for a period of a few hours at a time. A program of mockups will be needed to determine whether Skylab type foot restraints or restraints behind the knees are preferred by the crew.

The instrumentation in the RMPF rack includes:

1) O_2 partial pressure sensors measuring the composition of gas in the glove box, and serving as leak detectors, triply redundant.

2) H_2O partial pressure sensors measuring the composition of gas in the glove box, triply redundant.

3) Temperature sensor co-located with the composition sensors.

4) Cabinet temperature sensor.

5) Cold Plate Temperature sensor.

6) Temperature sensors on the outlet side of each QD pair carrying coolant to the SC while in the Chamber.

7) Delta pressure sensor between glove box and airlock.

8) Delta pressure sensor between airlock and cabin.

9) Delta pressure sensor between SCA Canister-SCA Chamber and glove box.

10) Temperature sensor in airlock.

11) Current sensor for sterilizer heater element.

12) Temperature sensor on cabin side of relief valve, serves to confirm operation of relief valve.

13) Current and speed sensors on small pump supporting analysis unit.

14) Current and speed sensors on refrigerant pump.

15) Temperature on inlet side of 6°C cooling loop to thermoelectric unit.

16) Temperature Sensor on outlet side of 6°C cooling loop from thermoelectric unit.

17) Current sensor for thermoelectric unit.

8.3 Thermal Analysis

8.3.1 Insulating Concept for the Rack Mounted Processing Facility

Conventional insulating materials used in terrestrial environments for applications similar to the Rack Mounted Processing Facility are usually cellular, fibrous, or sometimes layered in structure. Heat propagation in the insulation is the complex interaction of free convection, conduction, and radiation. The function of the cellular or fibrous structure in the insulation material is primarily the elimination of convection and also the reduction of radiation. The conduction heat transfer is reduced by the use of low conductivity filler gas in closed cell materials, such as in polyurethane foams.

In zero-g environment conduction and radiation are the modes of heat propagation. Free convection does not play a role.

The recommended material for the walls of the refrigerated part of the cabinet is either 3 pound per cubic feet (PCF) Polyurethane Foam or Mineral Wool board in the 1 PCF to 3 PCF range. Practical insulation thickness for the cabinet is 2 to 3 inches. This thickness would depend on the results of the overall mechanical and thermal design and verification test program.

The advantage of the polyurethane foam is the low thermal conductivity. It is shown in Fig. 36 that typical conductivity values are:

k = 0.130 Btu, in/hr, ft^2, °F at 70°F (21°C)
k = 0.125 Btu, in/hr, ft^2, °F in the -40°F/70°F (-40°C/21°C) range

The conductivity in the -40°F and 70°F operating range of the cabinet is the estimated integrated average conductivity of the material based on the slightly aged curve. Aging is the process by which the low thermal conductivity halocarbon gas in the cells is gradually replaced by air, which has a higher k value. This can be prevented or retarded by molding the foam between two metallic plates, such as the walls of the cabinet or by coating the foam surfaces with a plastic skin, e.g. epoxy. The disadvantage of polyurethane foam is its service temperature limit. It should not be used above about 93°C. Furthermore, it is a flammable material, and appropriate protection should be provided to avoid its exposure to ignition sources.

The conductivity curve in Figure 36 is essentially gravity field independent.

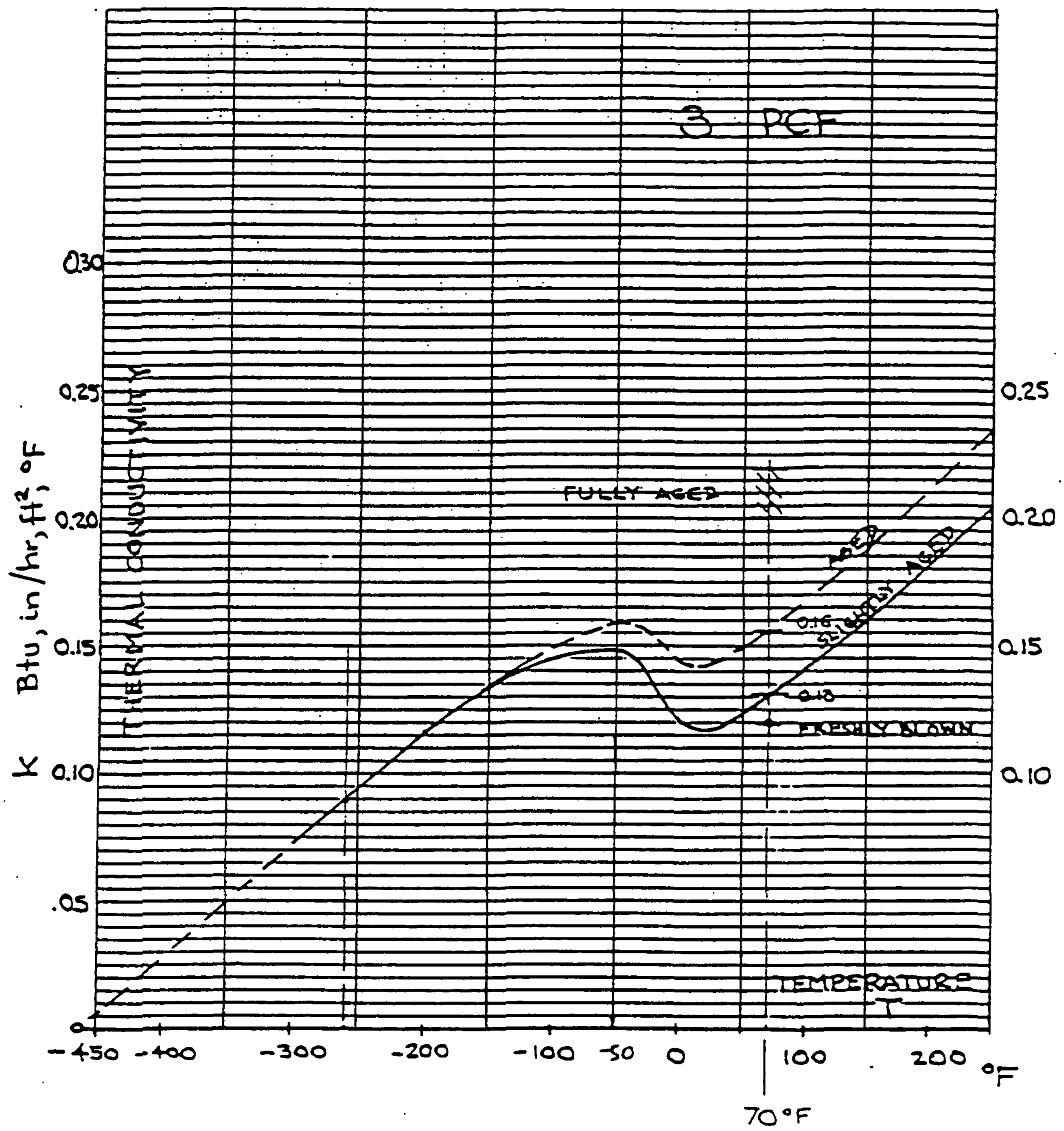

Figure 36, Thermal Conductivity of Polyurethane Form

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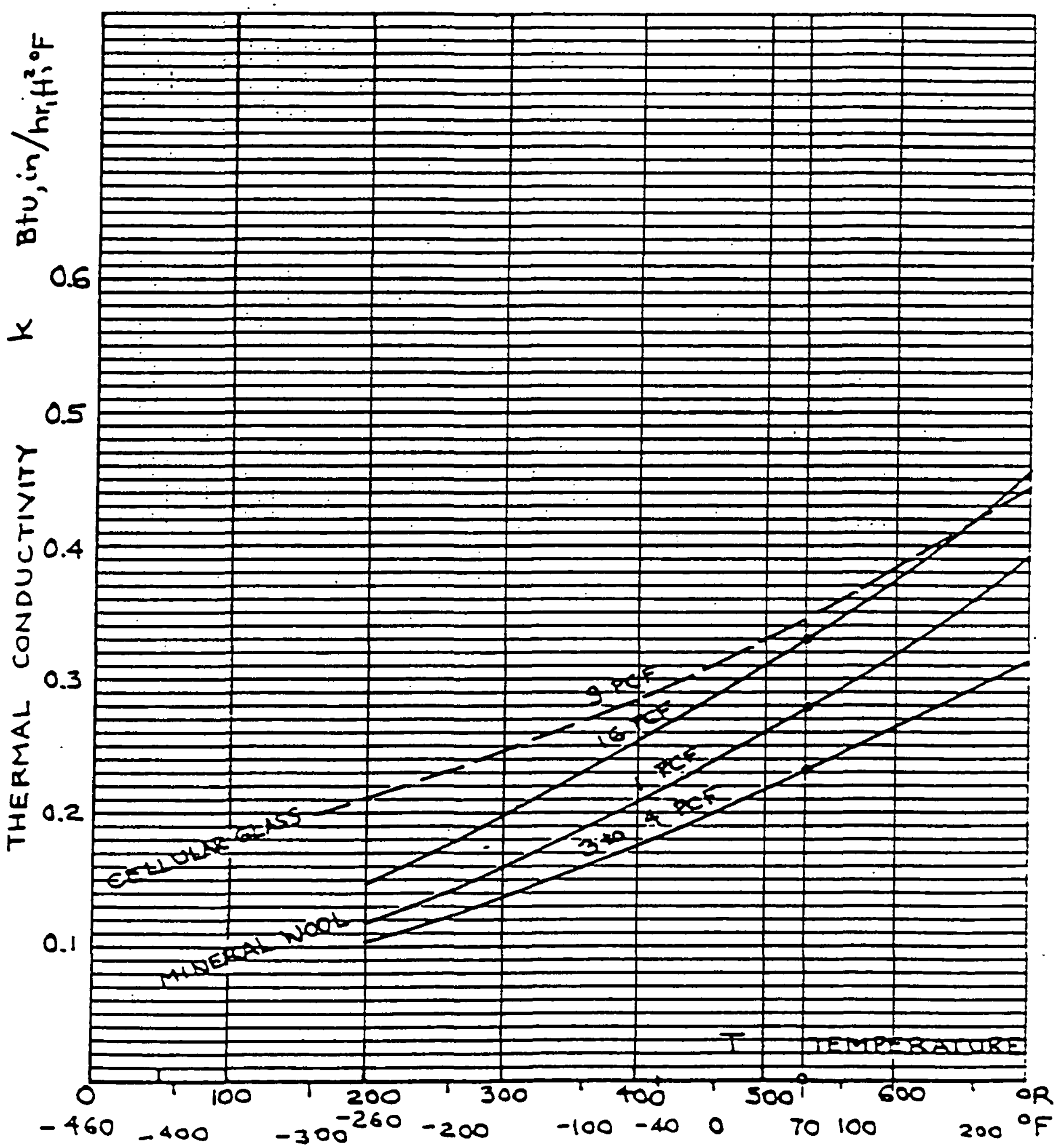

Figure 37, Thermal Conductivity of Fibrous Insulation and Cellular Glass

The ultimate selection of insulating materials and their thickness should depend on the thermal design of the cabinet.

The simplified heat balance of the cabinet in schematic form can be written as:

$$cW\frac{dT}{dt} = \sum_{i=1}^{n} U_iA_i\,(T_e - T_i) + q_s - q_r \qquad (1)$$

$$t = 0 \qquad\qquad T_i = -40^\circ C$$

where cW is the thermal capacity of the sample, U_iA_i is the product of conductance and surface area element of the cabinet, q_s is heat input, e.g. by a stirring motor, q_r is heat removed by refrigeration and T_e is the environmental temperature.

Ideally, the sample temperature should not change, i.e. in Equation 1)

$$\frac{dT}{dt} = 0$$

Then the refrigeration requirement is:

$$q_r = \sum_{i=1}^{n} U_iA_i\,(T - T) + q_s \qquad (2)$$

In reality, the sample temperature will change with time. For cabinet design, a practical value for the tolerance band of this temperature needs to be selected.

8.3.2 Recommended Cooling System

The sizing of the insulation panels and the evaluation of equation (1) in Task 2a yields the required thermal load on the refrigeration system.

For a 62°C degree temperature difference, 3" of foam insulation and a cabinet area of 33 feet the heat gain by the cabinet is 137 BTU/hr.

This will be the basis for the selection of the optimum type of refrigeration system for the cabinet, which is best done once the design parameters are known.

Possibly the simplest type of refrigeration for the cabinet is thermoelectric rejecting heat to the air. The large temperature difference between the sample and the cabin air

$$T = 21^\circ C - (-40^\circ C) = 62^\circ C$$

will require multistage or cascade cooling. In case the heat from the thermoelectric cooler is directly removed by the spacecraft air, a circulating fan on the hot side might be needed because of the lack of convection. Similarly, a stirring fan might be needed inside the cabinet for even temperature distribution. In that case, the refrigeration system capacity should cover the extra electrical input of the fan, as indicated in Equation 1.

Some improvement in performance and size reduction can be obtained by utilizing the cold plate of the spacecraft with 42°F (6°C) water loop to cool the thermoelectric unit. Even then it is likely that the temperature difference

$$T = 6°C - (-40°C) = 46°C$$

still requires a cascade thermoelectric unit.

The direct connection of the water loop with the thermoelectric cooler's hot plate will require connection and disconnection of the fluid loop when the RMPF is installed and removed respectively.

Although no detailed design of the thermoelectric system has been undertaken, the unit is roughly the same size as required for freezers in orbit. At present the power consumption is estimated at 600 w.

8.3.3 Window Concept for the RMPF

Because of lack of convection in a zero-gravity environment, a double-walled window with a couple of inches of spacing can provide sufficient thermal insulation on the window side of the cabinet. The space can be filled with dry air or dry nitrogen.

In case the conceptual design of the RMPF indicates that the outside surface of the outer window pane might experience condensation in the spacecraft environment, a window with triple glazing is recommended.

The spacing between the outer and middle pane can be less, e.g. about 1/2 inches versus about 2 inches spacing between the middle and inside pane. In the 1/2 inches spacing a dry, warm gas can be circulated to warm the outer glazing and thus avoid water vapor condensation on the spacecraft side of the window.

Heat leak through the handling gloves can be reduced by using insulated or preferably 2 concentric thin walled gloves with air space in between.

8.3.4 Insulation for the Sterilizing Process.

Polyurethane foam insulation discussed above is not recommended on those RMPF surfaces which will be exposed to 150°C during sterilization. Mineral wool, discussed above is an acceptable material. In case only the interior of the cabinet is exposed to high temperature, a composite wall with mineral wool on the high temperature side during sterilization and polyurethane foam on the lower temperature side can be used. The selection of wall thickness should assure that the highest temperature in the polyurethane foam should not exceed about 93°C. Mineral wool is another recommended insulating material. Its thermal conductivity is higher than that of polyurethane. The average thermal conductivity in the -40°C/21°F range according to Fig. 37 is:

$k = 0.2$ Btu, in/hr, ft^2, °F

It has very good temperature resistance, some types can be used at over 540°C, and is not flammable. It is not subject to aging. The recommended type for the insulation of the cabinet is board insulation with binder. The conductivity of the material is gravity dependent. It is likely that in zero-g environment the k value of the 1 PCF material is closer to that of the 3 PCF material perhaps less.

8.4 Flight Support Equipment and Transfer to Earth

8.4.1 Rack Transport Equipment

The RMPF can be carried up in either a pressurized logistics module or an unpressurized carrier in the Orbiter payload bay. The same two options exist for the trip down. In the event that the Mars sample is found to be biologically active, the rack will have to be sterilized on orbit. Heat sterilization will not be practical, and the unit will have to be chemically sterilized by procedures defined through the earth based analysis of the sample. Pending development of the procedures, which might take more than a year to define, the cabinet will have to be secured on orbit.

8.4.2 Special Tools and Equipment

Numerous special tools will be required to process the sample in a micro-g environment. The only tool highlighted in this report is the device to open the sample tubes brought from Mars. (Figure 38) The concept for the tool is derived from the drive tube extruder used on both the small and large diameter Apollo drive tubes. In the device the sample tube is clamped in a restraining device. The end cap or plug is removed. The end of the sample is placed in a high purity silica glass cup. The bottom of the tube is cut off with a device similar to tube cutter with a circular blade. Then a screw driven plug is inserted in the end and driven into the tube using a threaded multi-handled device. The sample is extruded. As each sample spacer is extruded a new silica vial is used to catch the sample. Once the desired number of samples have been obtained then, the tube is plugged with stopper which snugly confines the samples. The silica vials, are placed in an insulated packing container, possibly with an active cooling loop.

8.5 Weight Estimates

Preliminary estimates of the weights of the cabinet are shown in Table 7. The weights are scaled from those of the airlock Service and Performance Checkout System which support the EMUs. That unit has a volume of about 35 cubic feet and weighs 1,050 pounds. Allowing for the fact that the glove box has at least 1/3 empty space, the total for the unit is estimated at about 875 pounds.

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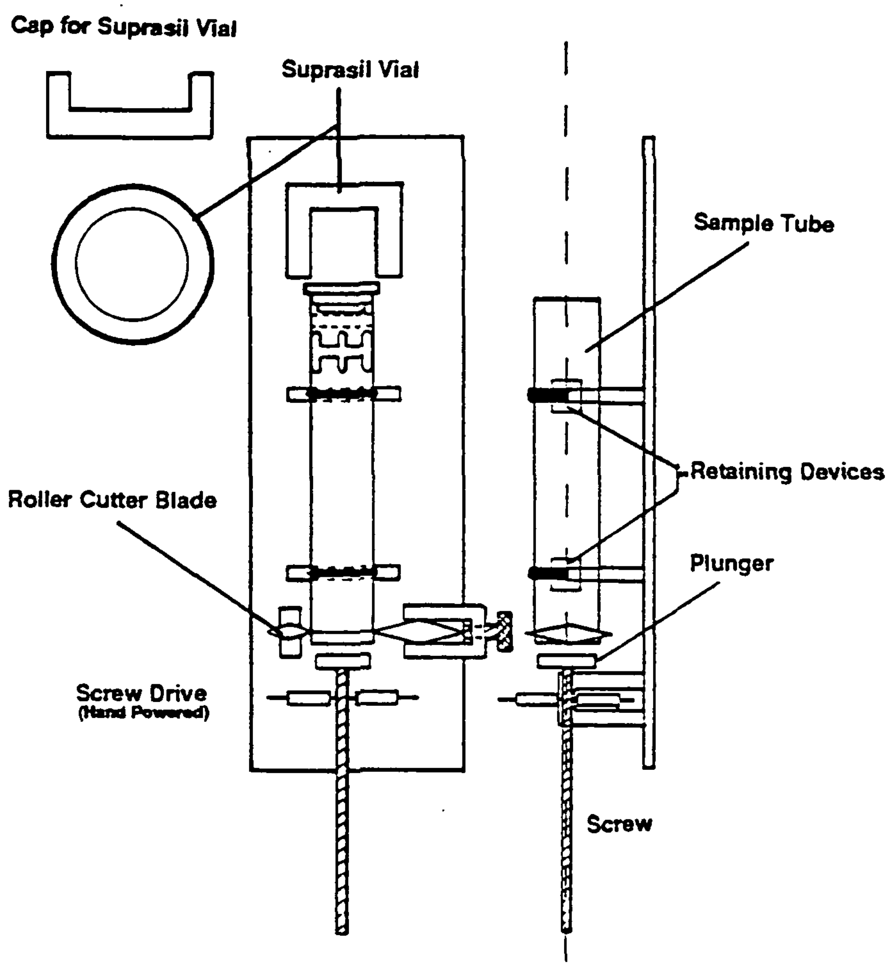


Figure 38, Tool for Opening Sample Tube Containing Martian Soil

Table 8, Weights for Rack Processing Equipment (Pounds)

Internal Processing Rack	400
Structure	100
Mechanisms	100
ECLSS	25
Avionics(DMS,C&T,GN&C)	50
Cooling System	100
Laboratory Outfitting Equipment	100
TOTAL	875 pounds

8.6 Interface Requirements

The interface requirements of the processing rack are shown in Table 9. All sensors and control in the cabinet comes from the Rack's local controller which includes both a multiplexer/demultiplexer and an embedded data processor. The interface between the Data Management System the rack local controller would be a standard 1553 serial bus that is part of the internal payload network. The internal payload network has access to mass storage units to hold large volumes of data collected by the cabinet's instrumentation. The rack switches and controls act through the local controller. Top level resource allocation to the rack is controlled through the stations's operations management system (OMS) as its top level fault detection and isolation.

Electrical power like the data will be controlled within the rack by a small power distribution and control assembly (PDCA). That unit is in turn controlled by the Local Controller.

The Internal Thermal Control System will provide chilled water to remove heat from the Thermo electric unit. Chilled water will come through 3/4" flex lines.

The fluid system will supply the high purity CO_2 and dispose of the waste gas. The filtered CO_2 will go into the waste gas system and then to the electrically heated resistojet in the Stinger between the JEM and Columbus module (Figure 6).

Table 9, Interfaces for Processing Rack

DATA MANAGEMENT SYSTEM	
Interface to Space Station - 1557 Bus	
Temperature sensors, number	6
Pressure Sensors, number	4
$P(O_2)$ Sensors, number	3
$P(CO_2)$ Sensors, number	3
Valve and Solenoid Drivers, number	0
Discrete (Latches) Indicators, number	4
Motor Speed, number	2
Motor Current Sensors, number	2
POWER	
208 VAC 20,000 hz (switched)	
Lights peak (w)	70
Sterilizer (w)	5000
Thermoelectric unit(w)	600
Average Power Usage (w)	610
THERMAL CONTROL SYSTEM	
Active (35°F loop) (w)	800

FLUIDS SYSTEM

CO_2 (SCF)	500
Waste Gas (for LN2 dewar)	tbd

8.7 Hooks, Scars, and Other Provisions

The DMS table-driven software architecture readily accommodates operation of the Rack Mounted Processing Facility. The fluid, cooling and power interfaces are standardized to be similar to other rack mounted Payloads. The fluid, internal thermal control interfaces are generally similar to other internal payloads.

9.0 Hatch Mounted Processing Facility (HMPF)

Design Reference Mission 2E uses a processing cabinet mounted at one of the Node hatches. The principle component of this Mars sample processing system in this option is a combined sample holding facility and processing facility mounted on a node hatch. Figure 39 shows a concept for the facility.

The HMPC is an processing facility to use to remove a small sample of martian material for one of the SCA's. This small sample can be sent in advance of the bulk of the material for biological testing.

9.1 Requirements

The principal requirements for the Hatch Mounted Processing Facility are: 1) that it fit to a standard Space Station berthing docking mechanism, 2) it be able to sterilize the exposed surface of any material passed out of the cabinet, 3) that the cabinet support biological isolation of the Mars Sample with a two fault tolerant system, and 4) that it be able to hold both Mars samples in the canisters, plus one or two sample vials, and biological testing alloquates at a temperature of less than -40°C.

The facility is not intended to support any analysis of the sample on orbit other than visual examination. In this respect the facilities are like the Rack Processing Facility. The advantages that the HMPF has over the RMPF are 1) the ability to work with two sample return connectors from separate EOC's, 2) the ability to hold the SRC's in the Node Facility and 3) the option of using the Node Facility to transfer the sample to Earth.

9.2 Conceptual Design

9.2.1 Configuration

The HMPC is designed to hold both Mars SCAs and to process samples from one or both. Unlike the processing cabinet that is in a standard interior rack, the node mounted facility does not conform completely to Space Station architectures defined in the Baseline Configuration Document or the Architectural Control Documents. The basic parts of the facility are:

1) Four airlocks each large enough to hold either a SC or a SCA or SCA canister. Each airlock has a cold plate to maintain temperatures and data/and control multi-pin connecters to mate with the SC or the SCA. Each airlock is supplied with high purity CO_2. Figure 39 shows the concept and Figure 40A is a fluid schematic and Figure 40B is an electrical schematic. The option exists to make the airlocks strong enough to hold the Sample Return Connectors in the orbiter Payload Bay. In such a design the connectors must be strong enough to maintain biological isolation after an accident like that discussed for the Connector pallets.

2) Four glove ports, similar to those proposed for the rack cabinet - the glove will be laminated with successive layers from the hand surface of: punctures resistant cloth, a thin vapor/biological barrier, insulation, a second vapor/biological barrier, and an outer puncture resistant layer. In practice the gloves will be encased in a teflon overglove as is current practice with lunar samples.

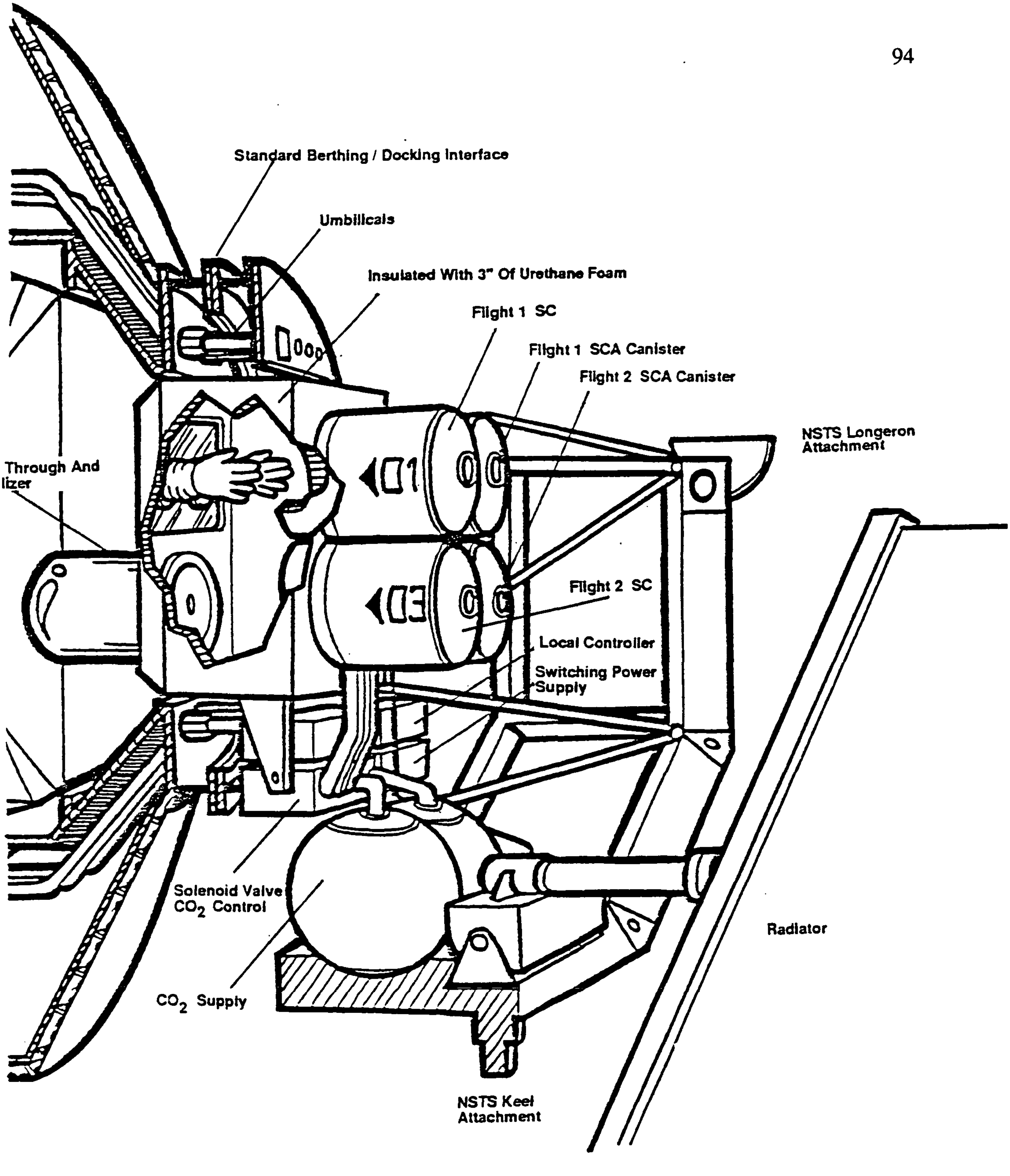


Figure 39, Processing Cabinet Mounted on Node Hatch

3) Pass-though airlock and sterilizer - The insulated chamber pass though airlock, is derived from the concept for the medical pass though used on the hyperbaric airlock. The chamber consists of a metal bell jar shaped device that attaches to the processing cabinet by a breech lock arrangement. The interior fitting is a matching plate with a similar breech lock. The interior of the pass though has an electric heater sized to heat the outside of the container holding the vials of Martian material to a temperature of 200°C for 10 minutes. The exterior of the canister is insulated with mineral wool encased in a thin protective metal jacket.

4) Quick disconnects (QDs) for passing refrigerant around the SC and the subsample containers.

5) -40°C refrigeration system, with a working fluid TBD cooling is provided by a rotating radiator with an area of about 100 $feet^2$. The system does not need to be connected to the -6°C water cooling loop.

6) Cabin atmosphere composition measurement system with sensors to measure humidity and O_2 in a stream of gas extracted from the cabin by a small pump.

7) Control panel to control the flow of CO_2 into the various chambers and to turn on and off the sterilizer and cooling equipment and display critical data.

8) Crew aides will be required to allow the crewman to work in the gloves for a period of a few hours at a time. A program of mockups will be needed to determine whether Skylab type foot restraints or restraints behind the knees are preferred by the crew.

9) Pressurized CO_2 storage, with a volume of about 2000 SCF

Numerous specialized tools will be needed. Most of the tools will be the same as would be used in the rack mounted installation.

9.2.2 Special Tools and Equipment

9.2.3 Analysis of Options for Location of Rack

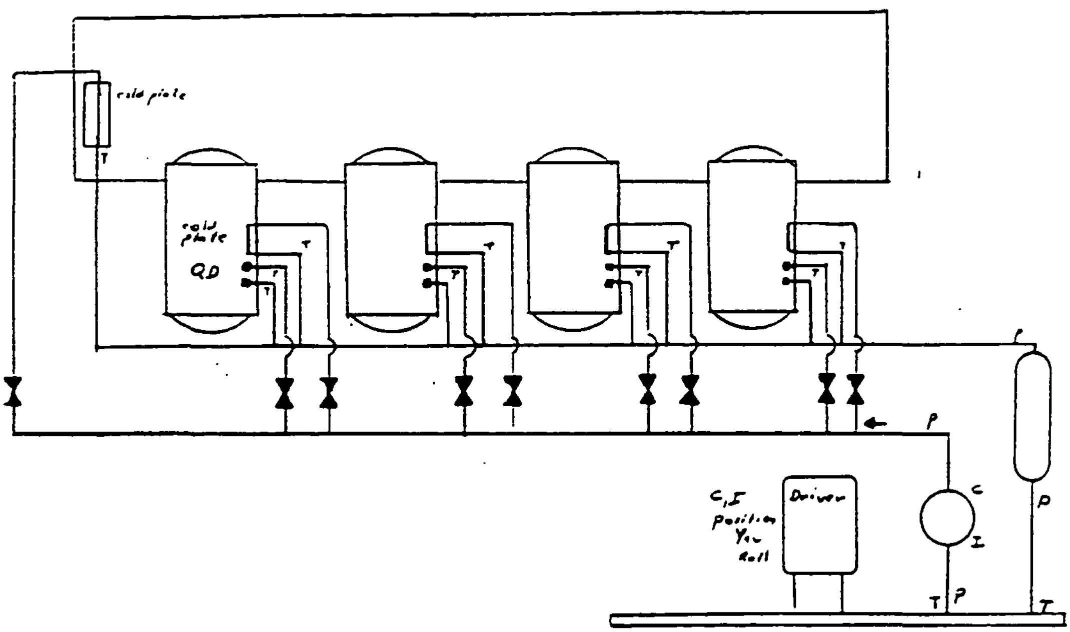
The facility can only be located at a port on one of the two rear nodes between the U.S. modules and the JEM and Columbus modules. The preferred option would operate the processing facility in the standard heads up orientation of the bulk of the Space Station. Only one hatch is available, located on the Node extending to the port or North side of the central module cluster as shown in Figure 40.

9.3 Thermal Analysis

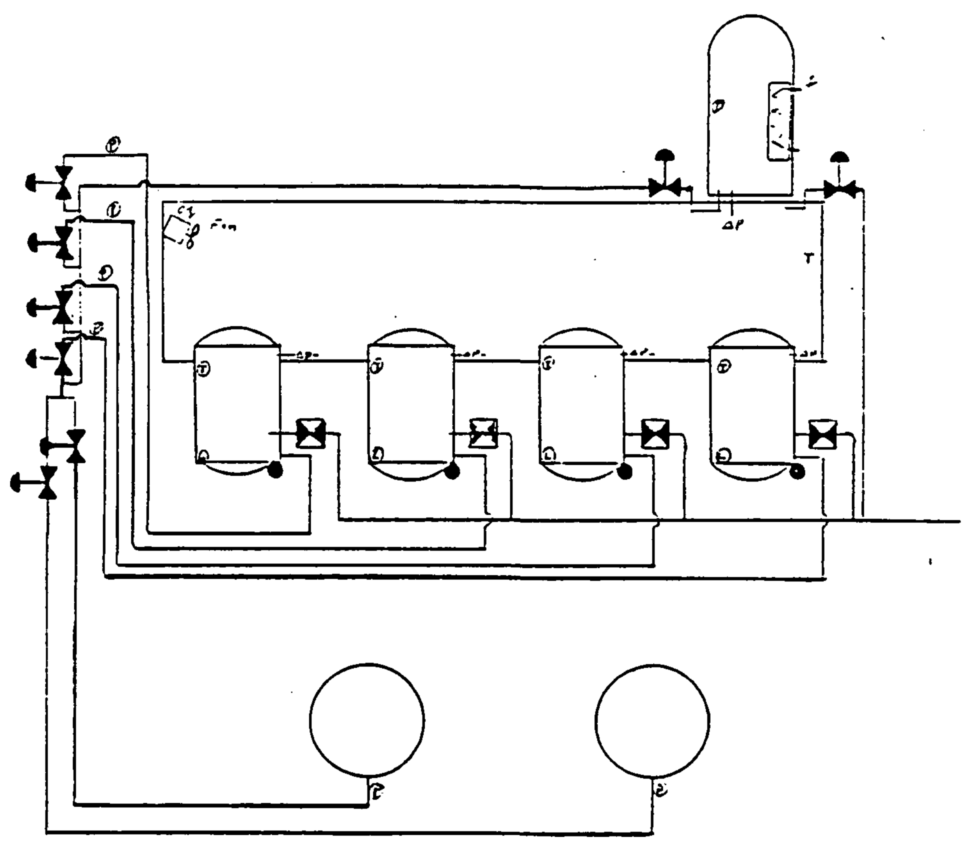
No specific thermal analysis of this concept has been undertaken at this time.

9.4 Flight Support Equipment and Transfer to Earth

The facility would be built with integral flight support equipment to transfer launch and landing loads to the Orbiter's keel and trunion fittings as shown in Figure 39.



a) Fluid Schematic



b) Electrical and Schematic

Figure 40, Schematic of Cooling, Fluid, Power and Data System of Processing Cabinet Mounted on Node Hatch

Table 10, Hatch Mounted Processing Cabinet

	Pounds
External Truss	1,260
Mechanisms	600
Containers for small sample	100
Container for SC and SRC	400*
CO_2 Supply	250
Wiring Harnesses and fluid lines	100
Avionics(DMS,C&T,GN&C)	64
Cooling System	400
Laboratory Outfitting Equipment	300
	3,474 pounds*

*3520 lbs if the containers are strengthened to transfer hazardous material to earth, Total weight 6594 lbs.

9.5 Weight Estimates

The weight estimate for the unit (Table 10) is estimated from the weight for a PAM cradle or other rack to mounted in the Orbiter payload bay.

9.6 Interfaces

The interfaces for the Hatch mounted Processing Facility are summarized in Table 10.

Table 10, Interfaces for Hatch Mounted Processing Facility

INTERNAL

DATA MANAGEMENT SYSTEM

Interface to Space Station - 1553 Bus	
Temperature sensors	16
Pressure Sensors	12
Valve and Solenoid Drivers	8
Motor Speed	3
Current	4
Position Sensor	2

POWER

208 VAC 20,000 hz (switched)	1
115 VAC 60 hz (for pumps)	3
Peak Power usage (w)	250
Average Power Usage (w)	50

THERMAL CONTROL SYSTEM

Through Integral Mounted Radiator

FLUIDS SYSTEM

Carbon Dioxide (high purity) self contained, 2000 scf
Waste Gas (for LN2 dewier), up to 2000 scf over life of facility

9.8 Hooks, Scars, and Other Provisions

10.0 Orbital Biological Isolation Facility

A Biologic Isolation facility is required if a preliminary biological analysis of the martian sample must be done on orbit. The definition of the biological certification analysis that must be performed on-orbit comes from DeVincenzi and Bagby (1981),the Antaeus Report. In essence that report recommends a series of protocols for analysis of the sample involving chemical analysis, optical and electron microscope examination, and challenge to a variety of different environments to determine if the Martian life is metabolically active and whether it interacts with a range of terrestrial biota.

10.1 Requirements

The biological analysis module is assumed to contain a combination of biological isolation cabinets designed to operate both at -40°C and at room temperature, and possibly above room temperatures. The cold chambers are used to remove the bioassay sample from the bulk of the Martian material which will be held for analysis on Earth. The room temperature and above room temperature facility are for physical and, chemical analysis of the Martian soil and biological challenge experiments. The latter are assumed to be done using a combination of tissue cultures and lower life forms. It is explicitly assumed that extensive testing on higher life forms such as mice or primates will not be necessary or desirable.

10.2 Conceptual Design

10.2.1 Configuration

Figure 41 shows the general layout of such a facility. The general design follows the Antaeus concept, which in turn generally reflects biological isolation facilities. The facility consists of the following elements:

1) A structure derived from the JEM or a shortened US Laboratory module.

2) A laboratory area running about 2/3 of the length. The facility has standard rack sized cabinets on two sides. The two banks of the cabinets on either side nearest the airlock operate at -40°F. The remaining four banks on either side operate at room temperature or slightly above should that be deemed desirable for challenge cultures. These areas contain microscopes, electron microscopes, and other instrumentation required for the analysis.

3) A change area to don and doff biological isolation garments.

4) An air shower and disinfecting man lock.

5) An airlock identical to the JEM Airlock.

6) A cooling system able to dispose of about 1,000 BTU hr at -40°F.

Detailed listing of the control sensors required for the Orbital processing facility is not attempted within this report.

10.2.2 Special Tools and Equipment

A large amount of equipment will be required to perform the biological analysis to a standard acceptable to the organizations which will have to certify the Mars Sample safe for transfer to Earth.

10.2.3 Analysis of Location of Racks

A preliminary layout of the racks in the module is shown in Figure 41. In the concept two standard racks located at the end next to the airlock are refrigerated. All other cabinets operate at room temperature (70°F).

10.2.4 Analysis of Options for Location of Module

The facility is best located so that it can maintain the heads up orientation of the Space Station. There is only a single node hatch available for this. This is the Port or north hatch of the Node just in front of the JEM. Figure 42 shows this position.

10.3 Thermal Analysis

No detailed thermal analysis has been performed, however each of the four cold cabinets will require removal of about 140 BTU per hour at -40°C. The electrical power load for this will be sufficiently large that use of a body mounted radiator to maintain the temperatures will reduce power demands on the Station.

10.4 Flight Support Equipment and Transfer to Earth

The Facility is supported in the Orbiter Payload Bay by internal longer and keel fittings similar in concept to those used by Spacelab and the Space Station Modules.

The local controller will interface with one of the payload networks and associated Standard Data Processors and mass storage units. Data can be down linked via the TORSR network to support ground based data analysis.

10.5 Weight Estimates

The weight of a sample analysis is summarized in Table 12. The weights are based on the estimates for the JEM which is a similar sized module C in NASDA (1986).

Table 12, Weights for Sample Analysis Facility (lbs)

Structure	6,055
Mechanical	1,845
Electrical Power System	1,135
Communication and Tracking	1,015
Thermal Control	1,430
ECLSS	915
Laboratory Outfitting	10,773
Total	23,168

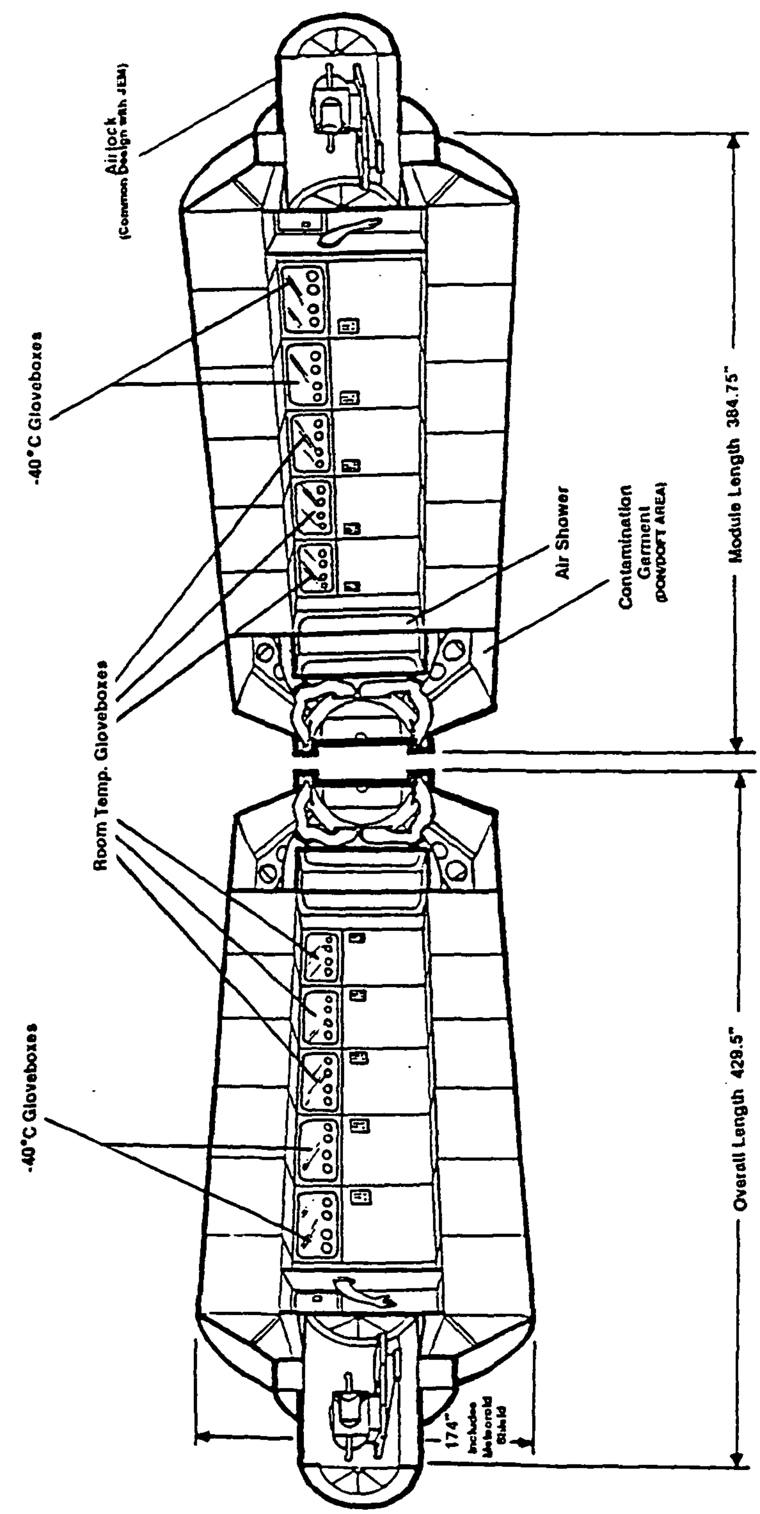


Figure 41, Interior Layout Concept for Orbital Biological Isolation Facility

10.6 Interfaces

The interfaces for the unit (Table 13) are estimated from the sensor array defined in section 8 for a glove box allowing for the fact that there are four refrigerated glove boxes. The unit will certainly be equipped with at least one and probably two local controllers to provide analog to digital conversion for the sensors and to multiplex the data. The local controller also sends out signals to control valves. Control of power operated equipment will be provided by the switching power supply called a Power distribution and Control Assembly (PDCA).

Table 13, Interfaces for Sample Analysis Facility

EXTERNAL

DATA MANAGEMENT SYSTEM

Interface to Space Station - 1663 Bus	
Temperature sensors	24
Pressure Sensors	24
$P(O_2)$	9
$P(CO_2)$	9
Valve and Solenoid Drivers	
Motor Speed	10
Current Sensors	10
Latch or discrete sensors	20
Analog output	10
Discrete Output	10

POWER WATTS

208 VAC 20,000 hz (switched)	1
Peak Power usage (w)	2000
Average Power Usage (w)	500

COMMUNICATIONS AND TRACKING

Mounting Points for External Pan/Tilt units

THERMAL CONTROL SYSTEM

The unit will have integral body mounted radiator

FLUIDS SYSTEM

Waste Gas (for LN_2 dewier)

10.8 Hooks, Scars, and Other Provisions

The addition of additional module is accommodated by the Space Station distributed system architecture.

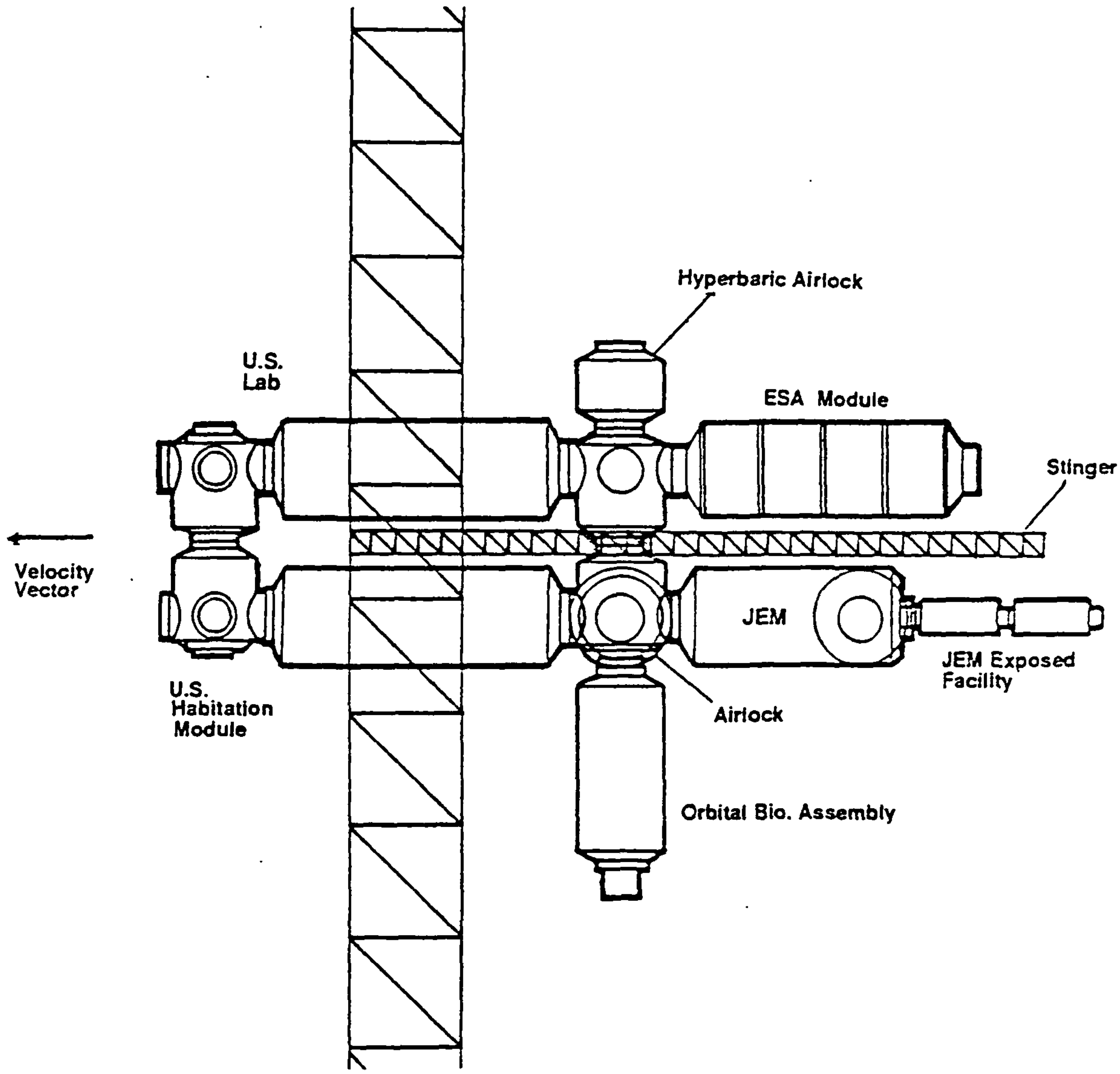


Figure 42, Location for Orbital Processing Facility in a View Looking Down on Space Station

11.0 Conclusions and Recommendation

The following significant conclusions resulted from this study:

1. The author's choice of the Space Station related design reference missions was DRM 1A or 1B (See Table 2 and Table 14). In this option the sample is placed in the SCA canister and returned to Earth without being brought into the Space Station. More work is needed before final decision is made.

   DRM 2A-E do not appear to provide a qualitative reduction in risk of breaking biological isolation over DRM 1. DRM 3 is optimal for biologically isolating the sample. However, the cost of designing, building, testing, delivering to orbit and operating the single purpose facility are extremely high.

2. The phase 1 Space Station is properly scarred to support the scenarios discussed, but enhancements are required. For example, a place to dock the OMV is required. Only two transverse truss Payload fittings are baselined for phase. This mission alone requires at least three, two for the Canister Pallets, one for the OMV.

3. All the scenarios require a place to dock the OMV to the Station. If two MRSR missions are flown at once, propellant module changeout at the Station is desired.

4. There is no inexpensive way to do a biological analysis that would identify an acceptable range of hazards at the Space Station. Short of a dedicated module, only repackaging is possible. A rack on the interior or cabinet mounted on a node only allows repackaging.

5. The Space Station is at the limits of its ability to control the temperature of a cabinet in a module. Special efforts will be required if this path is chosen. Body mounted radiators supporting low temperature. Fluids provide as possible solution, and may be baselined by the program for many modules.

The following recommendations resulted from this study:

1. A specification for the containment of the Mars sample should be developed by the biological community and approved by a mechanism that is both rationally and internationally acceptable. In particular, failure tolerance and sterilization procedures should be agreed upon.

2. The conditions under which the sample will be held should be agreed upon by the parties involved. The temperature, pressure, and type of gas the sample will be held in greatly influence the problems the Space Station will have containing it inside the modules, and in the Canister Pallet.

3. A biological assay protocol must be agreed upon by the political/biological communities concerned. The specifies of this protocol determines the problems the Space Station will have accommodating it. Even a preliminary design of a biological analysis module requires this protocol be agreed upon.

4. The handling of the sample on Earth needs to be defined. The difficulties and cost of handling in space can then be better compared to the costs.

5. Preparations for the Space Station Preliminary Design Review (PDR) should be monitored to make sure the Phase 1 Station has the hooks and scars to support the mission, while it is still possible to get them onboard.

6. The problems of a manned Mars mission with biology should be considered and integrated with the MRSR plan. Must Mars be certified free of life before a crew can land, or will isolation and biological analysis facilities be needed for a manned Mars mission as well. Either way, the MRSR program will be influenced, particularly with regard to the sample analysis and facilities.

7. A risk analysis, assessing probability of mission success, and probability of biological contamination should be performed comparing the several options using the Space Station with direct entry and Shuttle retrieval. The options using the Space Station should be compared with each other, in particular, a repackaging externally, subsample removal internally, and dedicated module analysis.

8. The procedure and hardware for sterile transfer of the sample to the EOC in Mars Orbit needs definition, in particular how it might be made fault tolerant.

9. The canister pallet concept requires a detailed thermal analysis to insure passive thermal control will work. Otherwise, power requirements may go up substantially.

Table 14, Ranking

OPTION	Biological isolation Integrity	IVA Time	EVA Time	Launch Weight	Cost	
1	7	1	1	1	1	Preferred option
2A	5*	2*	6*	2*	2*	
2B	5*	2*	6*	2*	4*	
2C	3*	2*	2*	2*	2*	
2D	3*	2*	2*	2*	4*	
2E	2	2*	4	6	6	
3	1	7	5	7	7	

1 = most desirable
7 = least desirable
* = tie

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