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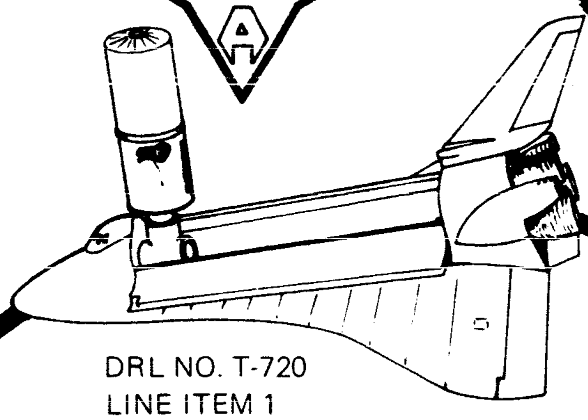

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REPORT NO. T-192-RP05
CONTRACT NAS9-12507

study of space shuttle eva/iva support requirements

VOLUME I
TECHNICAL SUMMARY REPORT

30 APRIL 1973

VOUGHT SYSTEMS DIVISION

STUDY OF SPACE SHUTTLE
EVA/IVA SUPPORT REQUIREMENTS

VOLUME I

TECHNICAL SUMMARY REPORT

REPORT NO. T-192-RP05

30 APRIL 1973

Prepared by:

R. J. Copeland
ECS Systems

P. W. Wood, Jr.
Systems Design

R. L. Cox
Project Engineer

Approved:

R. J. French,
Supervisor,
EC/LS Group

Submitted to

NASA - Johnson Spacecraft Center
Under
Contract No. NAS9-12507

VOUGHT SYSTEMS DIVISION
LTV Aerospace Corporation
P.O. Box 5907
Dallas, Texas 75222

PREFACE

This document is submitted by the Vought Systems Division, LTV Aerospace Corporation, P.O. Box 5907, Dallas, Texas 75222, to the National Aeronautics and Space Administration, Johnson Spacecraft Center (JSC), Houston, Texas, in accordance with Contract No. NAS9-12507, dated 28 March 1972. It is the Final Technical Summary Report, and fulfills the requirements of DRL No. T-720, Line Item 1, DRD MA-182-T. It contains final documentation on Work Breakdown Structure Subtasks 1.3 Life Support System and 1.5 Vehicle Support Provisions. In addition, it summarizes Subtasks 1.1 EVA/IVA Tasks, Guidelines, and Constraints Definition; 1.2 Pressure Suit Requirements; 1.4 Mobility Aids; and 1.6 Emergency IV Support Requirements. It also summarizes a special task on 10 psia Orbiter Impacts. These following Subtasks are, in addition, the subject of separate detailed volumes:

Volume II - EVA/IVA TASKS, GUIDELINES, AND CONSTRAINTS DEFINITION
Volume III- REQUIREMENTS STUDY FOR SPACE SHUTTLE PRESSURE SUITS
Volume IV - REQUIREMENTS STUDY FOR SPACE SHUTTLE MOBILITY AIDS
Volume V - REQUIREMENTS STUDY FOR SPACE SHUTTLE EMERGENCY IV SUPPORT

The special task on the 10 psia Orbiter Cabin Impacts, plus a delta-task on Emergency IV Requirements, were conducted for NASA subsequent to the completion of basic contract work. This was accomplished by agreement between the Technical Monitor, Mr. D. L. Boyston of NASA-JSC, and the VSD Project Engineer, Dr. R. L. Cox. In this connection, the detail of final documentation was relieved, and Volumes I, II, and V are largely updates of briefing material previously presented to NASA.

Work on this contract was conducted over the time period 28 March 1972 through 30 April 1973.

CONTENTS

I SUMMARY

I. SUMMARY

This volume summarizes results obtained for equipment requirements for the space shuttle EVA/IVA pressure suit, life support system, mobility aids, vehicle support provisions, and emergency IV support. An initial study of tasks, guidelines, and constraints and a special task on the impact of a 10 psia orbiter cabin atmosphere are included. Supporting studies not related exclusively to any one group of equipment requirements are also summarized. Other volumes of this report contain detailed data on tasks, guidelines, and constraints, requirements for pressure suits, for mobility aids and for emergency IV support.

During conduct of the program major support was supplied by ILC, Inc. (Dover, Delaware), under subcontract to the Vought Systems Division (VSD), for definition of pressure suit requirements. Consultation support was provided in the areas of tasks, guidelines, and constraints, vehicle support provisions, and emergency IV support requirements through purchase orders with General Dynamics - Convair Aerospace Division (San Diego, California) and Rockwell International Corporation - Space Division (Seal Beach, California).

Representative EVA/IVA task scenarios were defined based on an evaluation of missions and payloads. Analysis of the scenarios resulted in a total of 788 EVA/IVA's in the 1979-1990 time frame, for an average of 1.3 per shuttle flight. Duration was estimated to be under 4 hours on 98% of the EVA/IVA's, and distance from the airlock was determined to be 70 feet or less 96% of the time. Payload water vapor sensitivity was estimated to be significant on 9%-17% of the flights. Further analysis of the scenarios was carried out to determine specific equipment characteristics, such as suit cycle and mobility requirements.

A suit operating pressure of 8 psia was selected. A modular EVA suit made in a standard sizing schedule (up to 9 sizes per module) was found to offer a significant economic advantage and is recommended. Mobility requirements were defined and are considerably in excess of current Apollo/Skylab suit capabilities. A suit useful life of 8 years and a cycle life of 200,000 cycles is recommended. A contaminant barrier overgarment has been defined for use when working near sensitive payloads. Requirements for a separate emergency IV suit were determined, with greatly reduced mobility and again employing modular sizing.

A 4-hour completely portable primary extravehicular life support system (EVLSS) was selected. The basic system recommended has an expendable heat rejection system (water evaporation) and vent gas contaminant control system (LiOH). Crewman temperature control is by a water transport loop and liquid cooling garment. Oxygen storage is at 2100 psia. An optional leg-mounted modular replaceable ice pack (1-hr duration per module) is recommended for use with water vapor sensitive payloads, and an EVLSS contaminant barrier cover has been defined to contain offgassing products. A duplex voice communications system with subcarrier telemetry on voice channels is recommended. A separate 24-minute emergency oxygen pack (EOP) was selected. This system provides cooling, breathing gas, and CO_2 control by blowdown from 7500 psia oxygen storage. The EOP is also used as a contingency transfer life support system and as a portable oxygen supply for emergency face mask usage.

A mobility aid system was defined which includes translational devices, worksite restraints, and worksite provisions. Tethers with a maximum free length of 25 ft. are recommended for all EVA operations. The baseline system selected includes permanent handrails around the periphery of the cargo bay, docking module, and sortie module. Mission-specific handrails on payloads and cargo bay equipment are also included, as required. A manipulator work platform end effector is recommended as a major element of the baseline system. The platform folds for easy stowage in the cargo bay, contains controls for the EVA crewman, includes restraint provisions at the worksite, and provides lighting and tool and equipment transport facilities. Emergency handholds on the vehicle exterior are also recommended; candidates are electro-adhesive devices and burn-off handholds.

Recommended vehicle support provisions are baselined for a capability of two EVA's (one unscheduled, one emergency) for two men. Provisions for planned EVA/IVA are added by carry-on of recharge expendables (LiOH and oxygen) and optional modular ice packs and refreezers. The baseline system includes 2 recharge stations/EVA panels, a liquid loop for crewman cooling during airlock operations, a suit drying loop, a battery recharger, recharge oxygen for the emergency/unscheduled EVA taken from the existing 3000 psia contingency storage, and recharge water taken from the existing fuel cell source. For carry-on oxygen, extra tankage is added to the contingency storage. A carry-on thermoelectric refreezer, which plugs into the airlock water loop for a heat sink, is baselined for ice module regeneration. An airlock depressurization system consisting of a simple vent arrangement is tentatively baselined, with the possibility of an added compressor system to exhaust airlock gas to the cabin recommended for further study.

An emergency IV system is recommended to guard against accidental decompression, fire/smoke/toxic gases, inability to re-enter, and a stranded crewman. A flood flow system is recommended to provide a shirtsleeves 95-minute return capability for the most likely decompression case with an effective hole diameter of less than 1/2 inch. A reduced cabin pressure in the 8-10 psia range is baselined for this condition. For larger hole diameters, pressure suits and a cabin suit loop integrated into the vehicle environmental control/life support system are recommended in order to provide the capability for on-orbit rescue. Other elements of the emergency system include face masks with portable (EOP) or plug-in oxygen supplies, communications and warnings; an EVA capability to inspect/repair external damage; a contingency transfer capability; contingency external mobility aids; a cabin pressure dump capability; portable fire extinguishers; and a basic vehicle capability to stabilize on-orbit in a depressurized mode for rescue. For development flights an escape capsule (Apollo Command Module) is recommended.

II INTRODUCTION

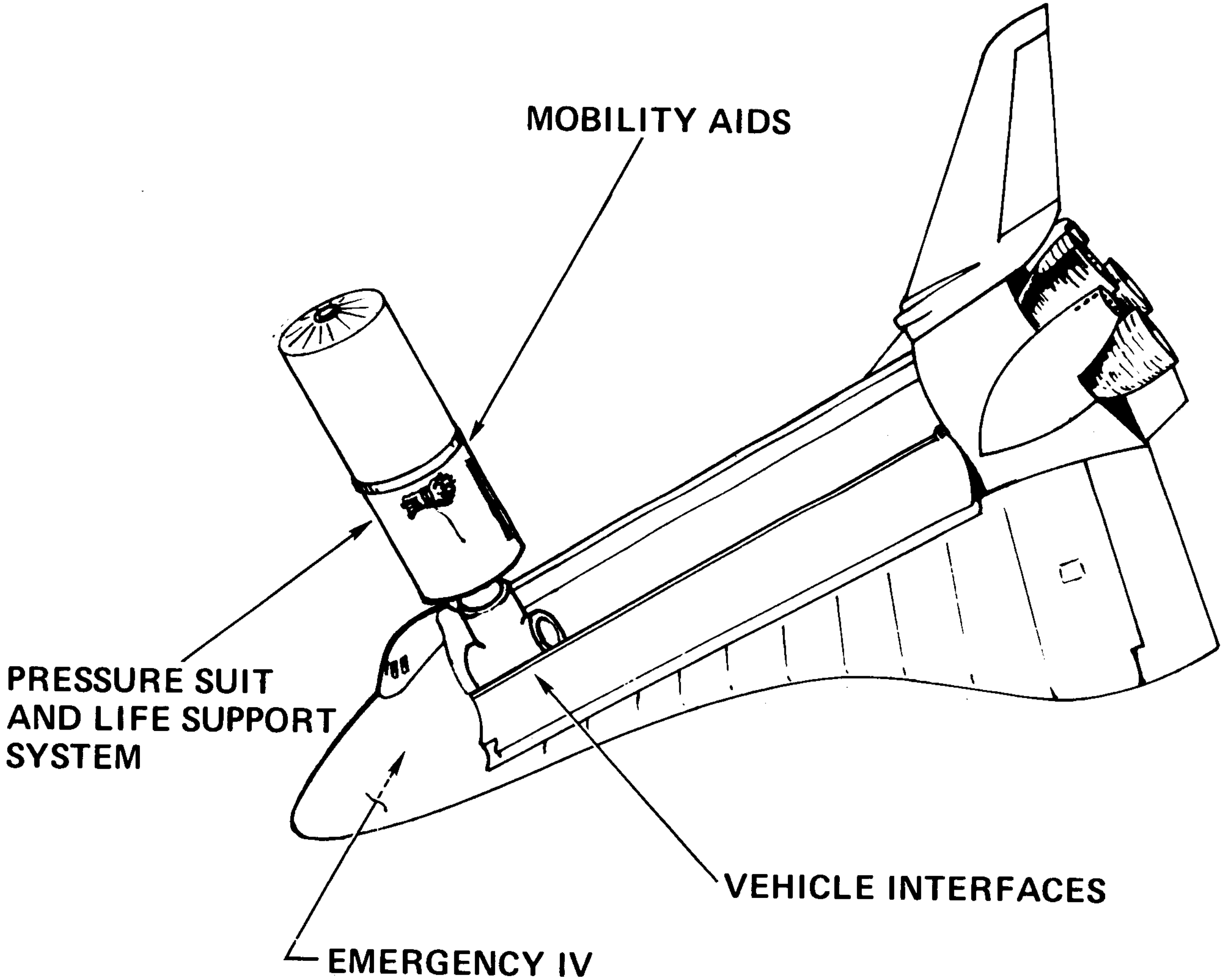
OBJECTIVES

This report is based on briefings given under Contract NAS9-12507, "Shuttle Orbiter EVA/IVA Equipment Support Requirements Study". The objective of the program has been to define the EVA/IVA concept for the shuttle and the resulting equipment requirements. The specific end products are a definition of requirements in the areas of EVA/IVA pressure suits, life support system, mobility aids, vehicle interfaces, and emergency intravehicular activities. Three formal presentations have been given: Tasks, Guidelines, and Constraints Briefing (June 1972); Midterm Briefing (October 1972); and Final Briefing (February 1973). Three informal presentations were also given; Supplementary Briefing (March 1973), IV Emergencies Briefing (April 1973), and Briefing on Impact of 10 psia Orbiter Cabin (April 1973).

A major goal of the study has been to definitize a common-sense engineering approach which utilizes the best capabilities of both EVA/IVA and remotely controlled systems. Results show that a practical EVA/IVA system can be provided which will permit the designer to chose this mode in many cases as a cost-effective operational alternate to other ways of accomplishing tasks. This same EVA/IVA system will provide significant advantages in contingency situations. In all elements of the study, cost effectiveness of each alternate concept was considered as a basic trade parameter.

Terminology used in this report are (1) EVA for extravehicular activity, which implies pressure suited operations external to the confines of the spacecraft and exposed to the full environment of space, and (2) IVA for intravehicular activity, which implies pressure suited operations internal to the confines of the spacecraft but exposed to space vacuum. Shirtsleeves IV activities are not IVA. These terms are consistent with the recommendations of the NASA Committee on Extravehicular Activities.

OBJECTIVES


MOBILITY AIDS
PRESSURE SUIT
AND LIFE SUPPORT
SYSTEM
VEHICLE INTERFACES
EMERGENCY IV

KEY ISSUES

The key issues listed are those central to the selection of the EVA/IVA concept and requirements which will be most beneficial in the overall cost-effectiveness context of the shuttle.

In order to effectively take advantage of man's work performance capabilities and use EVA/IVA as a routine tool, the man-hour "overhead" must be minimized. The major "overhead" items normally associated with EVA are prebreathing, don/doff/checkout times, and the standby assignment of a second suited crewman for contingency purposes.

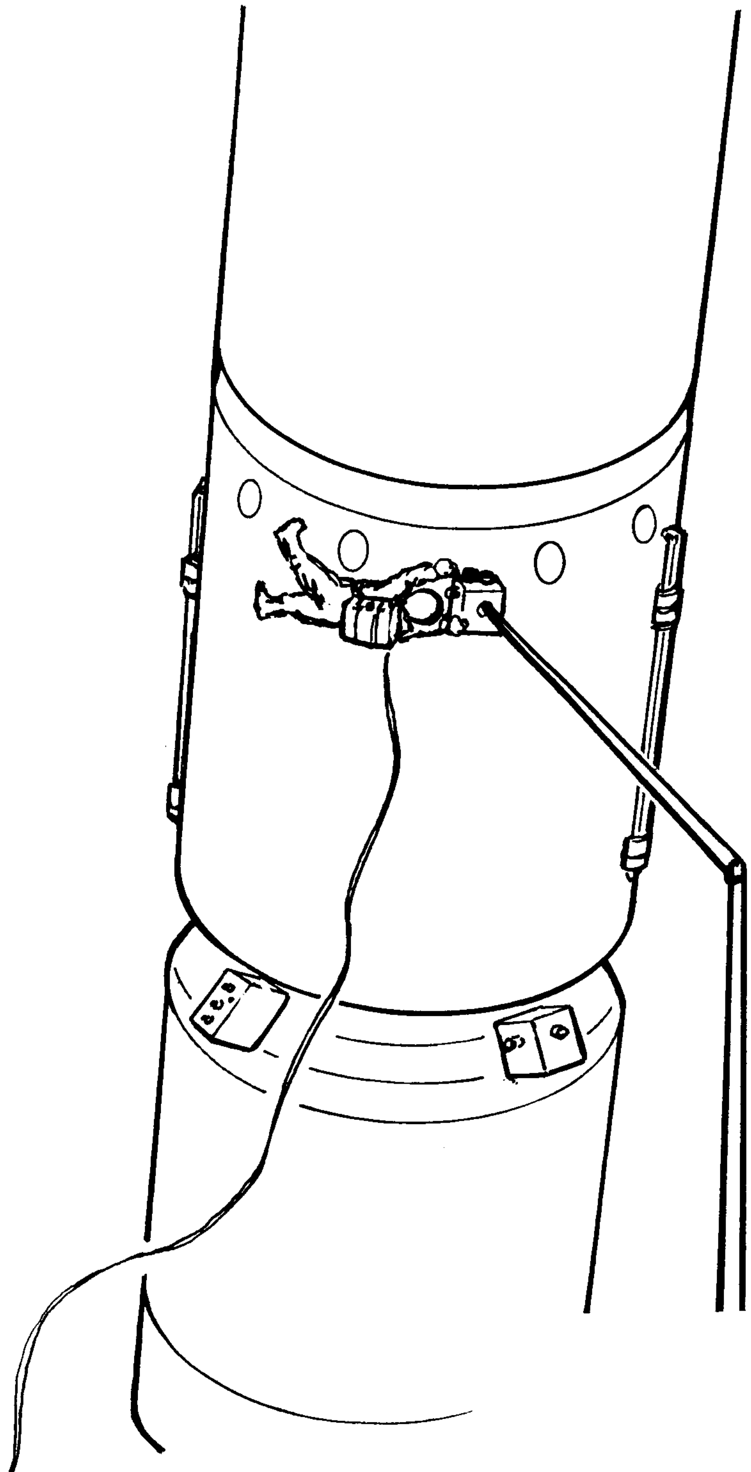
Another primary issue is the capability of the EVA/IVA equipment to effectively perform the task at hand. The crewman should be able to execute a high percentage of all tasks that are viable EVA/IVA operational alternates, and should not be hindered in effectiveness by poor suit mobility, a bulky EVA life support system, or a restrictive umbilical. A trade is implied, of course, between percentage task capability and costs involved to obtain the capability.

Some payloads contain contamination sensitive optical instruments, sensors, and subsystem components. Sophisticated counter measures have been devised to avoid their contamination by the orbiter. Thus another important issue relative to EVA/IVA utility is the capability of the EVA/IVA equipment to operate near these payloads without contaminating them.

Normally, for a large number of missions, reusability and maintainability are found to be cost effective relative to short life expendable systems, even though the reusable systems entail development costs. However, especially in the case of suits with a relatively large 12-year crew complement, each with his own suit, the question of reusable vs existing expendable hardware must be evaluated. Involved are both the economics of the hardware itself as well as differences in task effectiveness.

To be of positive benefit, the EVA/IVA capability should not only result in cost savings, but should also add to the total safety of orbital operations. While the EVA/IVA equipment must be designed with its own safety in mind, it should also provide the capability for survival (and possibly repair) when orbiter internal or external emergencies occur.

Payload costs will be an increasingly important consideration in future designs, and recent studies have shown major savings can be obtained by designing to utilize shuttle orbiter capabilities. Significant additional savings, such as relaxation of certain redundancy requirements, will be possible by the availability of EVA. The EVA equipment, payloads, and orbiter payload handling systems must be designed to work effectively with each other.



KEY ISSUES

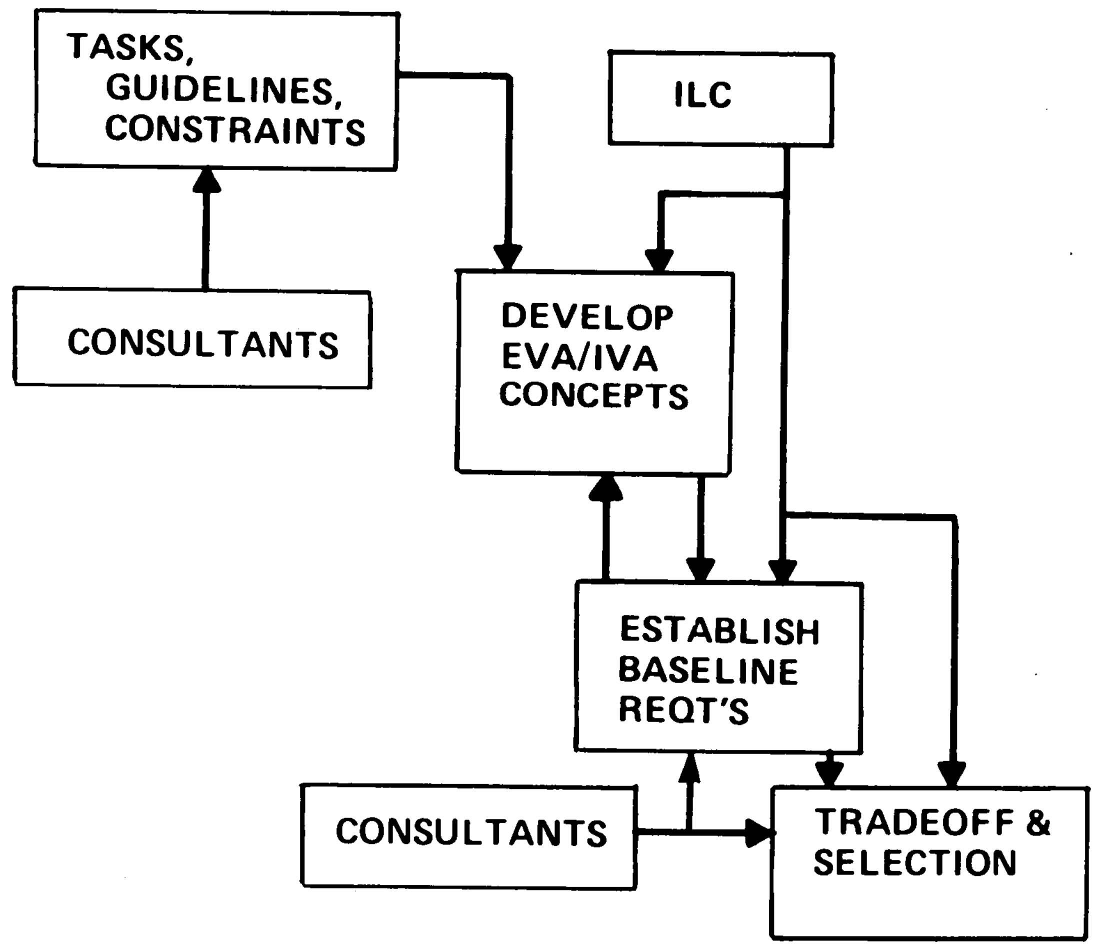
- EVA MAN-HOUR OVERHEAD
- TASK PERFORMANCE EFFECTIVENESS
- CONTAMINATION LEVEL AROUND SENSITIVE EXPERIMENTS
- REUSABILITY AND MAINTAINABILITY
- SAFETY
- OVERALL ORBITER EFFECTIVENESS

STUDY PLAN

The accompanying chart illustrates the flow of effort in the study. In the area of pressure suits, the International Latex Corporation (ILC) has participated with VSD as a major subcontractor, with the responsibility for defining suit requirements.

VSD was also assisted in the study by two formal consultants; General Dynamics-Convair in the areas of sortie missions and free flying observatory payloads, and North American Rockwell-Space Division in the areas of vehicle interfaces and general payload interfaces. Coordination with the McDonnell Douglas Astronautics Company-West was carried out on an informal basis in the area of the Shuttle Orbital Applications Requirements (SOAR) study.

STUDY PLAN


TASKS,
GUIDELINES,
CONSTRAINTS
ILC
CONSULTANTS
DEVELOP
EVA/IVA
CONCEPTS
ESTABLISH
BASELINE
REQT'S
CONSULTANTS
TRADEOFF &
SELECTION

III TASK ANALYSIS

SCOPE

The activities considered in this study were planned, unscheduled, and contingency EVA/IVA tasks. These terms are defined consistent with the recommendations of the NASA Committee on Extravehicular Activities as:

PLANNED EVA/IVA - activity which is included in the mission flight plan for the purpose of fulfilling the specific objectives of that mission.

UNSCHEDULED EVA/IVA - activity which is only performed as a planned backup to a primary method of carrying out a required mission function; for example, EVA performed to manually deploy an experiment that failed to deploy automatically.

CONTINGENCY EVA/IVA - activity performed to repair, refurbish, or maintain critical spacecraft systems or following failure of EV/IV life support system or suit, personnel rescue from research module, etc.

Planned or unscheduled EVA/IVA was identified, either as a primary mode, in conjunction with automated systems, or as a backup mode when consistent with the following considerations:

- Precise feedback is required
- The use of small force gradations is required
- Stereopsis is required
- Precise placement is required
- Several manipulator terminal devices would be required
- A wide field of view is required
- Access is restricted
- No hazards are present
- Work area outside manipulator envelope
- Primary means malfunctioned

The range of missions considered in the study included the full repertoire of shuttle capabilities, as illustrated in the list. From this comprehensive evaluation of candidate tasks, 7 representative tasks were selected and defined in detail for use in deriving requirements for mobility aids, suit cycles, EVA duration, etc. In addition to these representative tasks, emergency scenarios were also evaluated in detail, and are summarized under Section X-Emergencies.

SCOPE

ACTIVITIES

- PLANNED EVA/IVA
- UNSCHEDULED EVA/IVA
- CONTINGENCY EVA/IVA

MISSIONS

- SATELLITE PLACEMENT, RETRIEVAL, & SERVICE/ MAINTENANCE
- PROPULSIVE STAGES & PAYLOADS
- SORTIE
- LOGISTICS
- RESCUE

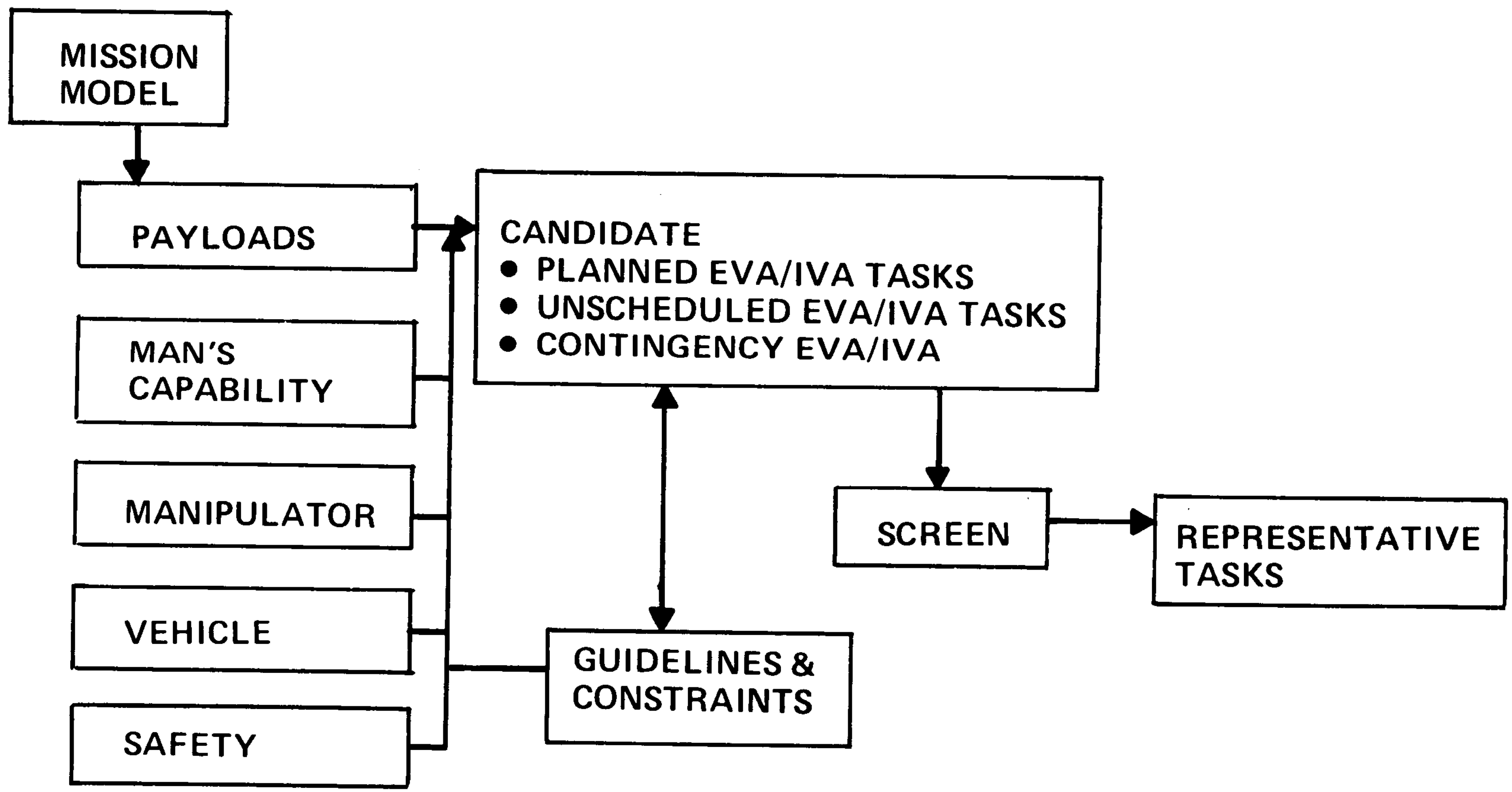
TASKS, GUIDELINES, AND CONSTRAINTS

In deriving tasks, guidelines, and constraints, payloads were first identified from the mission model. Payload requirements, together with man and manipulator capabilities, vehicle characteristics and operations, and safety considerations led to a definition of candidate tasks. Guidelines and constraints were also established from these considerations.

Scenarios were established, and screening criteria, such as commonality of EVA or IVA activities, were applied to derive representative planned and unscheduled tasks.

Tasks and task analysis are discussed in this section; guidelines and constraints in the following section.

TASKS, GUIDELINES, CONSTRAINTS



SOURCE DATA

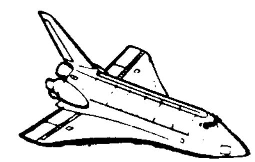
During the course of the study, the orbiter configuration has crystallized somewhat with the selection of a Phase C/D contractor and the development of the design past the Preliminary Requirements Review (PRR) in October 1972. The present study has maintained pace with the evolving configuration through the consultation arrangement with Rockwell International and close liaison with NASA-JSC.

A significant effort has been expended to maintain abreast of current payloads developments, some of the major data sources are listed. VSD participated in the September 1972 "Shuttle Payload Control and Checkout Conference" sponsored by McDonnell Douglas.

Mission and traffic models have evolved considerably during the period of study. The March 1972 shuttle RFP baseline traffic model was updated by VSD to include changes identified in the June 1972 NASA mission model. VSD also conducted an analysis to include retrievals in the traffic model for increased realism. The result has been the study baseline since August 1972. It has been compared to the most recent NASA traffic model (October 1972) and is considered to be representative for NASA payloads (the October 1972 model excludes commercial, DOD, and retrieval payloads).

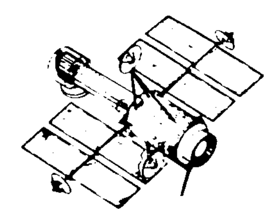
SOURCE DATA

ORBITER DATA



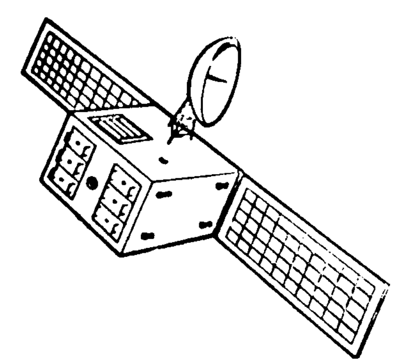
- JANUARY 1973 150K BASELINE
- OCTOBER 1972 PRR BASELINE
- ROCKWELL INTERNATIONAL
- NASA-JSC

PAYLOADS DATA



- RAM, SOAR II, SORTIE LAB
- AEROSPACE DATA BOOKS
- MAJOR PAYLOAD STUDIES (LST, LOCKHEED, HEAO, ETC.)
- TUG AND EXPENDABLE UPPER STAGE STUDIES
- MODULAR SPACE STATION STUDIES

MISSION AND TRAFFIC MODELS



- MARCH 1972 NASA-JSC TRAFFIC MODEL
- JUNE 1972 NASA-HEADQUARTERS MODEL
- INTEGRATED TRAFFIC MODEL BY VSD

EVA/IVA TASKS

Seven situations were selected to describe representative planned, unscheduled, and contingency tasks which a crewman could perform by EVA and unpressurized IVA during Orbiter operations. Contingency tasks will be covered further in the section titled EMERGENCY. Scenarios were prepared for each of these situations utilizing published references as data sources for physical characteristics of the equipment being discussed.

Each situation is shown pictorially and the associated EVA/IVA tasks enumerated.

These EVA/IVA tasks were analyzed to define representative performance requirements. The results of these analyses are presented.

EVA/IVA TASKS

1. EVA MAINTENANCE OF A LARGE SPACE TELESCOPE (LST)
2. EVA/IVA SUPPORT OF A EARTH OBSERVATION SORTIE
3. SATELLITE AND TUG RETRIEVAL AND DEPLOYMENT READINESS
4. EVA INSPECTION AND REPAIR OF THE ORBITER VEHICLE EXTERIOR
5. DEPLOYMENT AND RETRACTION OF PLASMA WAKE EXPERIMENTS
6. MAINTENANCE OF AN X-RAY ASTRONOMY OBSERVATORY
7. MAINTENANCE AND SERVICING OF ASTRONOMY EXPLORER

EVA MAINTENANCE OF A LARGE SPACE TELESCOPE (LST)

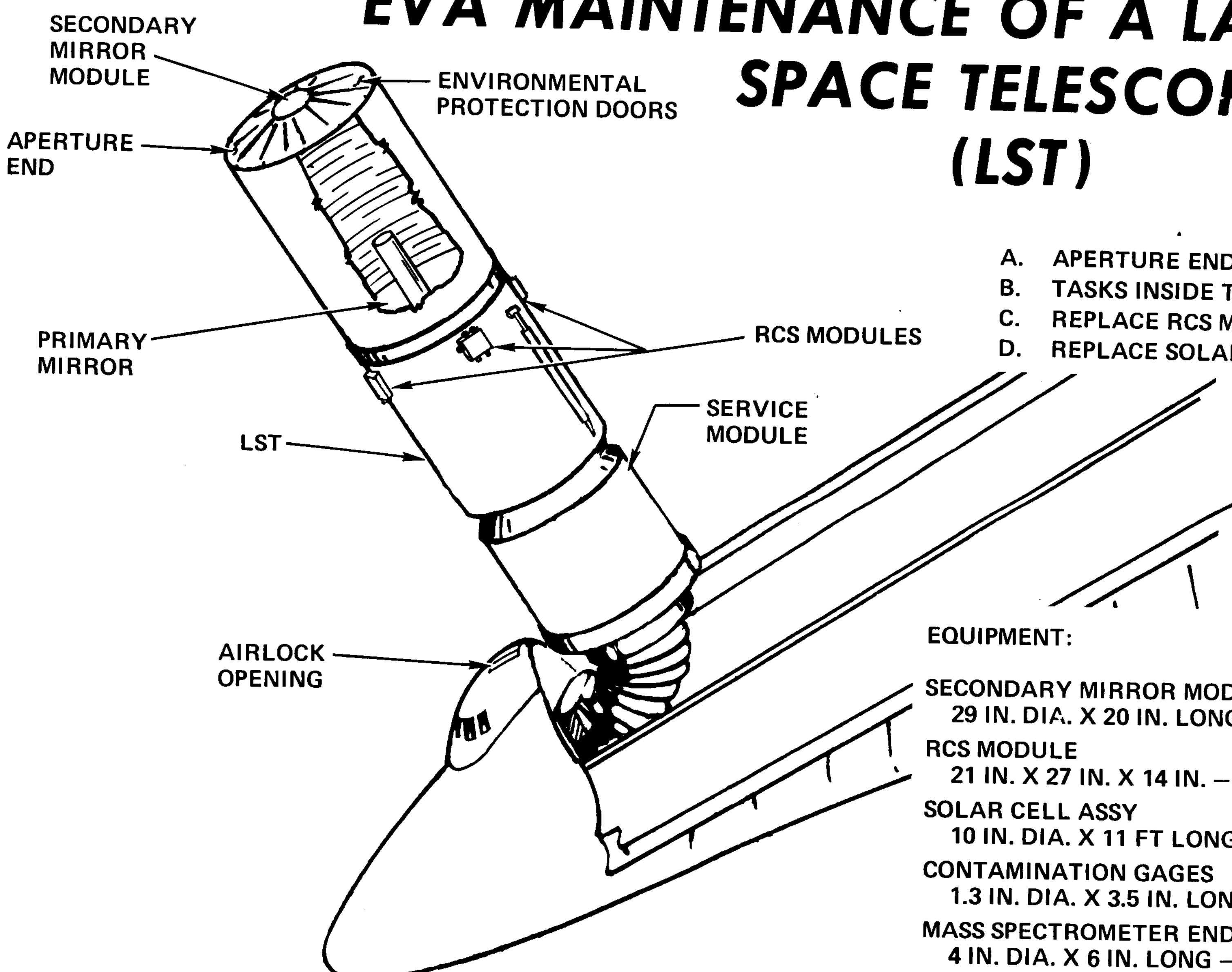
Nine Large Observatories plus two Meteoroid and Exposure Modules (MEM) are to be placed in orbit and left as unmanned free flying satellites for several months at a time. The nine observatories will require periodic maintenance and servicing and sample panels must be removed from the MEM before being placed in orbit and before recovery. The four EVA's listed are representative of these tasks.

Aperture End tasks are the replacement of the Secondary Mirror Module, six Contamination monitoring gages and two mass spectrometer end instruments.

Tasks inside the telescope tube are replacement of four contamination monitoring gages and cleaning the primary and secondary mirror surfaces.

Sketches of some of the equipment utilized in this scenario are presented on the following pages.

EVA MAINTENANCE OF A LARGE SPACE TELESCOPE (LST)



A. APERTURE END TASKS EVA
B. TASKS INSIDE TELESCOPE TUBE EVA
C. REPLACE RCS MODULES EVA
D. REPLACE SOLAR CELL ASSYS EVA

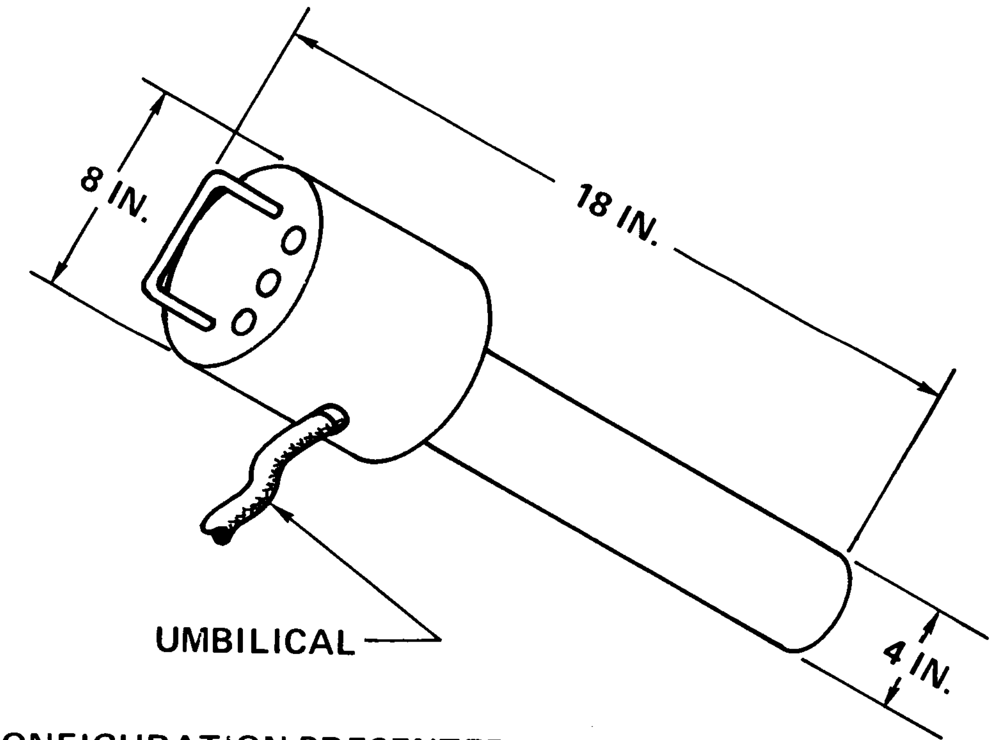
EQUIPMENT:

SECONDARY MIRROR MODULE
29 IN. DIA. X 20 IN. LONG – 120 LBS
RCS MODULE
21 IN. X 27 IN. X 14 IN. – 170 LBS (WET)
SOLAR CELL ASSY
10 IN. DIA. X 11 FT LONG – 90 LBS
CONTAMINATION GAGES
1.3 IN. DIA. X 3.5 IN. LONG – .5 LBS
MASS SPECTROMETER END INST.
4 IN. DIA. X 6 IN. LONG – 2 LBS
ACTIVE CLEANING DEVICE
8 IN. DIA. X 18 IN. LONG – 5 LBS

ACTIVE CLEANING DEVICE

The configuration shown is for any cleaning technique which is to be developed and proven by tests in an actual space flight environment. It is therefore the configuration which would be used for cleaning the LST primary and secondary mirror surfaces. Any cleaning medium such as ionized oxygen could be supplied by umbilical as shown.

ACTIVE CLEANING DEVICE



- CONFIGURATION PRESENTED IN BLUE BOOK

EXAMPLE REPLACEMENT COMPONENTS

Contamination Monitoring Gage

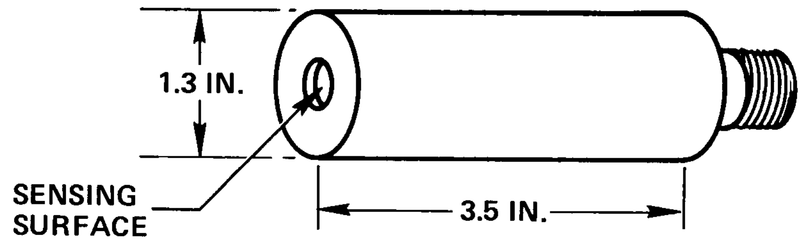
A Quartz Crystal Contamination gage for real time contamination monitoring. From the output of these gages rate of buildup and the state of the contaminant (solid, liquid or vapor) can be determined. Used on astronomy and Earth Observation payloads.

Mass Spectrometer End Instrument

An instrument for measuring the chemical composition of contamination gas. Measurements of neutral particle concentration in a mass range of 0 to 300 atomic mass units (amu) will be made on selected payloads.

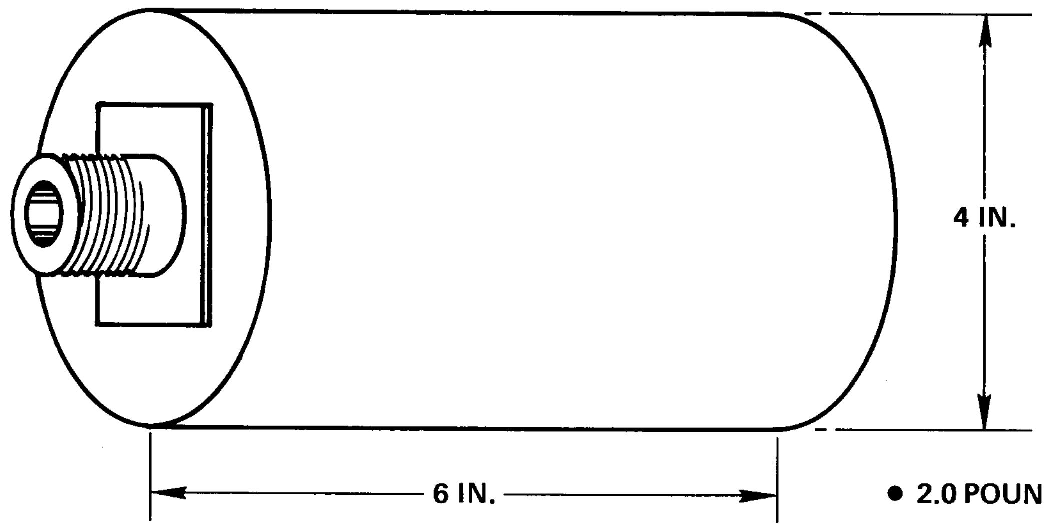
EXAMPLE REPLACEMENT COMPONENTS
(CARGO OR SPARE PARTS)

- CONTAMINATION MONITORING GAGE



- 0.5 POUND

- MASS SPECTROMETER END INSTRUMENT



- 2.0 POUNDS

EXAMPLE REPLACEMENT COMPONENTS

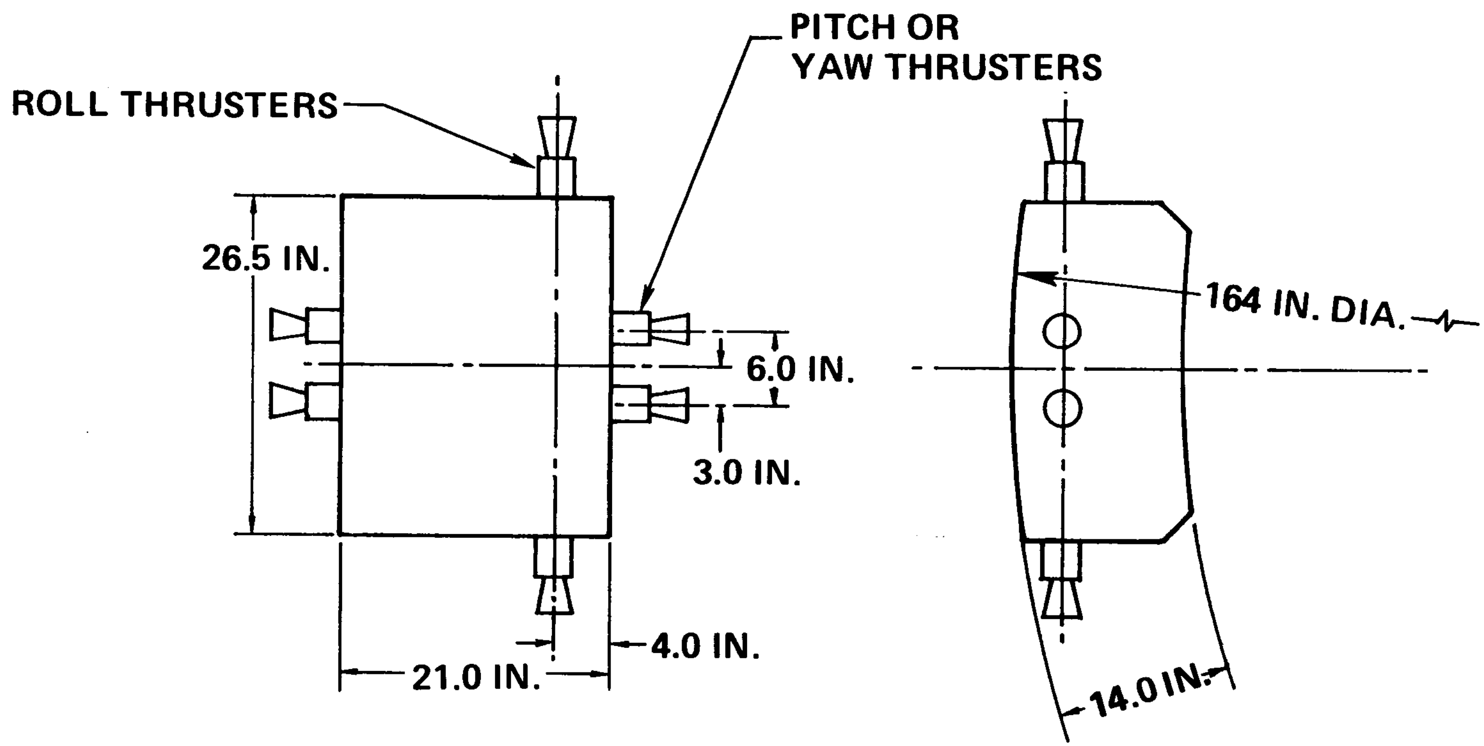
R.C.S. Module For Large Observatories

This module contains thrusters plus propellant. Four are used on each Free-flying Large Observatory to hold attitude during control moment gyro momentum dump. The 170 pound weight is a wet weight.

EXAMPLE REPLACEMENT COMPONENTS

(CARGO OR SPARE PARTS)

R.C.S. MODULE FOR LARGE OBSERVATORIES



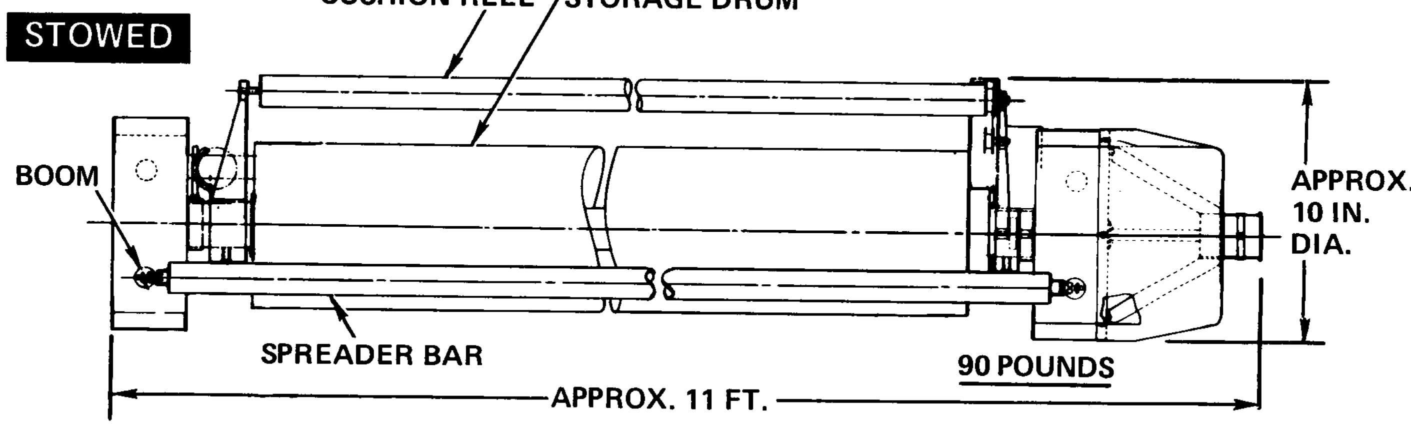
170 POUNDS

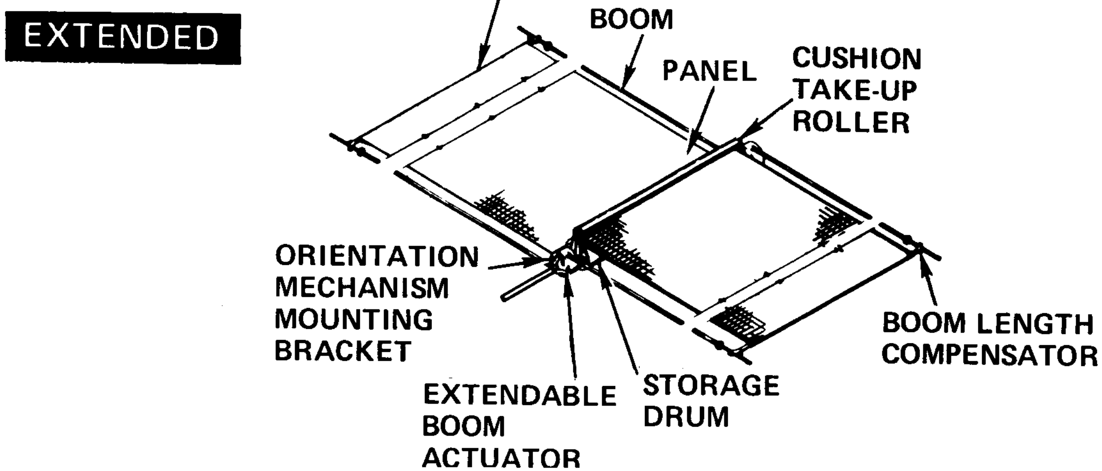
EXAMPLE REPLACEMENT COMPONENTS

Solar Cell Array For Large Observatories

This assembly contains flexible solar cells plus actuators and drums for extending and retracting. Two are used on each Free-flying Large Observatory for producing electrical power. This assembly has the largest moment of inertia (21 slug - ft^2) of the cargo packages considered.

EXAMPLE REPLACEMENT COMPONENTS
(CARGO OR SPARE PARTS)
SOLAR CELL ARRAY FOR LARGE OBSERVATORIES





EVA/IVA SUPPORT OF AN EARTH OBSERVATION SORTIE

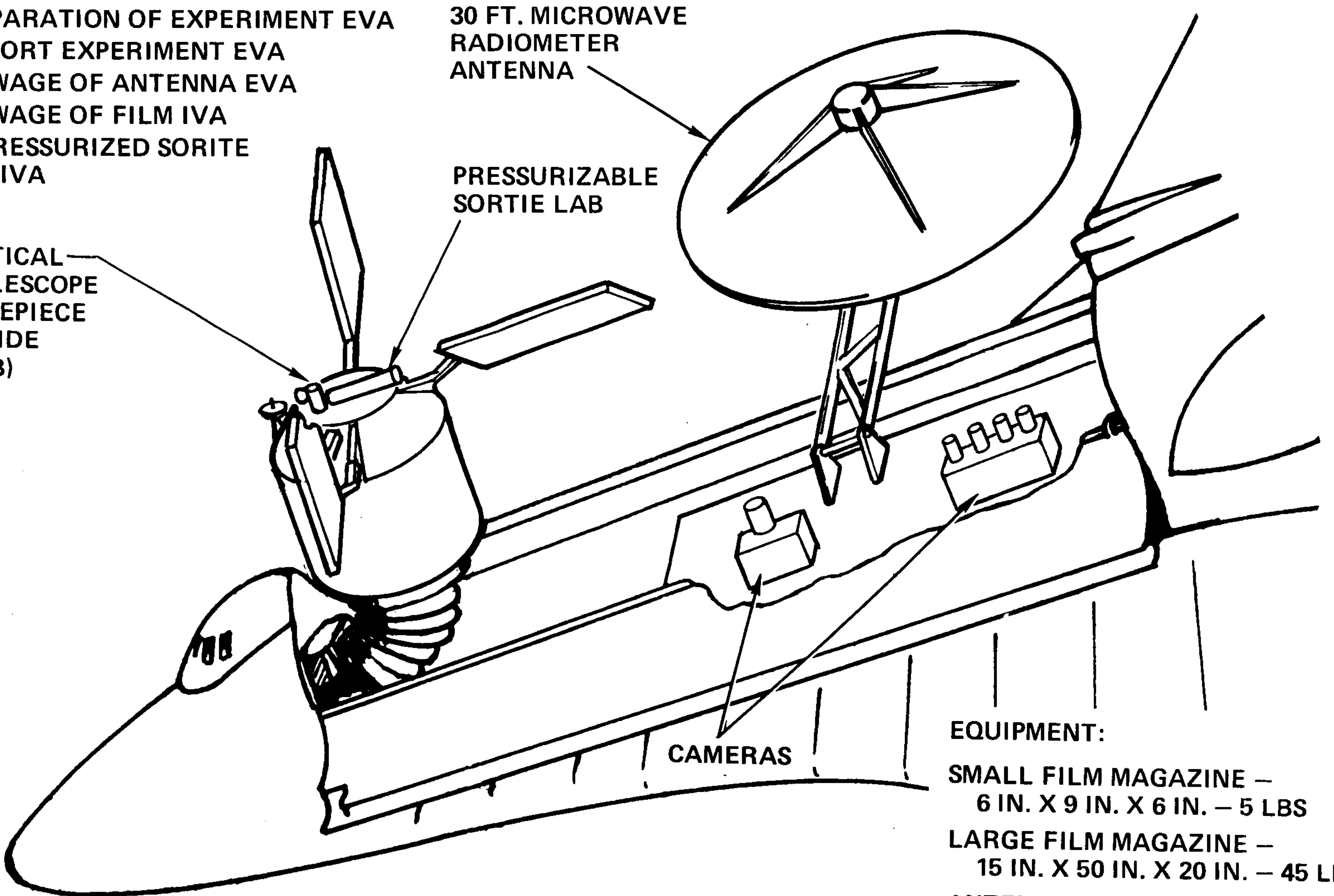
Fifty-six (56) sortie missions are to be flown during the 12 year period of 1979 through 1990. Several of these missions could use EVA and IVA for planned tasks and many of them could, in a contingency situation, be completed by unpressurized IVA in case of loss of pressurization in the Sortie Facility. The five tasks listed are representative of the tasks which could be accomplished EV and unpressurized IV on sortie mission.

Task E Unpressurized Sortie Facility requires that an IVA crewman use the optical telescope to locate areas on the earth and aim sensors while wearing a pressurized space suit. This task is representative of the use of a precise optical instrument while wearing a space suit such as the initialization of an inertial reference unit in a kick stage prior to release. Initialization assistance could be accomplished by an EVA crewman in the rear of the payload bay using a theodilite.

The 30-ft antenna is from the Blue Book description of some earth observation sorties. This size antenna would be very difficult to automatically erect and collapse. It was left off the sortie RAM definitions for this reason. General Dynamics suggested this as an EVA task that would contribute greatly to sortie operations. The antenna is assumed to be broken into a base plus 10 dish segments. The base would be assembled and mounted such that it could be manually rotated or erected into position. The antenna segments would then be assembled on the base.

EVA/IVA SUPPORT OF AN EARTH OBSERVATION SORTIE

A. PREPARATION OF EXPERIMENT EVA
B. SUPPORT EXPERIMENT EVA
C. STOWAGE OF ANTENNA EVA
D. STOWAGE OF FILM IVA
E. UNPRESSURIZED SORITE LAB IVA



EQUIPMENT:

SMALL FILM MAGAZINE – 6 IN. X 9 IN. X 6 IN. – 5 LBS
LARGE FILM MAGAZINE – 15 IN. X 50 IN. X 20 IN. – 45 LBS
ANTENNA DISH SEGMENTS – 9.5 FT X 15 FT X 1.5 FT – 20 LBS

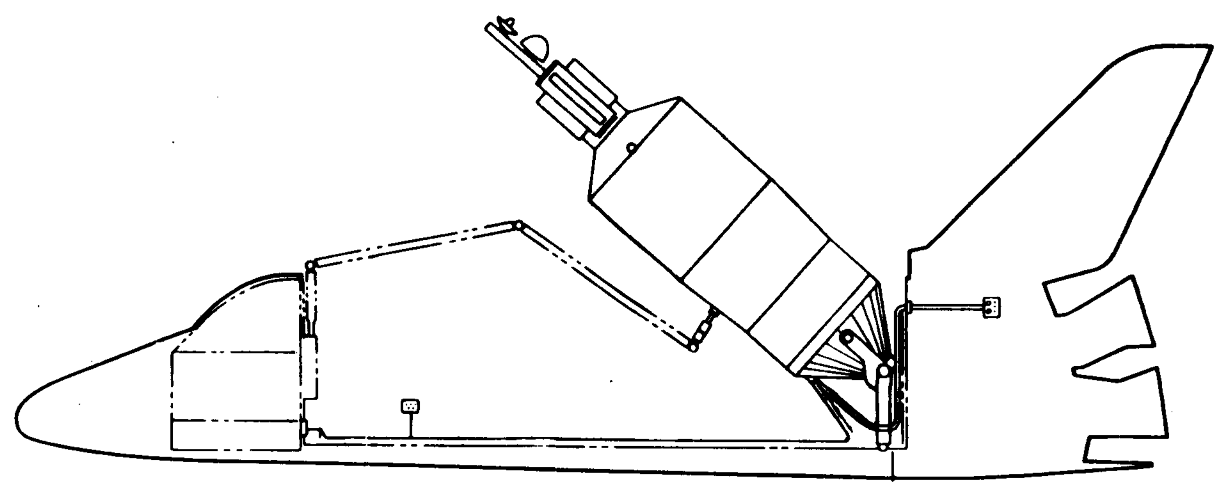
SATELLITE AND TUG RETRIEVAL AND DEPLOYMENT READINESS

The Shuttle Traffic Model, MSC-16746 dated March 31, 1972, and the later Mission Model dated June 6, 1972 show that the Orbiter vehicle handles (delivers to orbit, retrieves or revisits) NASA or DOD payloads 816 times in the 12 years from 1979 through 1990. A retrieval analysis identified 260 satellites currently orbiting the earth which are within the Orbiter vehicle's capability to retrieve, and 259 NASA Orbiter flights as having retrieval capability, either by Orbiter alone or by Orbiter plus the tug. If 50% of these Orbiter flights retrieve a satellite and the same ratio of retrievals is applied to the DOD flights, 129 NASA and 55 DOD payloads would be retrieved. This brings the total of times the Orbiter vehicle handles payloads to 1000. There exists a potential for a planned or unscheduled EVA or IVA each time a payload is handled.

This scenario is representative of the tasks which could be accomplished, either planned or unscheduled, to assist in making a satellite or tug ready for delivery, retrieval or revisit.

SATELLITE AND TUG RETRIEVAL AND DEPLOYMENT READINESS

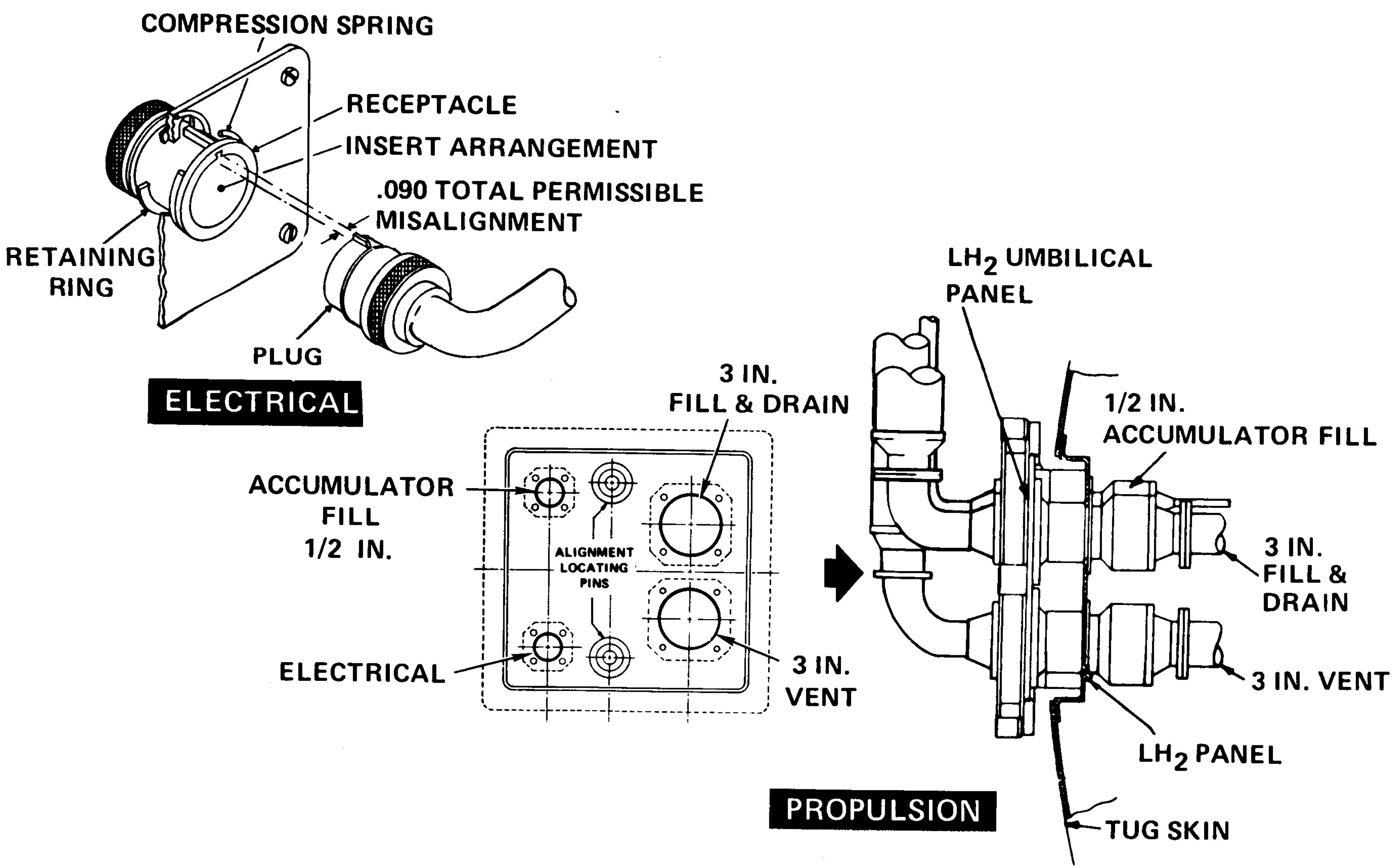
- Connecting & Disconnecting Umbilicals
- Removing & Installing Instrument and Lens Covers
- Purging Systems
- Inspecting Payloads for Safety and Health
- Securing Payloads in Payload Bay
- Stowing Deployed or Erected Devices



REPRESENTATIVE UMBILICALS

These are the types of umbilical connectors which will be used on the reusable tug. Similar umbilical connectors will be used on Satellites which are to be checked out prior to release from the Orbiter vehicle. The umbilical connectors on the tug are currently configured to be remotely connected and disconnected. An EVA crewman could connect and disconnect these connectors as a backup to the remote system or the umbilicals could be configured to be manually connected and disconnected by planned EVA.

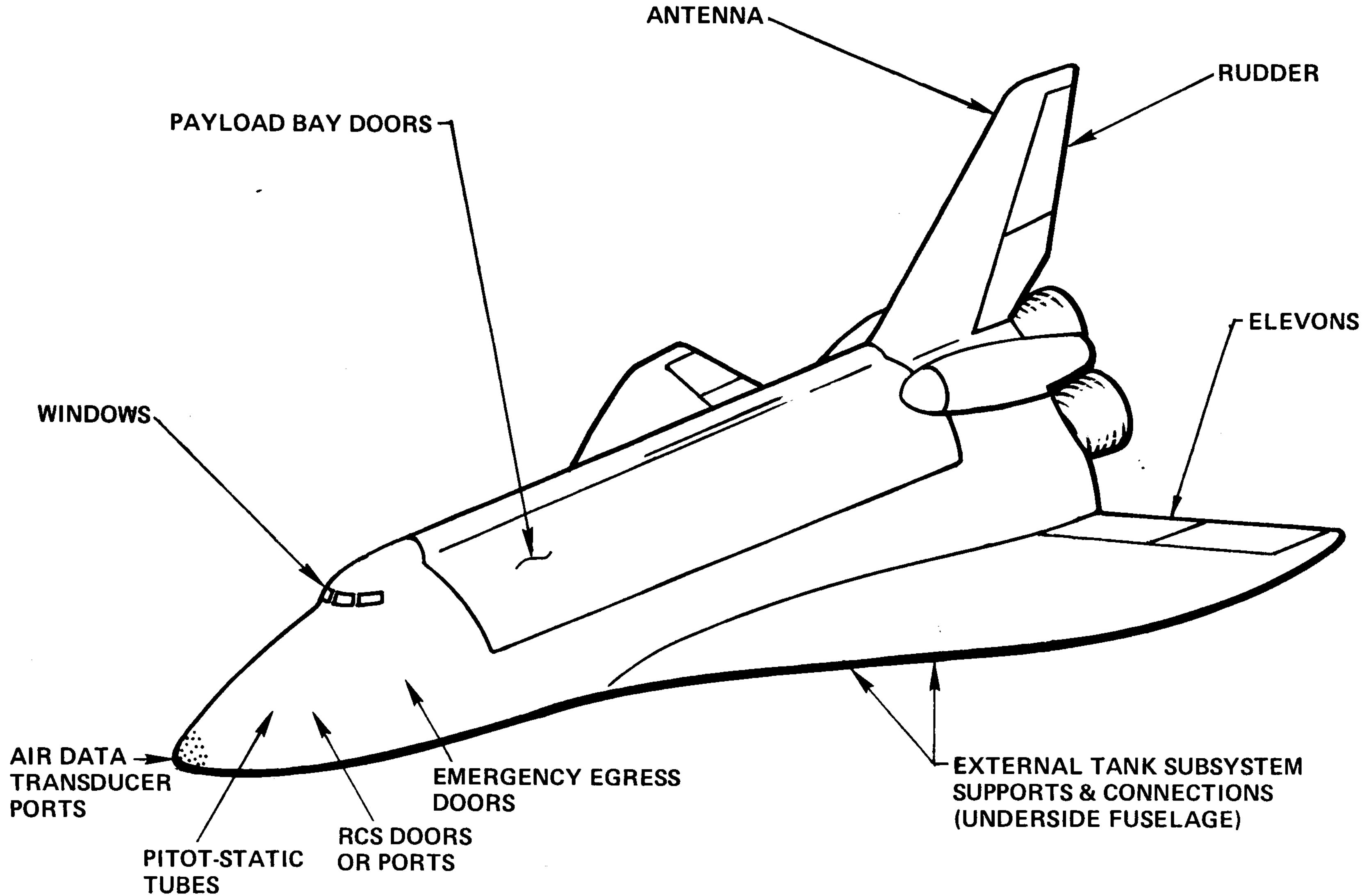
REPRESENTATIVE UMBILICALS



EVA INSPECTION AND REPAIR OF THE ORBITER VEHICLE EXTERIOR

There are almost 600 Orbiter flights planned through 1990. If the Orbiter or payload is damaged or even suspected of being damaged an EVA crewman could effect an unscheduled inspection and possibly repair any damage before de-orbit. The items identified are representative of items which may require inspection and repair on the Orbiter or a payload.

INSPECTION AND REPAIR OF THE ORBITER VEHICLE EXTERIOR



DEPLOYMENT AND RETRACTION OF PLASMA WAKE EXPERIMENTS

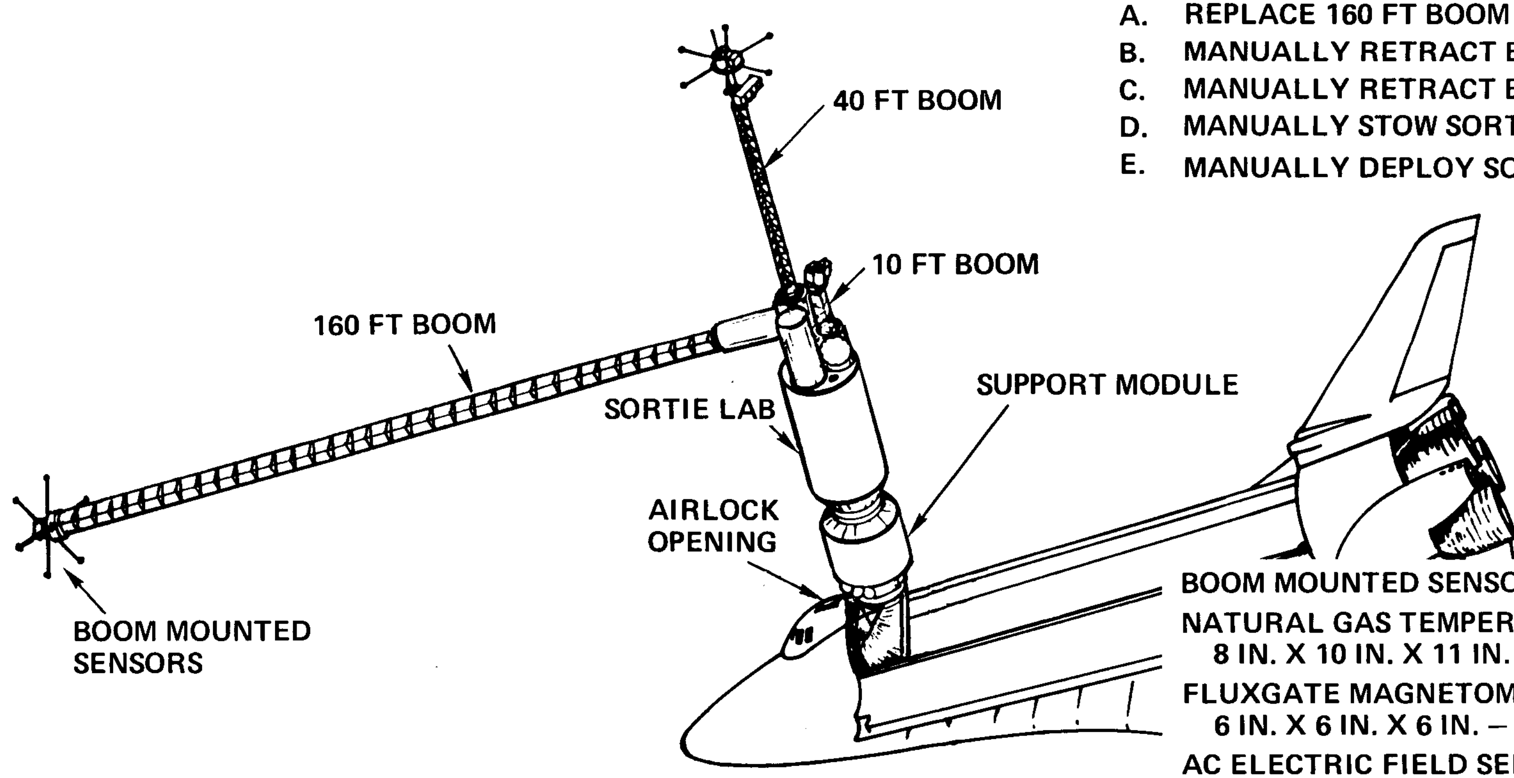
A number of the Sortie experiments utilize extendable booms for deploying sensors and antennas. In the situation where a boom cannot be retracted by the normal means it could be retracted by utilizing unpressurized IVA or EVA and manually retracting it. Also the sensors could be replaced by EVA if the boom cannot be retracted by the normal means.

Some payloads are deployed out of the payload bay prior to release or activation. Should the deployment mechanism fail the payload could be deployed or retracted manually by EVA.

The Plasma Wake Sortie Experiment is a representative payload to be deployed and contains representative boom mounted sensors.

DEPLOYMENT & RETRACTION OF PLASMA WAKE EXPERIMENTS

A. REPLACE 160 FT BOOM SENSORS EVA
B. MANUALLY RETRACT BOOM IVA
C. MANUALLY RETRACT BOOM EVA
D. MANUALLY STOW SORTIE LAB EVA
E. MANUALLY DEPLOY SORTIE LAB EVA



BOOM MOUNTED SENSORS:

NATURAL GAS TEMPERATURE SENSOR
8 IN. X 10 IN. X 11 IN. – 15 LBS

FLUXGATE MAGNETOMETER
6 IN. X 6 IN. X 6 IN. – 5 LBS

AC ELECTRIC FIELD SENSOR
2.5 FT^3 – 30 LBS

DC ELECTRIC FIELD SENSOR
9 IN. X 9 IN. X 12 IN. – 20 LBS

SUPRATHERMAL ELECTRON SENSOR
6 IN. DIA. X 1 IN. – 3 LBS

ION TRAP, PLANAR, THERMAL
5.6 IN. DIA. X 1 IN. – 5.5 LBS

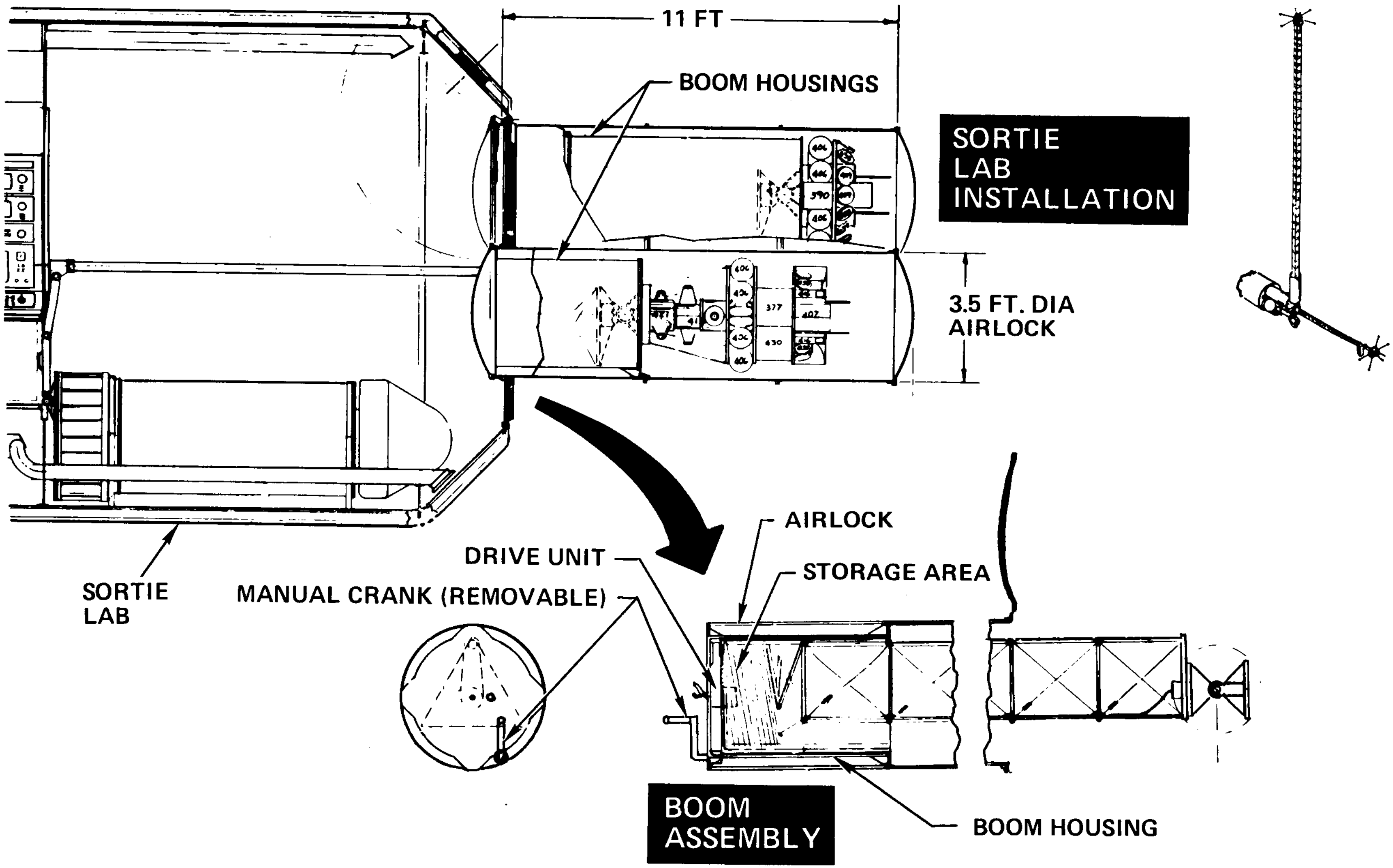
EXTENDABLE BOOMS FOR PHYSICS EXPERIMENTS

This chart shows a small view, upper right, of three booms installed on a sortie lab and erected. The large view, upper left, shows how the booms appear when retracted into the sortie lab airlocks. The lower view shows one boom assembly partially extended out of an airlock.

These booms are normally automatically erected and retracted using controls within the sortie lab. When retracted each boom may be pulled into the area of pressurized sortie lab shown. The sensors mounted on the boom may then be repaired or replaced.

Should any of the booms fail to retract, the airlock outer door could not be closed; therefore, the airlock could not be pressurized, prohibiting pressurized access to the boom. An IVA crewman in a space suit could manually retract the boom by depressurizing the sortie lab, opening the inner airlock door and using a crank, as shown. An EVA crewman could also retract a boom from the open end of the airlock by manually collapsing the boom link by link and forcing it back into the housing until he can close the outer airlock door.

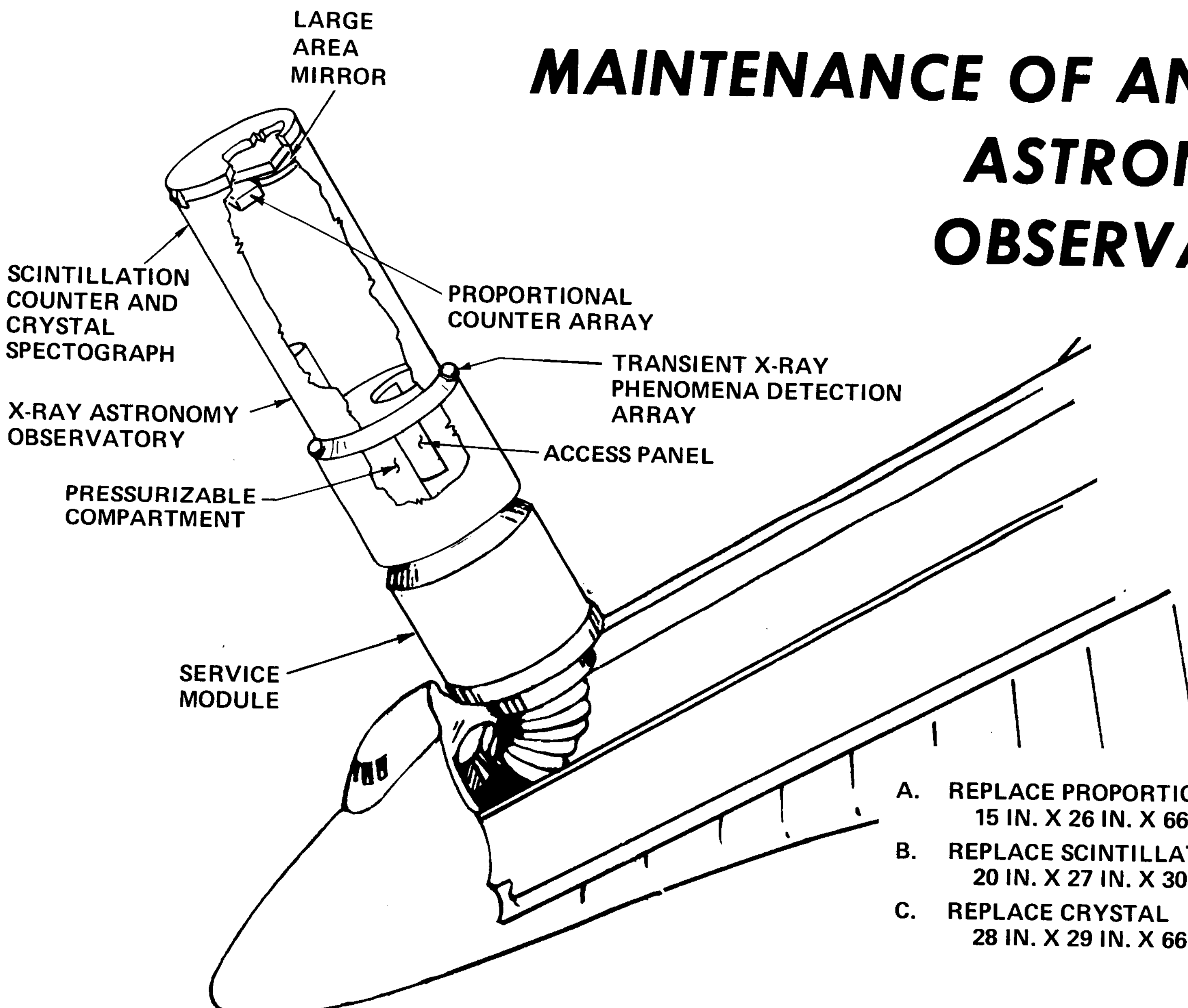
EXTENDABLE BOOMS FOR PHYSICS EXPERIMENTS



MAINTENANCE OF AN X-RAY ASTRONOMY OBSERVATORY

The nine Large Observatories contain large, heavy components. Three such components on the X-Ray Observatory are to be replaced on-orbit by unpressurized IVA. Unpressurized IVA is being considered as the primary mode of observatory maintenance on other observatories. This scenario is representative of several observatories if unpressurized IVA is utilized for maintenance.

MAINTENANCE OF AN X-RAY ASTRONOMY OBSERVATORY



A. REPLACE PROPORTIONAL COUNTER ARRAY
15 IN. X 26 IN. X 66 IN. – 166 LBS

B. REPLACE SCINTILLATION COUNTER
20 IN. X 27 IN. X 30 IN. – 286 LBS

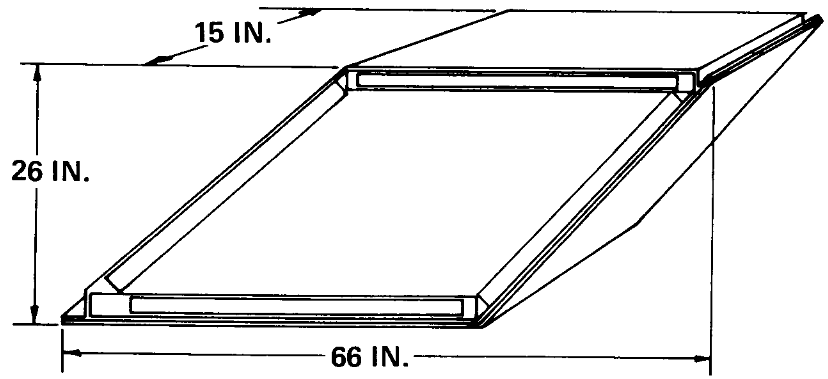
C. REPLACE CRYSTAL SPECTROGRAPH
28 IN. X 29 IN. X 66 IN. – 117 LBS

EXAMPLE REPLACEMENT COMPONENTS

X-Ray Sensors

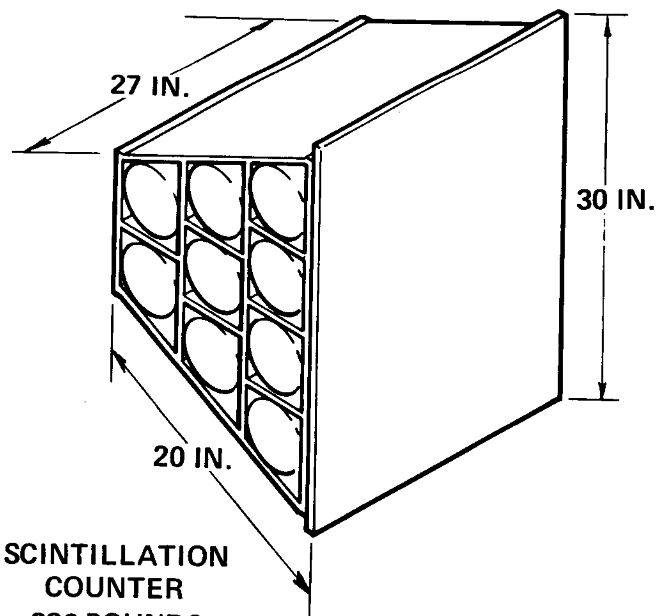
These three sensors are utilized in the Large High Energy Telescope (X-Ray) as a part of a system to obtain data over an energy spectrum from about 2 to 100 angstroms. They represent the three heaviest cargo packages considered.

EXAMPLE REPLACEMENT COMPONENTS (CARGO OR SPARE PARTS)

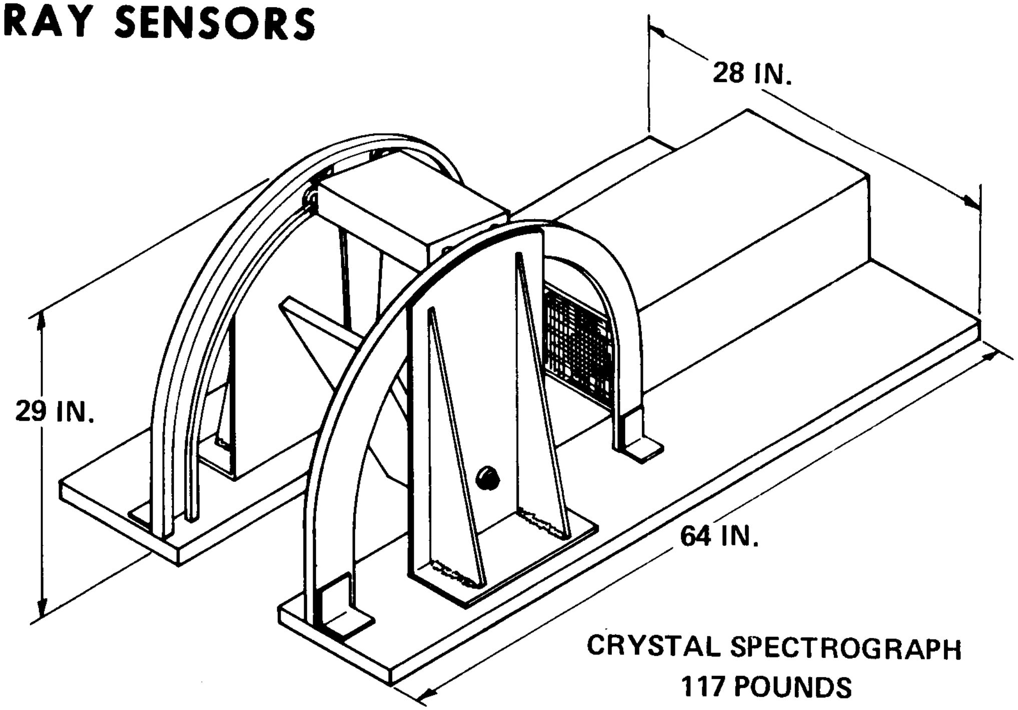


PROPORTIONAL COUNTER ARRAY
166 POUNDS

X-RAY SENSORS



SCINTILLATION
COUNTER
286 POUNDS



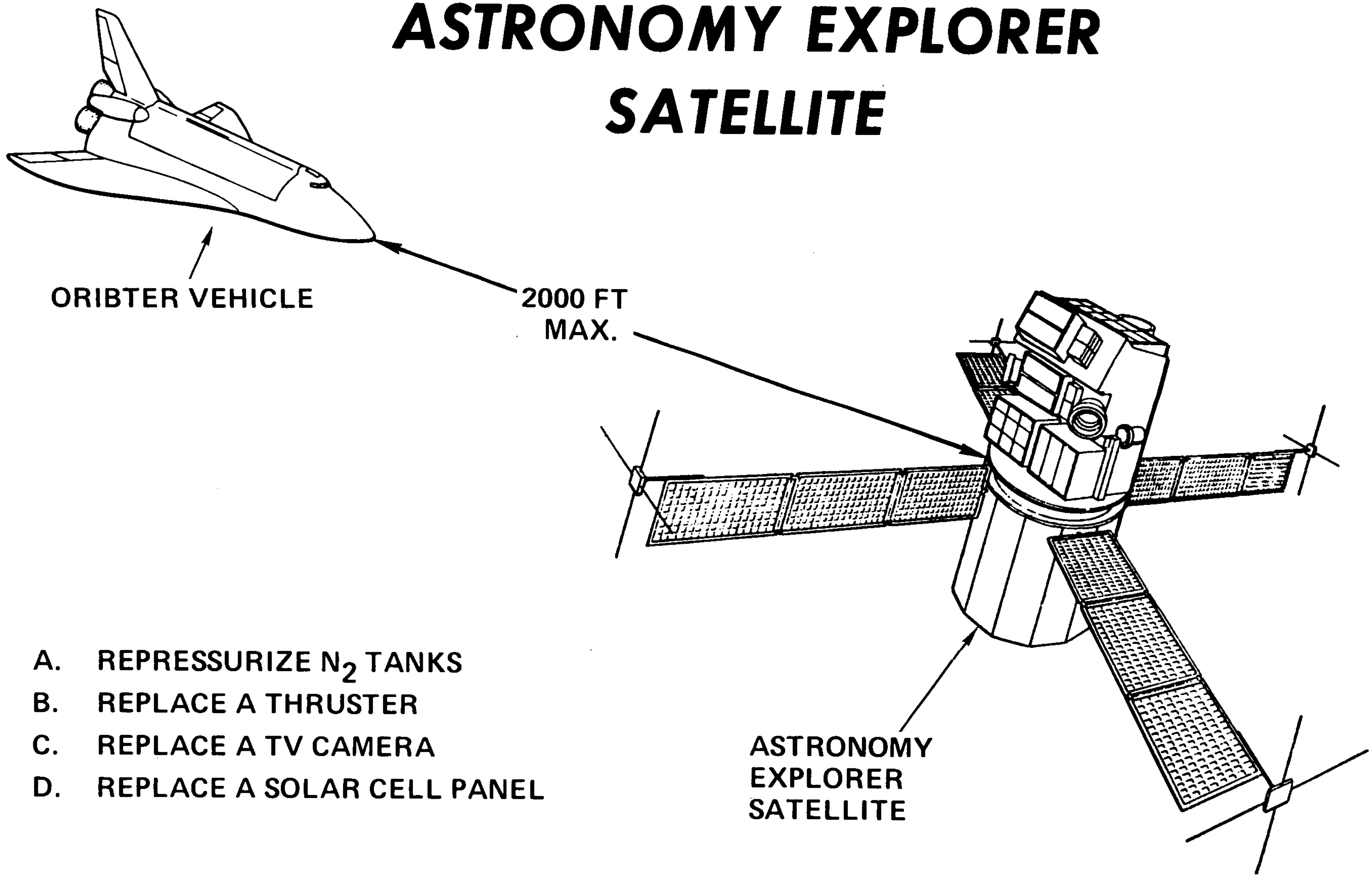
CRYSTAL SPECTROGRAPH
117 POUNDS

MAINTENANCE AND SERVICING OF AN ASTRONOMY EXPLORER SATELLITE

There will be almost 300 unrecovered U.S. satellites in orbit around the earth by the end of 1990 which are within the Orbiter's capability to reach. Some of these satellites will have degraded in performance and could be repaired or serviced by EVA on-orbit to improve performance. The Astronomy Explorer Satellite is representative of a contamination sensitive satellite which could be repaired or serviced on-orbit, and the four tasks listed are typical of tasks which could be accomplished.

(It was established at the Midterm Briefing that this was highly improbable. It was therefore eliminated from further consideration by the contract monitor.)

MAINTENANCE AND SERVICING OF A ASTRONOMY EXPLORER SATELLITE



A. REPRESSURIZE N_2 TANKS
B. REPLACE A THRUSTER
C. REPLACE A TV CAMERA
D. REPLACE A SOLAR CELL PANEL

REPRESENTATIVE SCENARIO EVA'S AND IVA'S

The Shuttle Traffic Model, MSC-06746, March 21, 1972, was updated to reflect the NASA Mission Model dated 6 June 1972. Each type payload was reviewed and EVA's and IVA's chosen as representative when planned, unscheduled or contingency EVA or IVA could be applicable. EVA's and IVA's on DOD Orbiter flights were estimated for payloads similar to NASA payloads. The numbers of EVA's and IVA's illustrated are estimated as representative of what will actually occur. The potential for EVA and IVA is greater, and will be considered in later charts.

REPRESENTATIVE EVA'S AND IVA'S

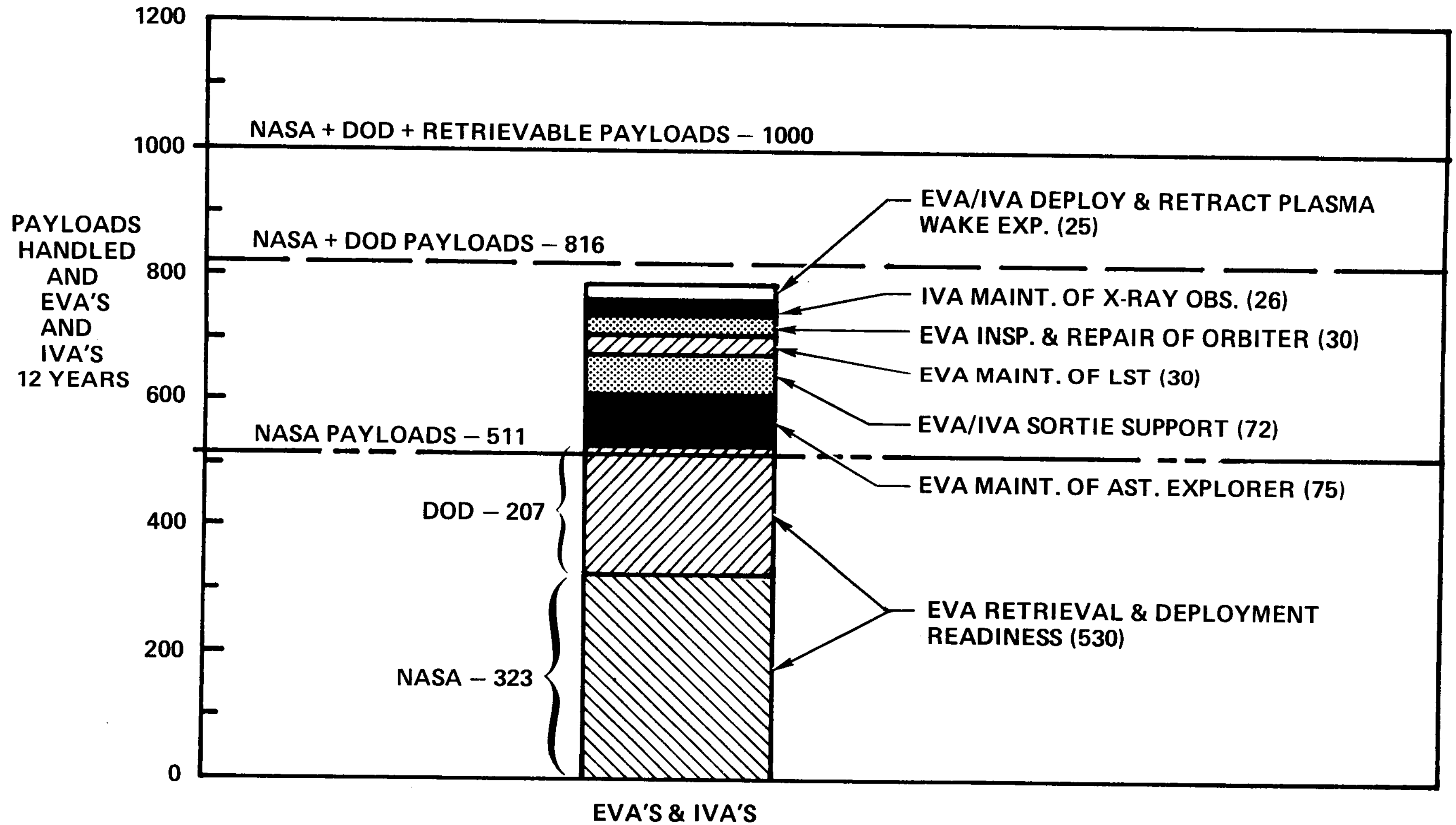
SCENARIO/EVA/IVA	NASA PAYLOADS	DOD PAYLOADS	TOTALS
1. EVA MAINTENANCE OF LST			30
A — APERTURE END EVA	9		9
B — INSIDE TELESCOPE TUBE EVA	2		2
C — REPLACE RCS MODULES EVA	12		12
D — REPLACE SOLAR CELL ASSY EVA	7		7
2. SUPPORT OF EARTH ORBIT SORITE SORTIE			72
A — EXP. PREPARATION EVA	17		17
B — EXP. SUPPORT EVA	17		17
C — ANTENNA STOWAGE EVA	17		17
D — PAYLOAD BAY FILM STOWAGE IVA	17		17
E — UNSCHEDULED IVA IN SORTIE FACILITY	4		4
3. SATELLITE AND TUG RETRIEVAL AND DEPLOYMENT READINESS EVA	323	207	530
4. INSPECTION AND REPAIR OF ORBITER EVA	30		30
5. DEPLOYMENT AND RETRACTION OF PLASMA WAKE EXP.			25
A — REPLACE BOOM MOUNTED SENSORS EVA	5		5
B — MANUAL BOOM RETRACTION IVA	5		5
C — MANUAL BOOM RETRACTION EVA	5		5
D — MANUAL POSITION SORTIE FOR EXPERIMENTS EVA	5		5
E — MANUAL STOW SORTIE FOR DE-ORBIT EVA	5		5
6. IVA MAINTENANCE OF X-RAY OBS.			26
A — REPLACE PROP. COUNTER ARRAY IVA	9		9
B — REPLACE SCINTILLATION COUNTER IVA	9		9
C — REPLACE CRYSTAL SPECTROGRAPH IVA	8		8
7. MAINTENANCE OF AN ASTRONOMY EXPLORER SATELLITE EVA	75		75
TOTAL EVA'S AND IVA'S			788

EVA/IVA TASKS VS PAYLOAD HANDLING

The number of EVA's and IVA's are shown compared to the number of times payloads are handled (delivered to orbit, retrieved or revisited) by the Orbiter vehicle.

Comparing the total EVA's and IVA's (788) to the number of Orbiter flights shown for the "More Realistic Shuttle Flight Frequency", total (597) in the Traffic Model, there will be an average of about 1.3 EVA's or IVA's per Orbiter flight.

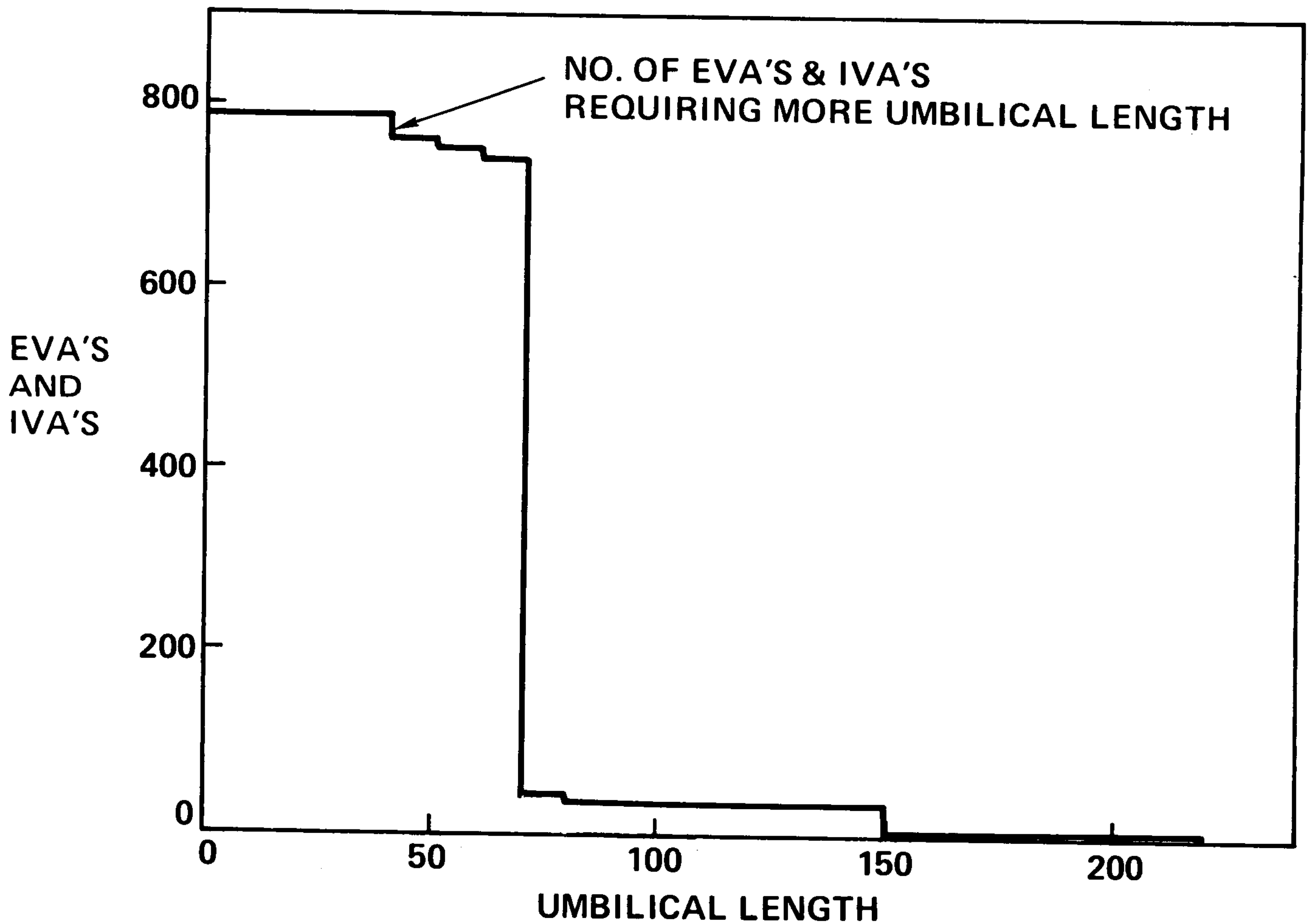
EVA/IVA TASKS VS PAYLOADS HANDLED



EVA/IVA VS UMBILICAL LENGTH

This shows the EVA's and IVA's related to umbilical length. It can be seen that an umbilical length of about 70 ft will accommodate a large percentage of the EVA's and IVA's. The EVA task requiring the longest umbilical is the replacement of the boom mounted sensors which would require a 220 ft umbilical.

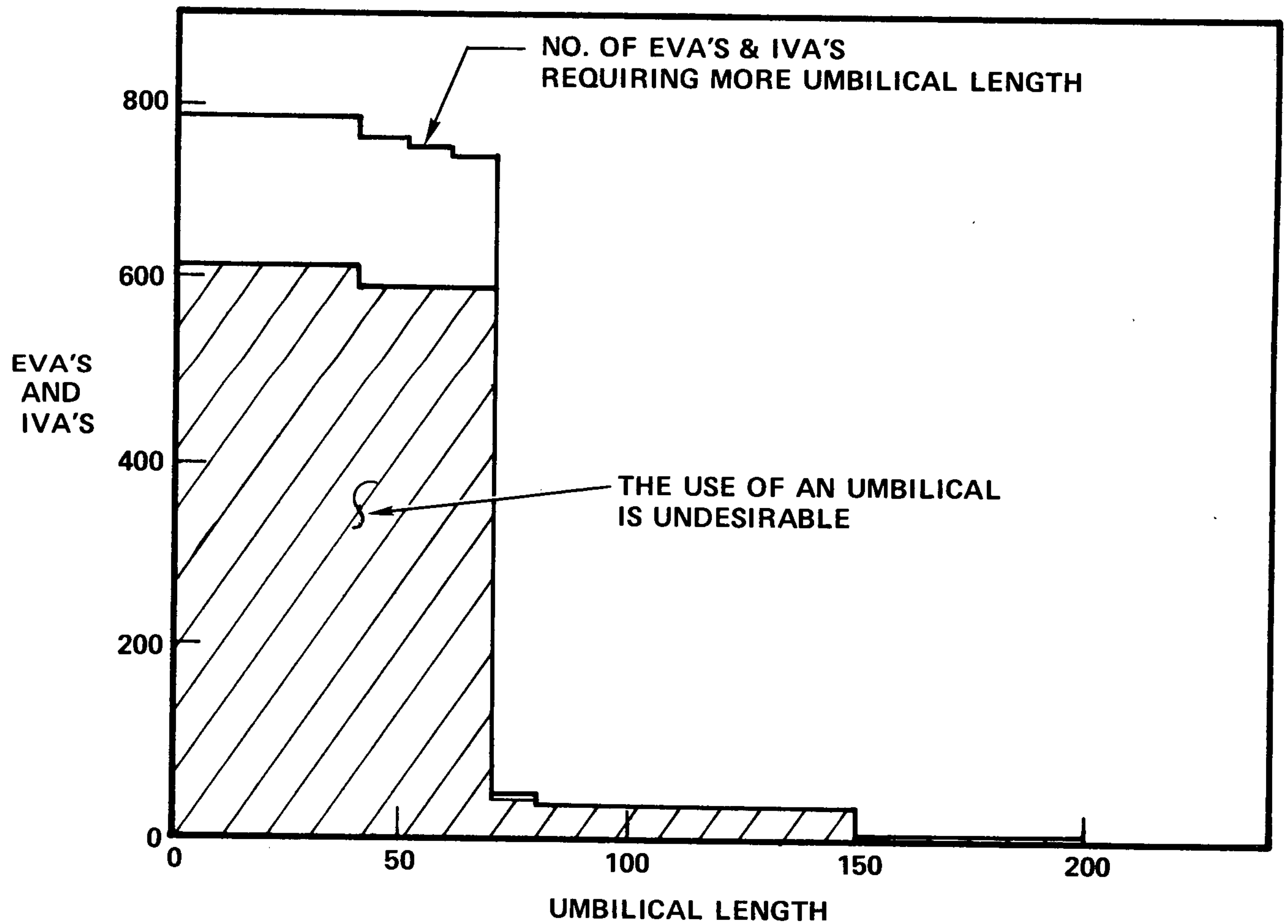
EVA/IVA VS UMBILICAL LENGTH



EVA/IVA WHERE UMBILICAL UNDESIRABLE

An analysis of the EVA's and IVA's and the routes to be covered if utilizing handrails indicates that for about 80% of the EVA's and IVA's it is undesirable to have an umbilical to manage. The umbilical could limit maneuverability or create a requirement for a second crewman for umbilical management.

EVA/IVA WHERE UMBILICAL UNDESIRABLE



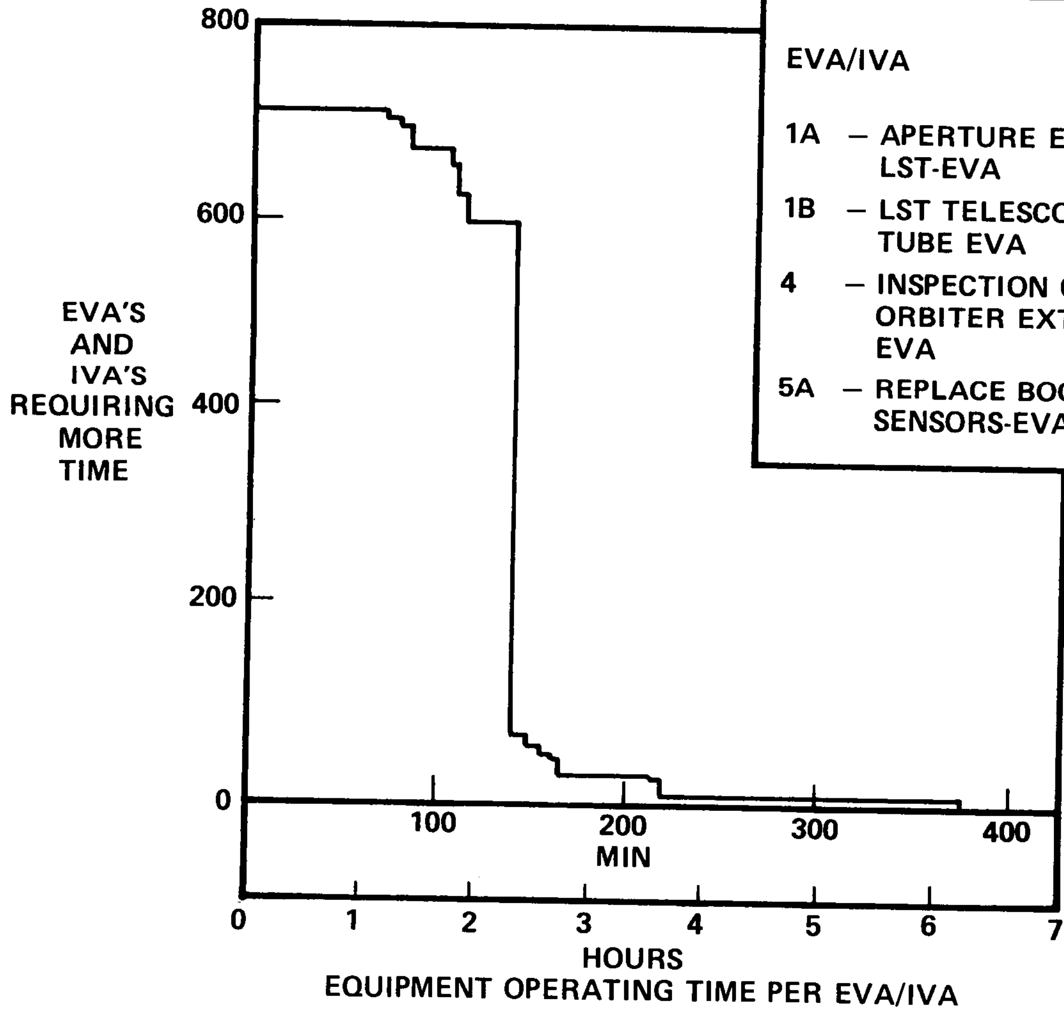
EVA/IVA DURATION

This is a summary of the timeline analyses conducted on the representative EVA's and IVA's.

The plot on the left shows the EVA's and IVA's related to the time required to accomplish them. It shows that a large portion of the EVA's and IVA's require approximately 2 hours operating time. Timeline analyses done at this stage in the development of the Shuttle hardware are only best guesses; therefore, in order to allow for the unknowns involved the times shown were obtained by multiplying nominal estimated times by a factor of two.

The table on the right gives the off-umbilical EVA and IVA time required if an umbilical is 70 ft. long. Note the maximum time off the umbilical is almost 3 hours.

EVA/IVA DURATION



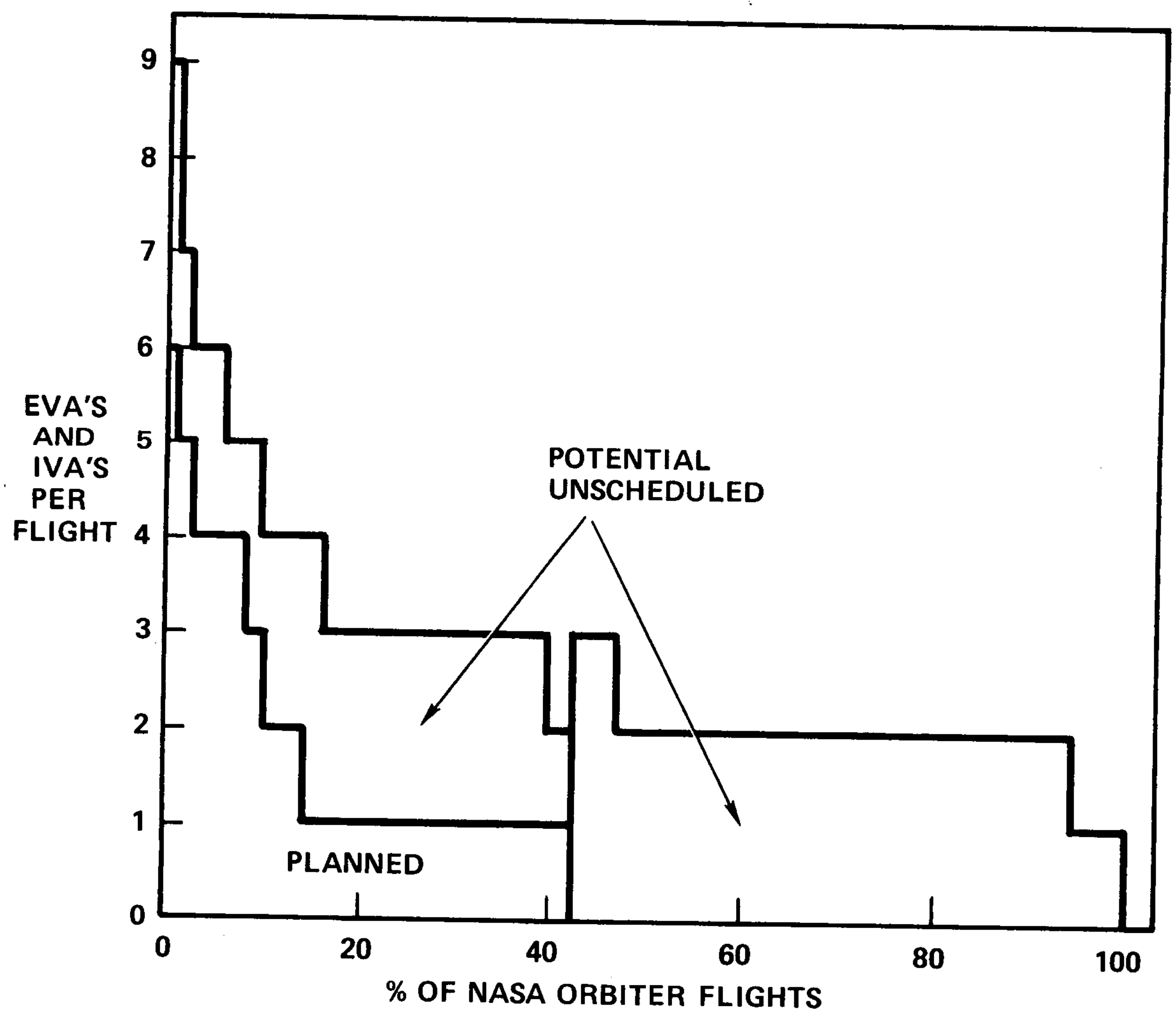
EVA BEYOND A 70 FT UMBILICAL		
EVA/IVA	EST. NO. OF EVA/IVA	OPERATING OFF A 70' UMBILICAL (MIN)
1A – APERTURE END OF LST-EVA	9	104
1B – LST TELESCOPE TUBE EVA	2	270
4 – INSPECTION OF ORBITER EXTERIOR-EVA	30	72
5A – REPLACE BOOM MOUNTED SENSORS-EVA	5	320

NUMBER OF EVA'S AND IVA'S PER FLIGHT

The "Payload Combination for Orbiter Flights" in the Shuttle Traffic Model, MSC-06746, March 1972 was updated to reflect the payloads in the NASA Mission Model dated 6 June 1972. The representative EVA's and IVA's previously selected for the payloads were related to the orbiter flights, avoiding unlikely EVA and IVA duplications.

This figure shows the number of potential EVA's and IVA's per flight resulting from this analysis. It is in contrast to the previous chart showing 788 total EVA/IVA's, which represents an estimated actual rather than potential number of excursions. The potential curve, shown is useful in determining required "pre-flight" EVA/IVA provisions.

NUMBER OF EVA'S AND IVA'S PER FLIGHT



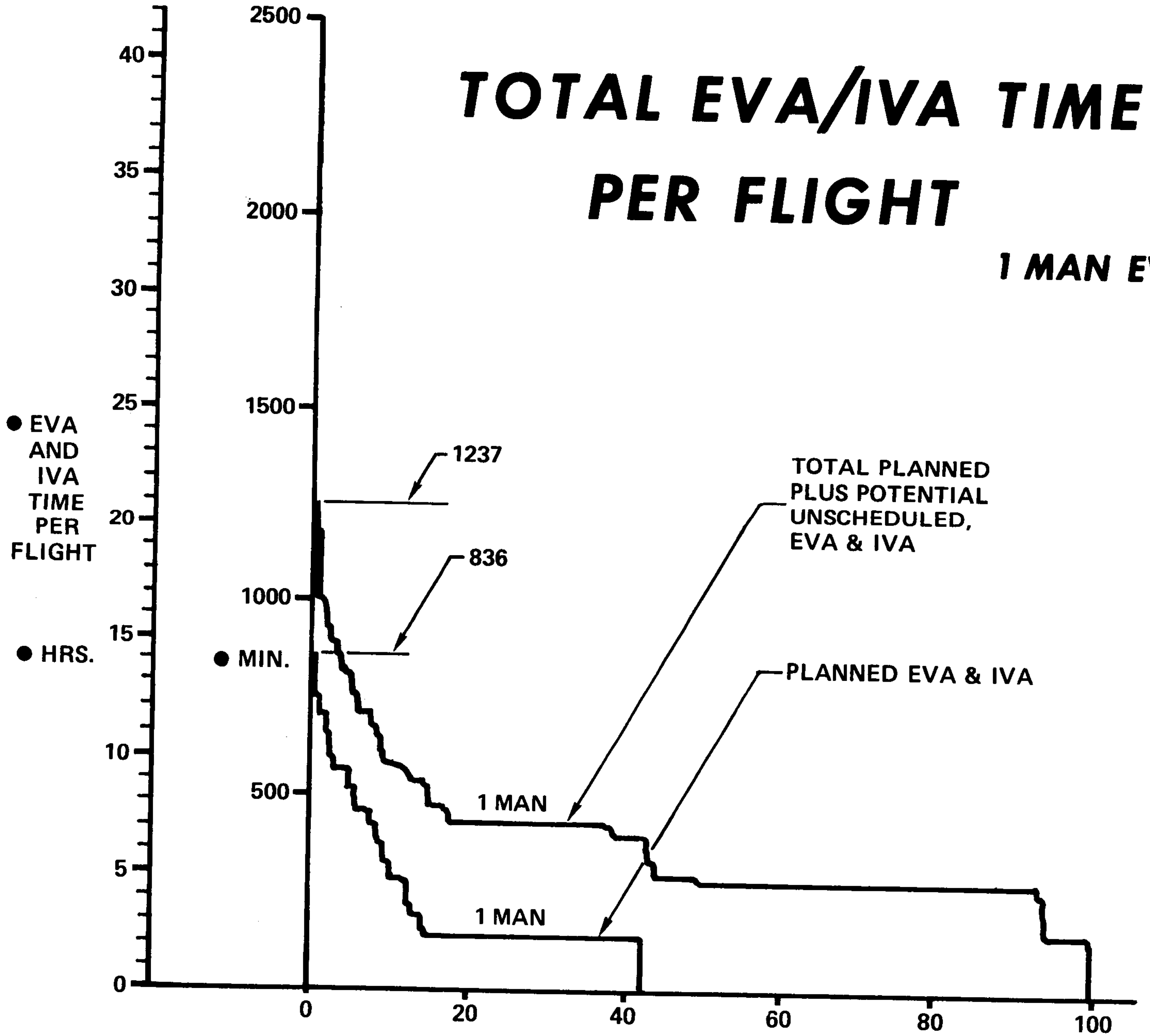
TOTAL EVA/IVA TIME PER FLIGHT

This figure shows the total EVA/IVA equipment operating time required per orbiter flight.

If one man EVA/IVA is used the total required time to cover all orbiter flights is 1237 minutes, approximately 21 hours.

TOTAL EVA/IVA TIME PER FLIGHT

1 MAN EVA



NON-VENTING EVA/IVA

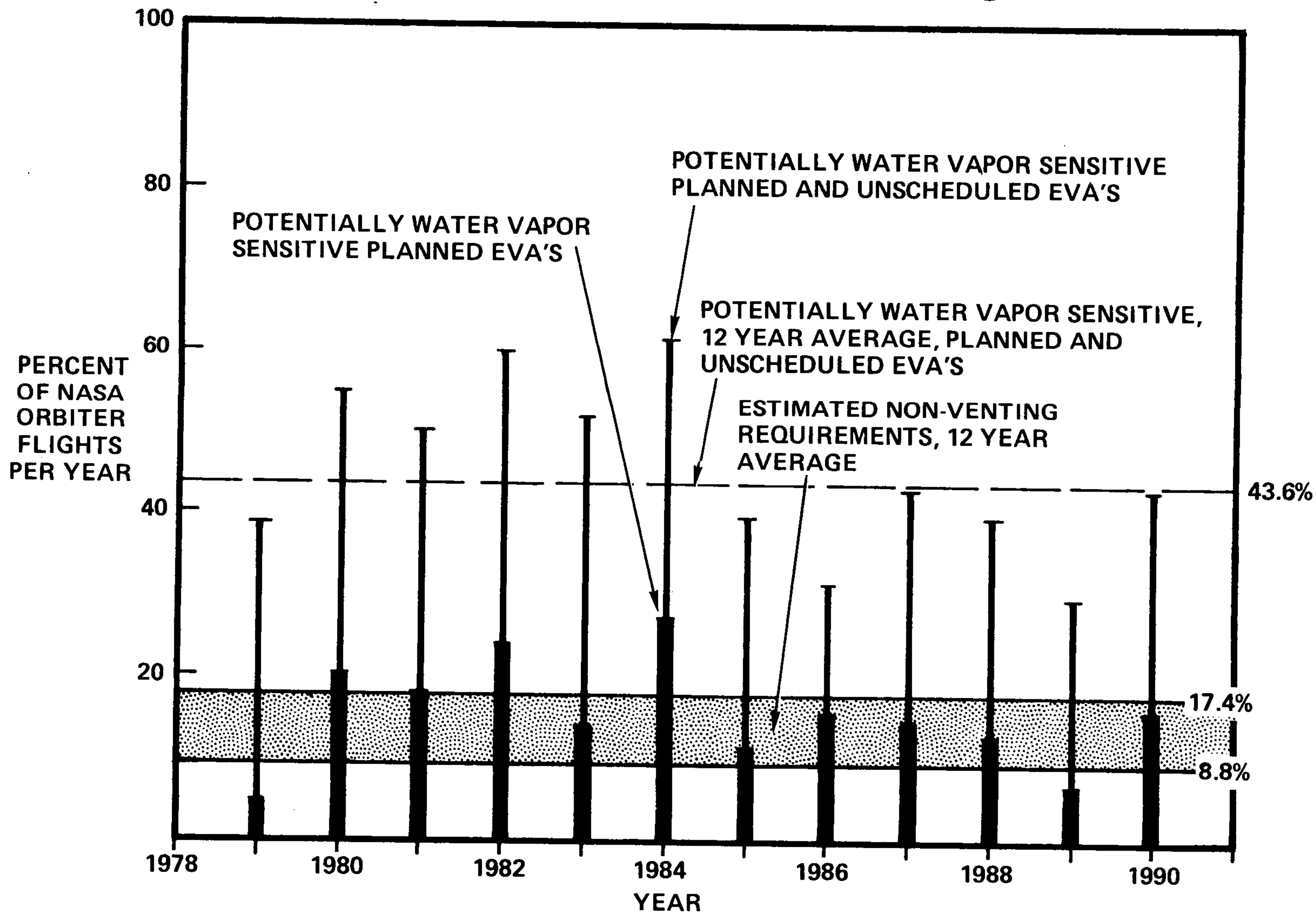
Contamination effects and spacecraft conditions requiring the elimination of water vapor from around optical elements are discussed under Supporting Studies. The opposing plot shows the potential for non-venting planned and unscheduled EVA/IVA being required on orbiter flights, year by year, for the case of NASA payloads. This potential is based on the type sensors and optics which are on the payloads, and would represent the actual non-venting requirements if adequate covers were not utilized to protect the sensitive devices. Contamination covers, however, will normally be used on payloads and will be automatically deployed except in the case of austere sorties where the covers may be removed and replaced by planned EVA in order to effect a cost savings.

It is anticipated that unscheduled EVA/IVA will be utilized for manually operating malfunctioning covers on all types of payloads. The incidence of such malfunctions has been rather high.

It does not seem unreasonable to expect that on 10%-20% of the water vapor sensitive payloads handled by the orbiter,which utilize contamination covers, a failure would occur which would prevent the cover from operating properly. These are the cases where unscheduled EVA/IVA would be used. Applying the 10%-20% fraction to the 43.6 average percentage of flights where planned or unscheduled EVA could be used near potentially sensitive surfaces, 4.4% to 8.7% of the total NASA flights, or 2 to 5 flights per year, would require non-venting EVA.

Secondary effects are another factor in determining non-venting requirements. In almost all cases, some areas of the spacecraft or payload will be at a very cold temperature during shuttle orbital operations. Water vapor from venting heat rejection systems will condense on these surfaces, and late re-evaporate as orientation is changed. The impact could be secondary deposition on cold sensors after the contamination cover is removed, or an undesirable delay in deploying the cover. This latter is especially important with astronomy sorties, where instruments are very water vapor sensitive and time-on-orbit is at a premium. Again estimating that secondary effects would be significant on 10%-20% of the potentially water vapor sensitive payloads, another 4.4% to 8.7% NASA flights would require non-venting, bringing the total to the 8.8% to 17.4% illustrated on the plot.

ESTIMATED NON-VENTING EVA REQUIREMENTS



IV GUIDELINES & CONTRAINTS

SHUTTLE EVA/IVA STUDY GUIDELINES

The guidelines presented in this section are intended to be used as general guidelines that can be violated if sufficient justification can be demonstrated.

SHUTTLE EVA/IVA STUDY GUIDELINES

1. Impact to the baseline Shuttle or payload design or specifications (Phase C-RFP) will be permitted if required to perform EVA/IVA tasks if studies show this to be desirable.

2. Vehicle interface equipment and SCAR will be identified.

3. EVA/IVA equipment will be designed to operate in the expected Shuttle enviroments (TBD).

4. The Orbiter on-board checkout and monitoring system can be used if needed.

5. Different equipment can be used for planned EVA, IVA, and contingencies.

6. EVA and IVA should be possible with closed cargo bay door.

7. Vacuum quick-disconnects should be avoided for critical functions.

8. The penalties used for evaluating and comparing various EV/IV equipment concepts will be :

   Power - Using Orbiter system - 1.3 lbm/kwh
   Dedicated system - 105 lbm/kw + 2.7 lbm/kwh

   Heating - Electrical power assumed for heating above 100°F

   Cooling - No penalty provided total heat load remains within vehicle capability

   Water - No penalty for expendable

   Oxygen - The penalty factory for dedicated EVA/IVA vehicle tanks will be:

   Supercritical - 1.24 lbm/lbm O_2

   High pressure gas - 2.0 lbm/lbm O_2

9. Suits should not be tailored to fit individual crewmen.

10. A second crewman should not be required for tether/unbilical management.

11. Ground monitoring should not be required duting EVA/IVA.

12. Additional shuttle crewman time required to monitor EVA/IVA crewmen should be minimized.

13. Provision for crewmen restraint will be provided at all planned and unscheduled EVA/IVA worksites.

14. Velocity for simple manual crewman translation during EVA/IVA will be:

Nominal - 0.5 ft/sec

Rapid translation - 2.5 ft/sec

Maximum attainable - 5-7 ft/sec

15. The considerations for selection of PGA operating pressure are:

Economic (Development & Production)

Physiological (Prebreathing)

Suit mobility & leakage

Safety

LSS impacts

Vehicle impacts

16. Manipulator may be used as a mobility aid or movable restraint device.

17. General design specifications for the EVA/IVA life support system are:

Metabolic rates:

400 btu/hr minimum rate

800 btu/hr mission average for all EVA's

1000 btu/hr maximum average for greater than or equal to 4 hour EVA

1200 btu/hr maximum average for less than 4 hour EVA

2000 btu/hr maximum average for 1/2 hour EVA

1200 btu/hr emergency (30 minutes)

Thermal storage:

Nominal ± 100 btu

Emergency ± 300 btu

Carbon Dioxide Partial Pressure :

5 mm Hg Nominal inspired

7.6 mm Hg Average inspired

15 mm Hg 30-minute maximum

18. The airlock should provide EVA capability during docked operations without restricting shirtsleeve access to a pressurized docked module.

19. Multiple failures will not be considered.

20. EVA crewmen will be trained and conditioned for planned and unscheduled tasks.

21. IVA operations in the cargo bay with doors closed are preferable to EVA if an option exists.

22. EVA/IVA equipment will be selected to avoid contamination of sensitive experiments and spacecraft components.

SHUTTLE EVA/IVA STUDY CONSTRAINTS

The constraints listed on the opposing page are those rules which are considered to be inviolable.

SHUTTLE EVA/IVA STUDY CONSTRAINTS

1. Tethers and Tether mounts will be designed with adequate factors of safety to preclude any reasonable possibility of failure.

2. Maneuvering units and other equipment containing potentially dangerous materials, hypergolics, etc. will be stored outside the pressure crew compartment.

3. Pre-breathing, airlock, or other EVA/IVA operations shall not cause the main cabin atmosphere composition and pressures to exceed the design envelope.

4. All EVA/IVA equipment will have "fail-safe' capability as a minimum requirement.

5. Maneuvering systems will have a fail operation/fail safe capability for critical systems.

6. The minimum oxygen flowrate supplied to the crewman will be calculated using a respiratory quotient of 0.875.

7. A radiation dosimeter is required for EVA/IVA crewmen. The total radiation exposure, including EVA/IVA, shall not cause the crewmen to exceed the Orbiter design limits.

8. EVA/IVA planned work sites and paths to planned work sites will be free of sharp protuberances, moving objects, thruster exhausts, harmful radiation, etc. during the course of the activity.

9. Continuous Shuttle communication capability with EVA/IVA crewman is required.

10. Umbilicals and Tethers will exert minimum torques or forces on the crewman regardless of position.

11. The maximum umbilical or Tether free length will be limited by Tether management and dynamic considerations.

12. EVA/IVA equipment should be provided to accommodate two men simultaneously.

13. The maximum allowable EVA/IVA duration will be 8 hours consistent with physiological considerations.

14. 8 hours out of 24 will be the maximum allowable suited duration; an unlimited number of decompressions are allowed in this period.

15. Harmful exhaust products from maneuvering unit thrusters will not impinge on experiment or spacecraft surfaces.

16. Orbiter maneuvering will not be allowed during unpressurized EVA/IVA.

17. Pre-breathing will be in accordance with the following figure:

SUIT PRESSURE PHYSIOLOGICAL REQUIREMENTS

The desire to provide as near to an Earth-like environment as possible has been a strong factor in the selection of a 14.7 psia, O_2-N_2 atmosphere for the shuttle orbiter. However, the selection of a somewhat lower pressure, still in the range between commercial aircraft cabin pressures of about 11 psia (≈8000 ft. equiv. altitude) and normal sea level, offers many advantages for the EVA/IVA system, particularly during contingency and emergency situations.

The human body is normally saturated with nitrogen at an equilibrium pressure equal, or nearly equal, to the ambient partial pressure. A reduction of the ambient pressure can lead to some of this nitrogen coming out of solution with resultant bubble formation and symptoms known as the "bends". This phenomena is the same as that sometimes encountered by divers and other hyperbaric workers. Bends are generally protected against by lengthy prebreathing of pure oxygen to eliminate the dissolved nitrogen prior to decompression or by slow, "stepped" decompression over an extended period.

The first part of this figure (1) indicates the influence of the pressure before decompression (cabin pressure) on the final pressure (suit pressure) that would not be expected to produce the bends. This figure illustrates both the wide range in bends tolerance among the general population and indicates that a reduction in orbiter pressure to 11 psia could allow current suit pressures to be safely used.

The second curve (2) shows the prebreathing time required to prevent bends when decompressing from 14.7 psia. An important difference between these figures is the fact that exercise effects, which tend to increase bends incidence, are not included in the first figure. This explains the discrepancy in the data for decompressions from sea level.

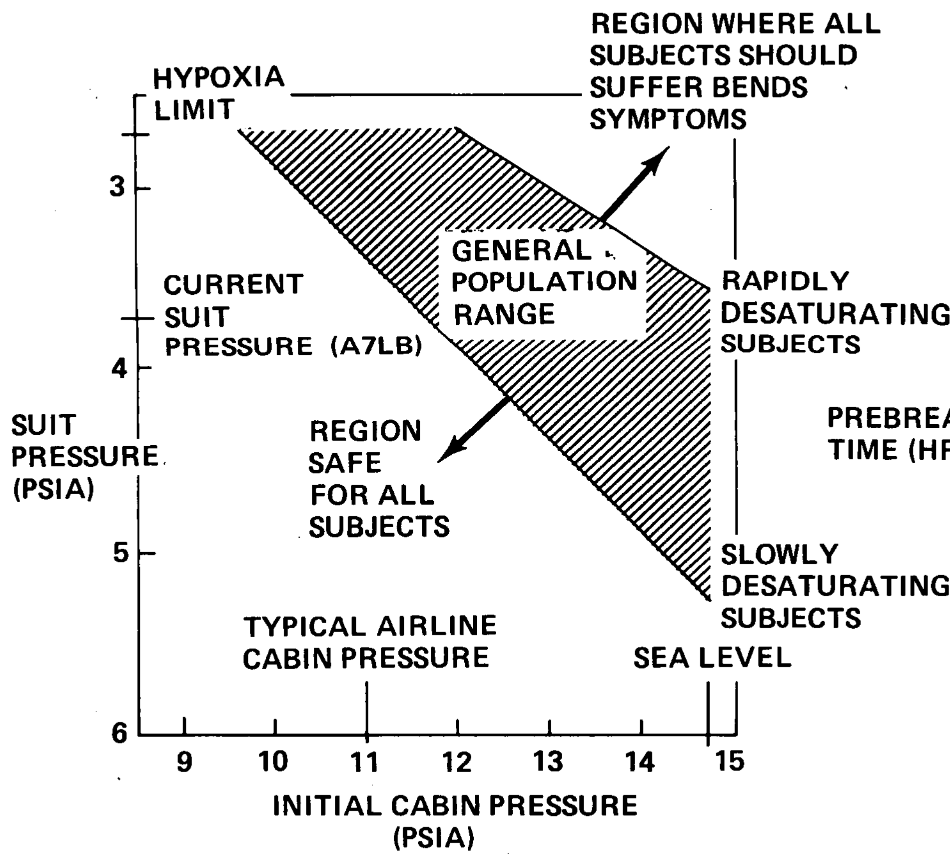
The elimination of prebreathing is a desirable goal to help reduce the man-hour overhead associated with EVA. These figures show that this can be safely accomplished by coordination of the selection of suit and orbiter operating pressures. The final recommendations will be made after consideration of all factors that are affected by pressure level. Additional physiological testing will be needed to fully define pressure level effects on bends protection.

(1) Taken from: Decompression Sickness; W.B. Saunders Co.; Philadelphia; 1951; page 250

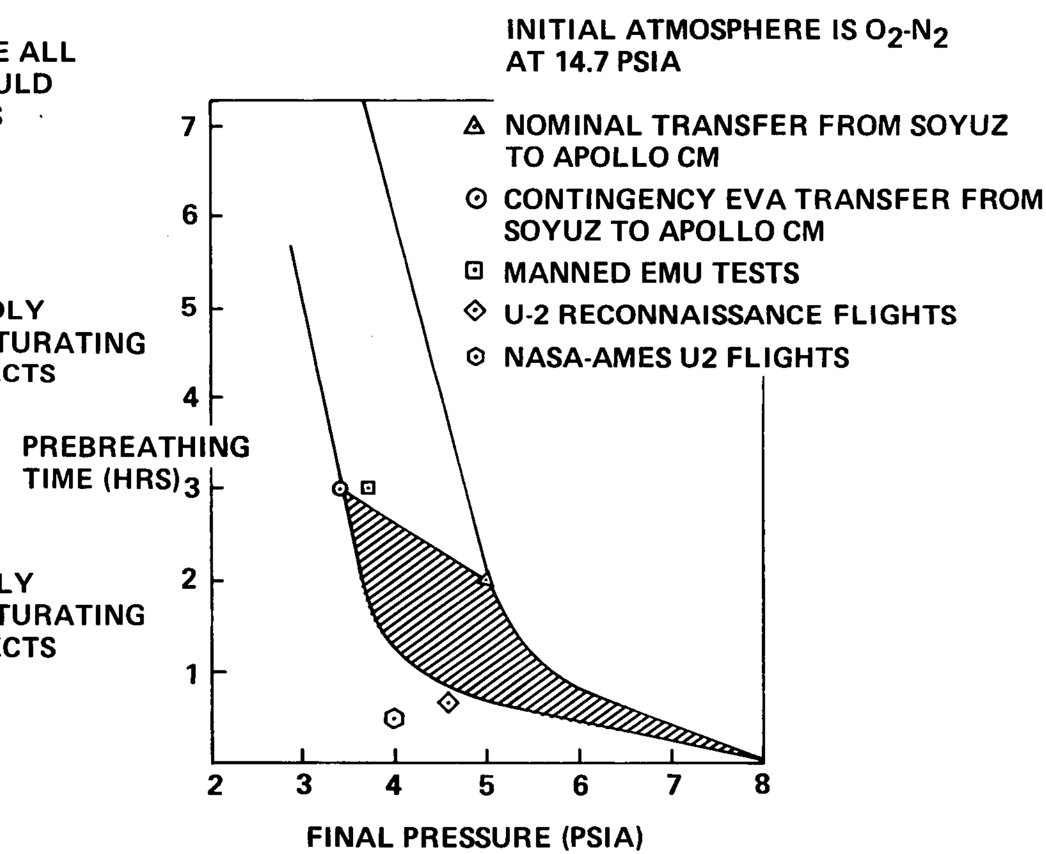
(2) Taken from: Pegner, E.A., et al, "Dissolved Nitrogen and Bends in Oxygen-Nitrogen Mixtures During Exercise at Decreased Pressures", Aerospace Medicine; May 1965.

SUIT PRESSURE PHYSIOLOGICAL REQUIREMENTS

EFFECTS OF ORBITER CABIN PRESSURE ON SUIT PRESSURE WITHOUT PREBREATHING



PREBREATHING TIME AS A FUNCTION OF SUIT PRESSURE



V PRESSURE SUIT

PRESSURE SUIT ISSUES

Fundamental issues resolved in arriving at suit requirements are shown. First, the suit must be capable of effective performance of a large percentage of the EVA/IVA tasks in order for EVA/IVA to be useful to the shuttle program.

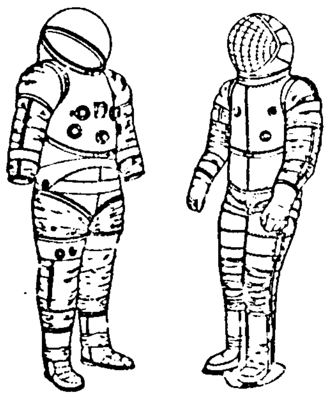
For cost and operational effectiveness, should common suits be used for both EVA and IVA? If not, how many different suits should be used? Should crewmen and passengers have the same IV suits? Is a suit required for effective pilot performance during re-entry after several days in zero-g?

Can existing operational suits be used effectivly for shuttle EVA/IVA with little or no change? How important and how practical is it to reuse and maintain suits? Are modular suits feasible and will they significantly improve maintainability and reduce total suit quantities required? What are shuttle suit cycle and shelf life requirements, and can these be met by individual suits, or must multiple suits per crewman be provided?

Can suits be made which will not be a significant contaminant threat to experiments due to leakage, outgassing, and particulate production? How does operating pressure affect suit performance?

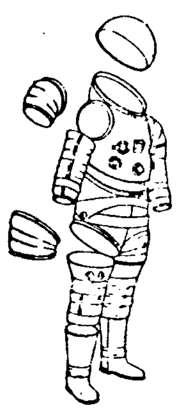
Many other issues also exist, such as whether to integrate the suit with the life support system, or whether to use a soft, hard, or combination suit concept. These are logically determined once the fundamental issues are resolved and a basic EVA/IVA concept is selected.

PRESSURE SUIT ISSUES

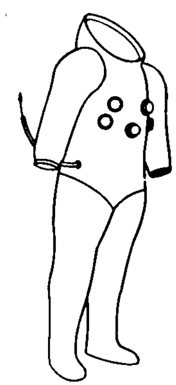


- TASK PERFORMANCE CAPABILITY
- EV & IV SUIT COMMONALITY
- G SUIT
- OPERATING PRESSURE

- PRESENT OPERATIONAL SUIT EFFECTIVENESS



- REUSABILITY AND MAINTAINABILITY
- MODULAR SIZING
- USEFUL LIFE



- CONTAMINATION AVOIDANCE

CREW AND PASSENGER CONSIDERATIONS

The opposing chart illustrates the EVA and IVA requirements which must be considered for the Commander, Pilot, Mission Specialist, Payload Specialist, and passenger/observers. The two assigned EVA/IVA crewmen will be designed from the group of Commander/Pilot/Mission Specialist(s) assigned to each particular Orbiter flight. The Payload Specialist and passenger/observers will not be involved in pressure suited operations, except in contingency situations. In this event, their requirements would be different. The Commander and Pilot would be concerned with safe return of the Orbiter, while the Payload Specialist and passenger/observer would basically be responsible only for his own survival. The Mission Specialist would also be required to perform contigency tasks.

Consideration of the tasks results in generally differing suit requirements for EVA/IVA crewmen, Pilot and Commander, and passengers, as shown. For the EVA/IVA suit, performance requirements are much more demanding than for the Pilot or Commander. In addition, usage per assigned EVA/IVA crewman is expected to be much greater, requiring a long cycle life. Examination of all the factors suggests a simpler suit for the Pilot and Commander. For cases where the Mission Specialist is not part of the assigned EVA/IVA crew, his contingency IVA suit mobility requirements will be similar to those for the Commander and Pilot.

The passenger suit (including Payload Specialist and observer) has still further reduced performance requirements. Total personnel complement in this category is uncertain. A third, low cost-high production suit would be economically advantageous if warranted by large quantities. Final resolution of the issue of a third suit will depend on future development of passenger/observer flight frequencies.

CREW AND PASSENGER CONSIDERATIONS

CREW & PASSENGER REQUIREMENTS

EVA

ASSIGNED EVA CREWMEN

- PLANNED TASKS
- UNSCHEDULED TASKS
- CONTINGENCY TASKS

ALL OTHERS

- CONTINGENCY TRANSFER

IVA

ASSIGNED IVA CREWMEN

- PLANNED TASKS
- UNSCHEDULED TASKS
- CONTINGENCY TASKS

PILOT AND COMMANDER

- CONTINGENCY TASKS

PASSENGERS AND OTHERS

- CONTINGENCY SURVIVAL

SAME OR DIFFERENT?

SUIT REQUIREMENTS

EVA/IVA SUIT

- HIGH MOBILITY WHEN PRESSURIZED
- LONG TERM ENVIRONMENTAL PROTECTION
- LONG CYCLE LIFE
- MODERATE QUANTITIES
- MINIMUM CONTAMINATION
- MANY EVA EQUIPMENT AND PAYLOAD INTERFACES
- QUICK DON/DOFF

IVA PILOT & COMMANDER'S SUIT

- MOBILITY TO OPERATE S/C WHEN PRESSURIZED, PERFORM CONTINGENCY IV REPAIRS OR EV TRANSFER
- ANTI-G SUIT INTERFACE (IF REQUIRED)
- VERY QUICK DON
- MODERATE QUANTITIES
- SMALL STOWAGE VOLUME
- SHORT TERM EV ENVIRONMENT PROTECTION

IVA PASSENGER SUIT

- HIGH UNPRESSURIZED MOBILITY AND COMFORT
- MOBILITY TO SAFE HAZARDS WHEN PRESSURIZED, PERFORM CONTINGENCY EV TRANSFER
- CONSTANT WEAR
- UNCERTAIN QUANTITIES
- SHORT TERM EV ENVIRONMENT PROTECTION

PRESENT OPERATIONAL SUITS -
PRESSURE EFFECTS ON A7L-B MOBILITY

Tests were conducted at ILC to obtain qualitative information on A7L-B mobility at increased pressure levels. Examination of the table indicates that suit pressure levels of less than 5.5 psi would be necessary to approach current Skylab mobility. Improvements to the existing design might permit usable operational pressure levels up to 6 psi to be achieved.

It is also worthwhile to observe that mobility is much too restricted at 7.5 psi to consider use of the A7L-B (beefed up to take the pressures with adequate safety margin) as an emergency pilot's IV suit, unless significant mobility improvements were also made.

PRESENT OPERATIONAL SUITS

PRESSURE EFFECTS ON A7L-B MOBILITY

	ELBOW	KNEE	SHOULDER UP/DOWN	SHOULDER FORWARD/BACKWARD	ANKLE	HIP/THIGH "BOW" MOVEMENT
5.5 PSI	SLIGHTLY HARDER TO MOVE BUT NO NOTICEABLE DIFFERENCE IN RANGE	SLIGHTLY HARDER TO MOVE BUT NO NOTICEABLE DIFFERENCE IN RANGE	SLIGHTLY HARDER THAN AT 4.0 PSI	NOTICEABLY HARDER TO MOVE THAN AT 4.0 PSI	SLIGHTLY HARDER TO MOVE THAN AT 4.0 PSI	SLIGHTLY HARDER TO MOVE THAN AT 4.0 PSI
6.0 PSI	SAME AS AT 5.5 PSI	SAME AS AT 5.5 PSI	STIFFER AND CAN-NOT HOLD JOINT IN INTERMEDIATE POSITION-BECOMING UNSTABLE	EXTREMELY STIFF AND DIFFICULT TO MOVE	SAME AS AT 5.5 PSI	RANGE DECREASED CONSIDERABLY. WAIST BEGINNING TO BECOME UNSTABLE
6.5 PSI	SAME FORCE AS AT 5.5 PSI BUT RANGE IS RE-STRICTED	APPROXIMATELY THE SAME AS AT 5.5 PSI	TOO STIFF TO MOVE	TOO STIFF TO MOVE	BECOMING HARDER TO MOVE THAN AT 6.0 PSI	RANGE APPROXIMATELY. THE SAME AS AT 6.0 PSI. BECAME MORE DIFFICULT TO MOVE
7.0 PSI	SLIGHTLY MORE FORCE REQUIRED THAN AT 5.5 PSI SAME AS 6.5 PSI	APPROXIMATELY THE SAME AS AT 5.5 PSI	TOO STIFF TO MOVE	TOO STIFF TO MOVE	DIFFICULT TO MOVE. MOVEMENT DECREASED IN RANGE	RANGE APPROXIMATELY THE SAME AS AT 6.0 PSI MORE DIFFICULT TO MOVE THAN AT 6.5 PSI (HIGH TORQUE)
7.5 PSI	SAME AS AT 7.0 PSI EXCEPT SLIGHTLY LESS RANGE	APPROXIMATELY THE SAME AS AT 5.5 PSI BUT LESS RANGE	TOO STIFF TO MOVE	TOO STIFF TO MOVE	SAME AS AT 7.0 PSI	ALMOST IMPOSSIBLE TO MOVE

NOTE: TESTS CONDUCTED BY ILC ON SKYLAB SUIT (WITHOUT TMG)

PRESENT OPERATIONAL SUITS - PERFORMANCE CONSIDERATIONS

The current A7L and A7LB suits have the distinct advantage of having been developed, qualified, and proven in space. However, their utility for the shuttle program must be examined from several viewpoints.

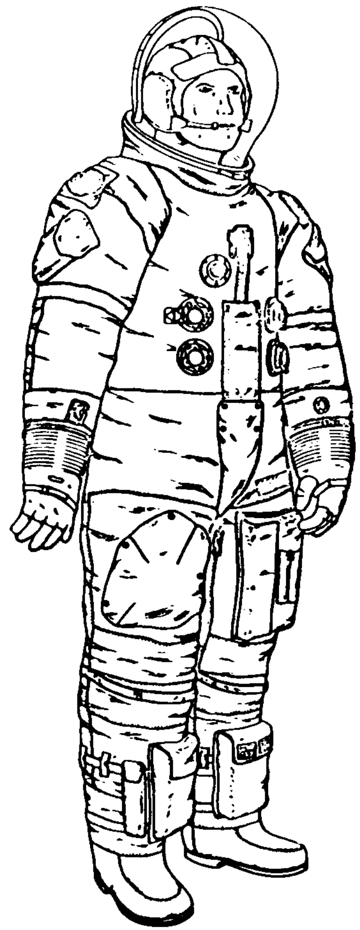
As the chart on suit pressure evaluation shows, the A7LB suit cannot effectively be used at pressures much above 3.7 psi. At 3.7 psi, existing Apollo transearth EVA results show that the suit is adequate for performance of well-designed tasks, although wrist and glove mobility is marginal. Consideration of projected shuttle tasks indicate that EVA mobility requirements will be greater for both planned and unscheduled EVA; use of the A7LB would inhibit EVA effectiveness, especially in unscheduled situations.

Potential use of the A7LB suit at significantly higher pressures than 3.7 psi is limited by structural integrity considerations. For an 8 psi operating pressure, the suit could not survive a 16 psi proof pressure in areas such as the seams, restraint material, boots, cables, and helmet.

Leakage rates on the A7L/B suits are high due to construction methods and the use of a zipper closure. Although it has been possible to meet the 180 sccm specification requirement by reworking individual zippers as necessary, another closure method is desired for low leakage and/or long life. Material selection on existing suits has not considered outgassing or lint contamination constraints.

PRESENT OPERATIONAL SUITS

PEFORMANCE CONSIDERATIONS



- CAPABILITY TO PERFORM MISSION OBJECTIVES
- STRUCTURAL INTEGRITY
- CONTAMINATION

PRESENT OPERATIONAL SUITS - COST CONSIDERATIONS

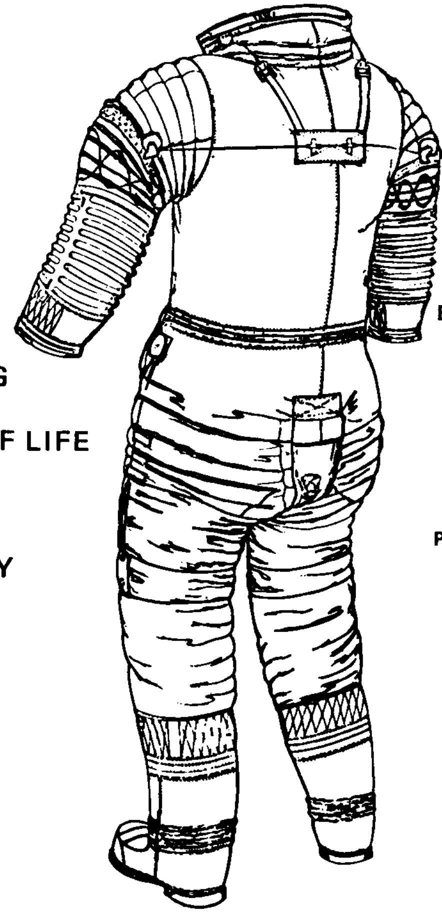
The cost of the A7L/B suits is relatively high because of the custom sizing and small lots required for Apollo and Skylab programs. In addition, certain components of the suit are expensive to produce (helmet) or of uncertain availability from suppliers (zipper). By the use of incremental sizing and larger production lots, improvements in design and the use of tooling, suit unit costs can be reduced.

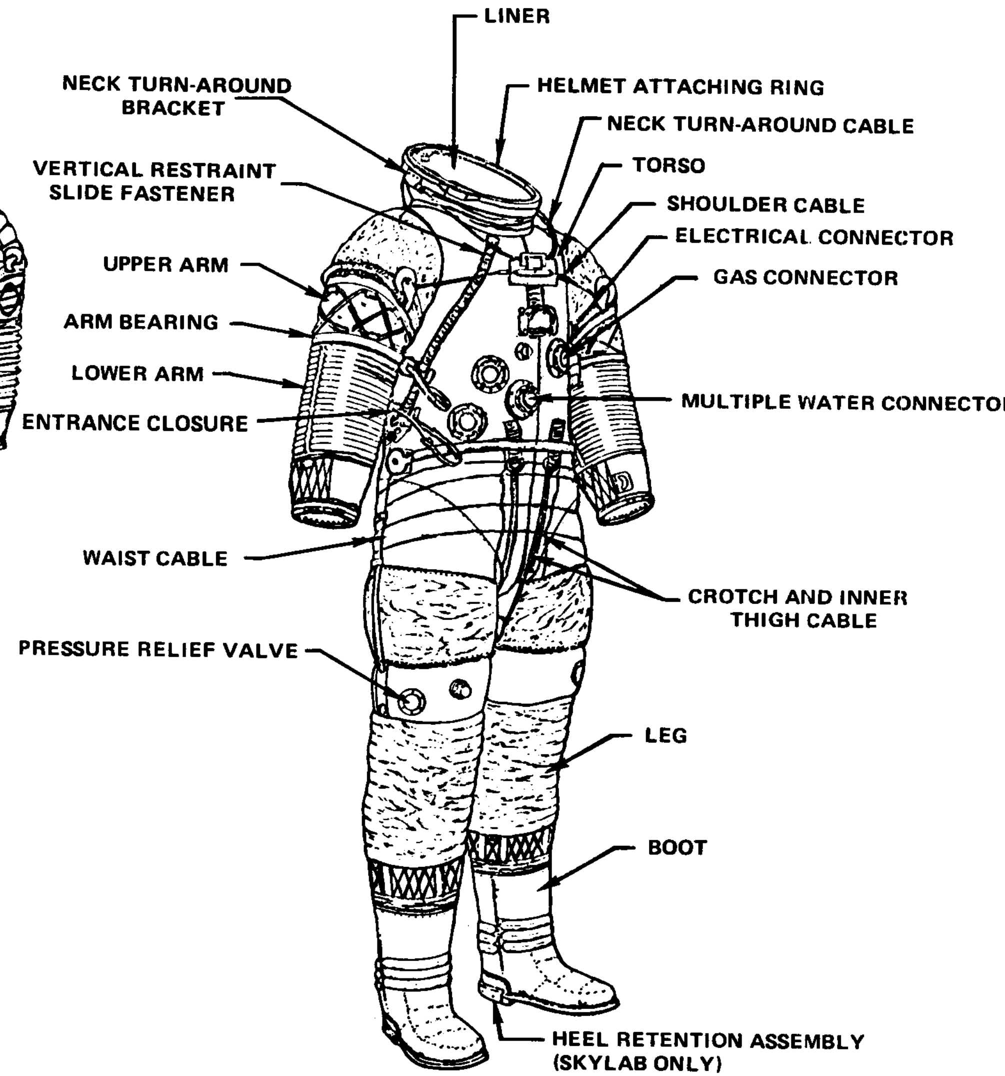
Demonstrated cycle life of many A7LB components is considerably lower than the design goal life of 100,000 cycles. Results on shuttle EVA cycling requirements indicate that 100,000 to 200,000 cycles will be required for a reusable suit concept. Cycle life of the A7LB joints would be reduced by an increased operating pressure. Shelf life of some current suit materials is limited; for instance 3 years for dipped goods.

The A7LB suits are custom sized, with some provisions for adjustment and maintenance incorporated. Sizing capability in the field is restricted to arms and legs. Maintenance is costly. Use of custom sized suits with limited maintenance provisions and short cycle life does not appear to be a cost effective approach.

PRESENT OPERATIONAL SUITS
COST CONSIDERATIONS

- MANUFACTURING
- CYCLE AND SHELF LIFE
- SIZING
- MAINTAINABILITY





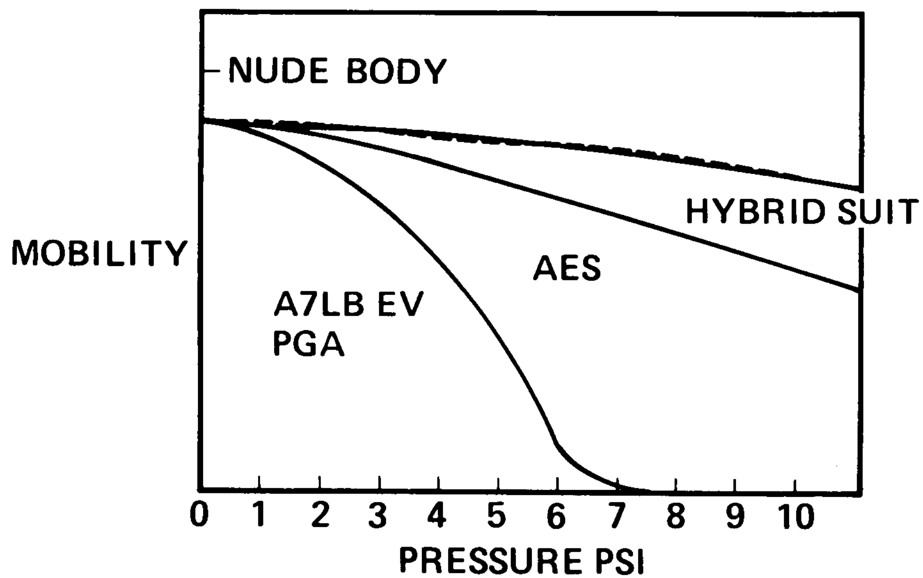
OPERATING PRESSURE EFFECTS

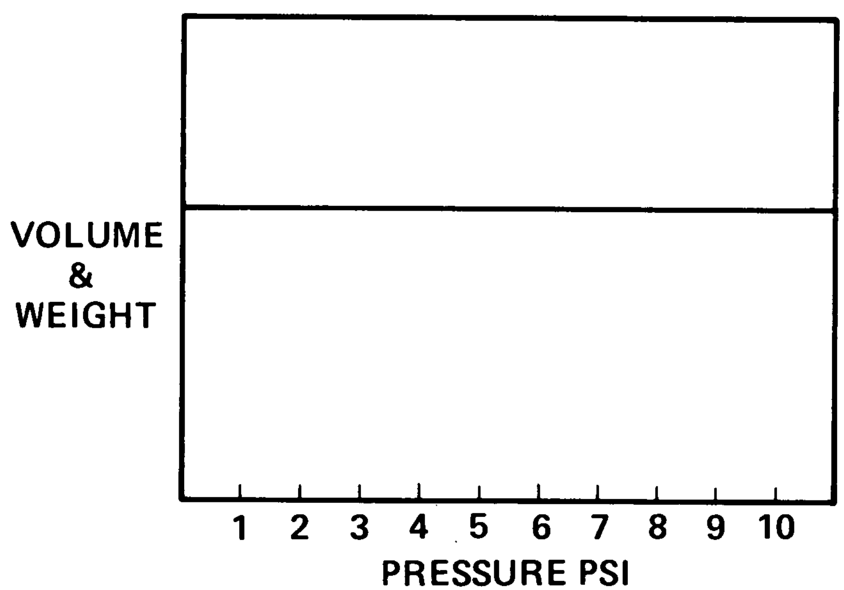
These curves indicate the trends in joint mobility and cycle life plus suit stowage volume and weight when suit operating pressure is increased.

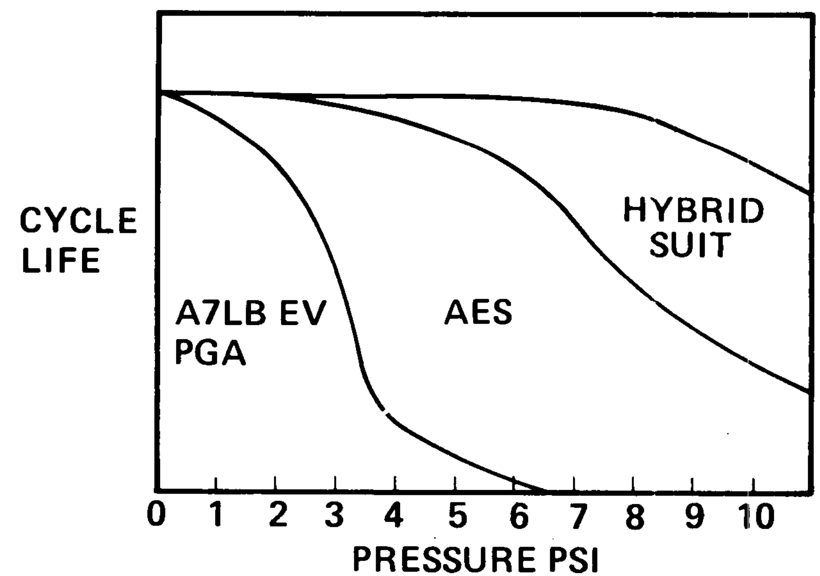
In the area of joint mobility and cycle note that the AES joints are a significant improvement over the A7LB joints. If these AES joints were integrated with a "soft" suit to create a hybrid suit even better joint mobility and cycle life could be obtained. The glove mobility is particularty critical in the area of mobility. The A7LB gloves are already marginal. To increase the operating pressure will render them unusable. Three companies have recently developed new 10 psi glove concepts with improved mobility.

The weight and stowage volume of the suit is almost insensitive to increases in operating pressure since it is usually not the pressure as such that causes the weight and stowage volume to be what it is for a particular suit. True, all structures must contain the operating pressure, but most suit structure is oversized greatly relative to the pressure due to other considerations such as fabric thickness sized for abrasion resistance, metal attachment rings sized for required fastener edge distance and sealing stiffeners, and seams and cables sized for man induced loads.

OPERATING PRESSURE EFFECTS





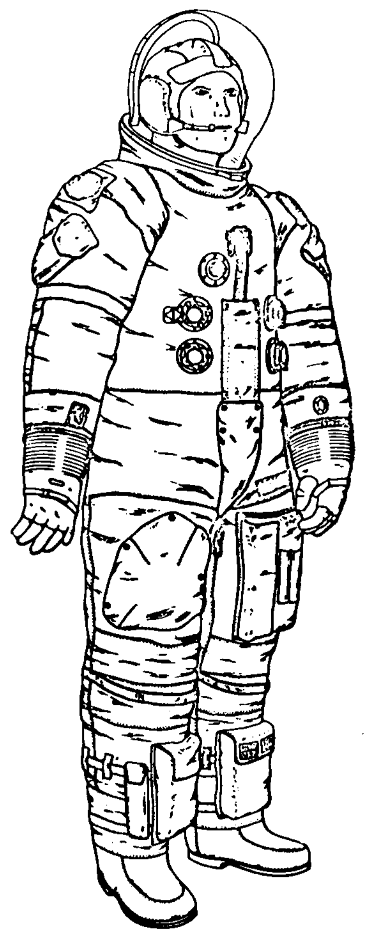


PRESENT OPERATIONAL SUITS

The opposite chart summarizes the major advantages and disadvantages of present operational suits. The conclusion is that a new suit should be developed for the shuttle.

PRESENT OPERATIONAL SUITS

ADVANTAGES	DISADVANTAGES
QUALIFIED FOR APOLLO AND SKYLAB	DIP GOODS NOT ADEQUATE – 3-YEAR SHELF LIFE
SMALL STOWAGE VOLUME	LEAKAGE HIGH DUE TO DESIGN FEATURES SUCH AS ZIPPER
ESTABLISHED RELIABILITY GOOD VENT PRESSURE COMFORT	CYCLE LIFE OF COMPONENTS CONSIDERABLY LOWER THAN 100,000 CYCLES
	SUITS DESIGNED FOR "ONE MISSION" CAPABILITY WITH CUSTOM-SIZING AND MINIMUM MAINTENANCE
	CONTAIN A NUMBER OF MARGINAL DESIGNS SUCH AS ZIPPERS, CABLES, CABLE GUIDES, SWAGE FITTINGS, AND SLIDER FLAP ASSEMBLIES
	UNIT PRODUCTION COST FOR AES AND A7LB ARE COMPARABLE AND THE AES HAS GREATER POTENTIAL FOR LOWER UNIT COST THROUGH TOOLING
	VENT SYSTEM PRESSURE DROP IS NOT AS LOW AS CAN BE ATTAINED
	RE-QUALIFICATION REQUIRED TO SHUTTLE REQUIREMENTS
	INFIELD SIZING CAPABILITY RESTRICTED TO ARMS/ LEGS
	MAINTENANCE WOULD BE COSTLY DUE TO THE INHERENT DESIGN
	STRUCTURAL INTEGRITY INADEQUATE AT AN 8.0 PSID OPERATING PRESSURE
	WAIST AND SHOULDER JOINTS TOTALLY UN-ACCEPTABLE AT 8.0 PSID
	THE CYCLE LIFE OF JOINTS WHICH DO FUNCTION AT 8.0 PSID WILL BE GREATLY REDUCED
	AS A RESULT OF THE ABOVE, PREBREATHING IS DEFINITELY REQUIRED IF USED AT LOWER PRESSURE
	MOBILITY, CYCLE LIFE, RELIABILITY, AND STRUCTURAL INTEGRITY PROGRESSIVELY DETERIORATE; PRESSURE IS INCREASED FROM 4.0 TO 8.0 PSI



EVA/IVA SUIT RECOMMENDATIONS

Incremental sizing of suit segments will reduce costs by allowing the fabrication of standard parts using production tooling and stocking of standard spare parts for fitting and maintaining suits in the field.

An integrated TMG will result in less overall bulk, allowing more joint mobility.

A hard, hemispherical helmet provides impact protection, structural integrity, good visibility and comfort at a low cost.

The hard waist connector provides quick donning and low leakage.

New pressure restraint materials, such as DuPont's PRD-49 high performance fiber, offer higher strength and modulus and would be self extinguishing in air.

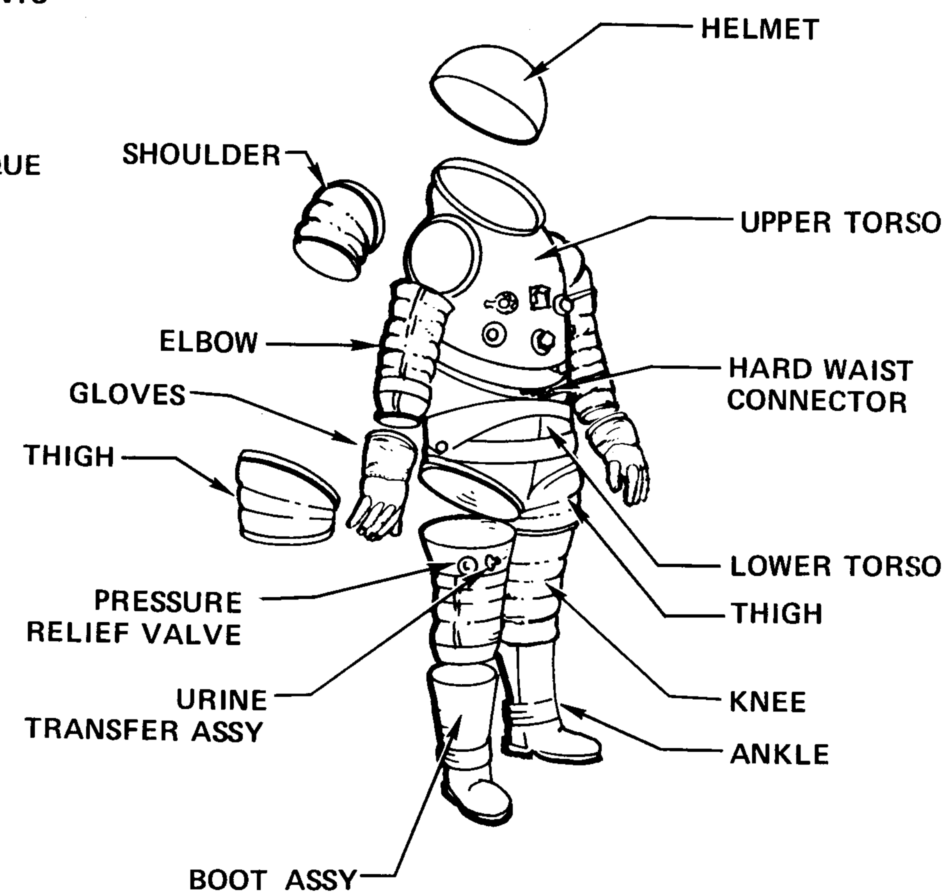
A heat sealing fabrication technique would allow rapid replacement of suit segments, in the field, without structural damage.

A removable EV visor will provide thermal protection and shielding of the eyes for EVA and the capability of removing it for IVA.

An LCG is required to properly cool the crewman, therefore it must be provided for in the basic space suit.

EVA/IVA SUIT RECOMMENDATIONS

- INCREMENTAL SIZING OF SUIT SEGMENTS
- INTEGRATED TMG
- HARD, HEMISPHERICAL HELMET
- HARD WAIST CONNECTOR
- NEW PRESSURE RESTRAINT MATERIAL
- HEAT SEALING FABRICATION TECHNIQUE
- REMOVABLE EV VISOR ASSEMBLY
- LCG PROVISIONS

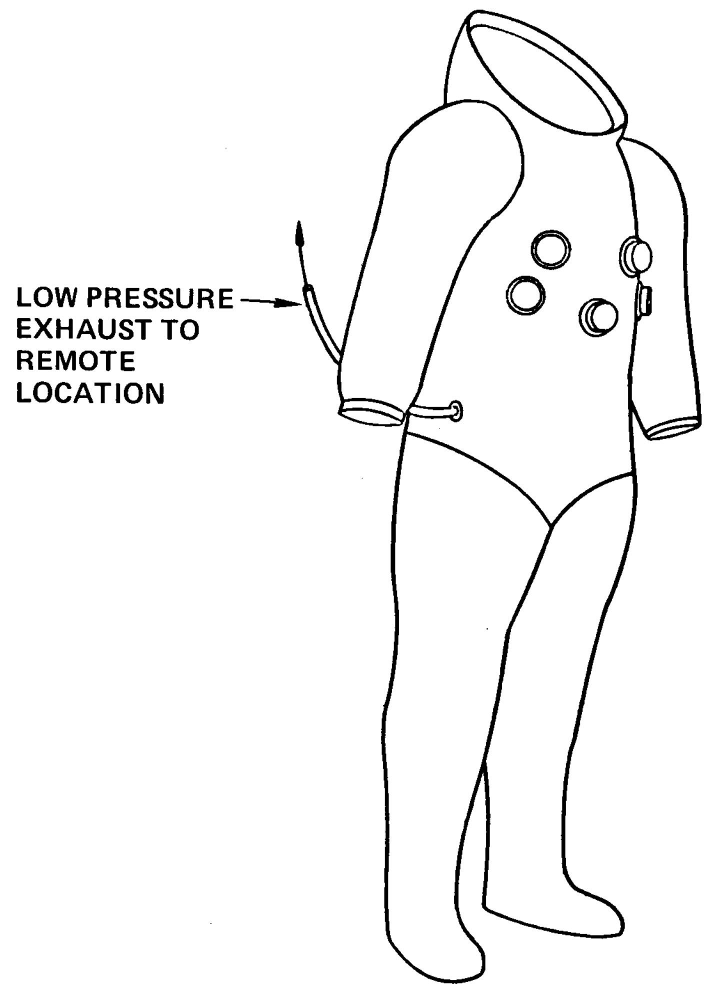


CONTAMINATION BARRIER GARMENT

Suit leakage is a source of contamination. The gas which leaks from a suit contains such things as water vapor and skin oil. The gas leakage rate is expected to be 80 scc./min.

In order to contain suit leakage and any lint which may be produced by abrading the suit exterior surface, ILC has proposed a barrier garment with the features listed. In order to prevent the barrier garment from being inflated to a pressure beyond the limit of the seals, an umbilical would be required for venting it to a remote area.

CONTAMINANT BARRIER GARMENT
FOR USE WITH EVA/IVA SUIT



FEATURES

- LOW PRESSURE GAS SEALS AT HELMET, WRIST UMBILICAL CONNECTORS
- THIN, DURABLE, PLIABLE
- REMOVABLE WHEN NOT REQUIRED

EMERGENCY IV SUIT RECOMMENDATIONS

The incremental sizing of suit segments for the Emergency IV suit is more advantageous than on the EVA/IVA suits because more suits are required and more people are involved, therefore more varied sizes required.

A soft helment will provide the protection and visibility require for less cost.

The hard waist connector, heat sealing fabrication technique and new pressure restraint materials provide the same advantages as stated for the EVA/IVA suit.

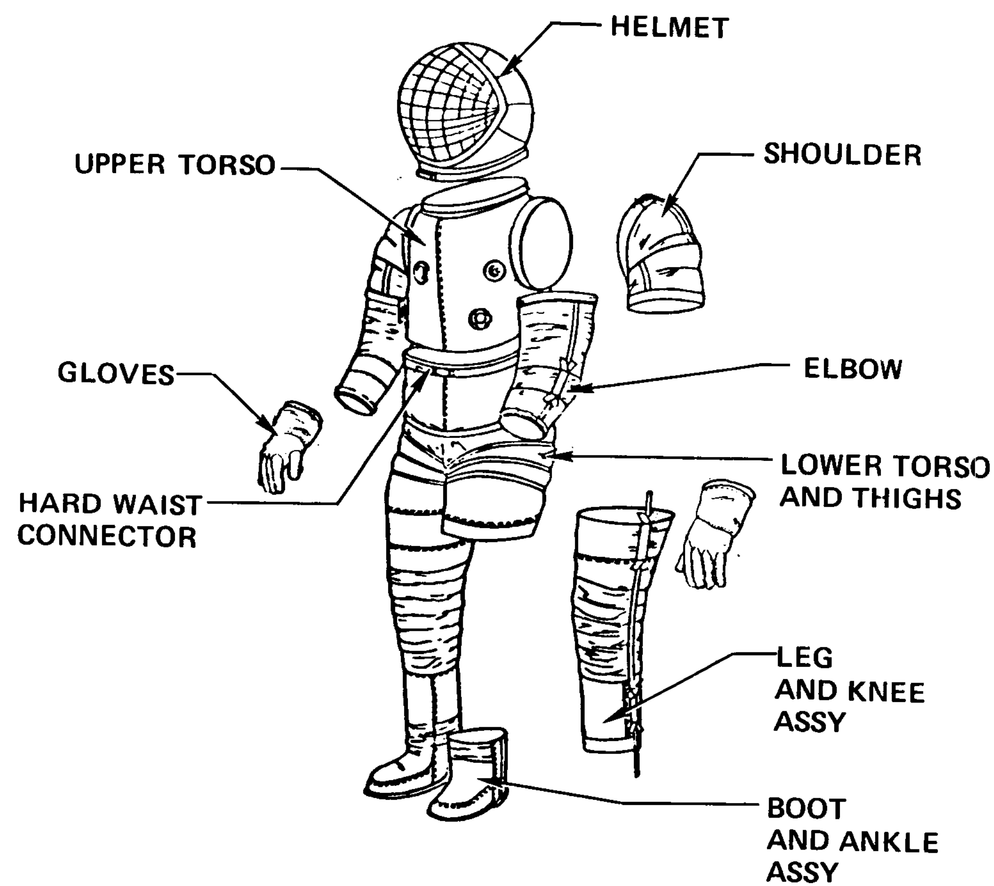
With the recommended emergency heat rejection system no LCG is required for emergency IV.

A thermal overcoat will be required for EVA transfer from a disabled orbiter to a rescue vehicle. An integrated thermal cover may be required for a long term stay in a depressurized cabin.

Based on study of passenger mobility requirements, it was determined that a third, simplified version of the IV emergency suit will be adequate for passenger/observers. This suit would eliminate shoulder bearings and hard disconnects at the neck, upper arm and wrist. A smaller visor would suffice. Economic justification for this suit depends on the yet-undefined flight frequency of such personnel.

EMERGENCY IV SUIT RECOMMENDATIONS

- INCREMENTAL SIZING OF SUIT SEGMENTS
- SOFT HELMET
- HARD WAIST CONNECTOR
- HEAT SEALING FABRICATION TECHNIQUE
- NEW PRESSURE RESTRAINT MATERIALS
- NO LCG PROVISIONS (ALTERNATE HEAT REJECTION CONCEPT WOULD REQUIRE USE OF AN LCG)
- THERMAL OVERCOAT FOR CONTINGENCY TRANSFER



SPACE SUIT SIZING RECOMMENDATIONS

Since the Orbiter is to accommodate both men and women, and a comparison of the physical dimensions of men and women show different percentile ranges, two sizing schedules are recommended.

This Public Health Service Publication has anthropometric measurements of 6672 Americans, both men and women, 18 - 79 years old, taken in 1960 - 1962.

Sizing studies done by ILC Industries resulted in the example sizing schedule shown. This schedule was derived using the astronaut population and could fit over 90% of the astronauts. A goal of fitting 90% of the source population with a sizing schedule is recommended as a reasonable goal.

SPACE SUIT SIZING RECOMMENDATIONS

- TWO SIZING SCHEDULES – ONE FOR MEN
  ONE FOR WOMEN
- ANTHROPOMETRIC DATA SOURCE – PUBLIC HEALTH SERVICE PUBLICATION 1000, SERIES 11, NO. 8
- FIT 90% OF DATA SOURCE RANGE WITH SIZING SCHEDULES AS A GOAL, TREAT REMAINING 10% AS SPECIAL CASES
- EXAMPLE SIZING SCHEDULE FOR MEN'S EVA/IVA SUIT:
  - TORSO – 9 SIZES
  - LEG LENGTH – 4 SIZES
  - ARM LENGTH – 6 SIZES
  - GLOVES – CUSTOM FIT
  - BOOTS – 5 SIZES

RECOMMENDED SUIT QUANTITIES

These quantities were derived by ILC Industries using the information shown plus a recommended change in the way the space suits are handled compared to handling in the past.

The handling approach would have the suit contractor produce and maintain suits at the component level. The assembly and fit checks would be accomplished at the using station, JSC, KSC and Vandenberg for example. Spare components would be stocked as required at the using stations for accommodating the issuance of new suits and the maintenance of issued suits.

RECOMMENDED SUIT QUANTITIES

- EVA/IVA SUIT – 246
- EMERGENCY IV SUIT – 466
- INCLUDES: TRAINING SUITS
  SPARE SUITS
  REPLACEMENT OF SUITS EXCEEDING USEFUL LIFE
- FOR SHUTTLE PROGRAM PERIOD 1978 THRU 1988
- UTILIZING EXAMPLE SIZING SCHEDULE
- BASED ON CREW COMPLEMENT ESTABLISHED BY LTV AND NASA MSC 24 OCT. 1972

SUIT PRESSURE DROP SELECTION

Electrical power requirements to drive the vent flow fan increase with increasing suit pressure drop. The penalty can be significant, especially for applications such as vehicle contingencies requiring long term suit loop operation. Available suit technology indicates considerable reduction in pressure drop over Apollo/Skylab suit designs are possible. Tests conducted on the AirResearch AES suit (CR108666) show that a pressure drop of 1.3 inches of water at 3.7 psi pressure and 7 ACFM is within current technology. This value was used as the basis for the recommended requirements, as it represents a significant, yet practical, improvement over Apollo/Skylab systems.

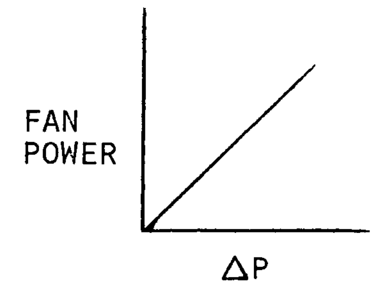
The value of 1.8 inches of water pressure drop shown was adjusted to the 5.5 ACFM flow rate and 8 psia pressure selected for EVA usage (see Supporting Studies). The equivalent NASA/MSC RFP No. 9-BC73-36-2-263P EV suit pressure drop is 2.35 inches of water.

The recommended pressure drop values at 12 ACFM and 8 and 14.7 psia correspond to contingency IV and suited IVA standby configurations, respectively, and are consistent with the 5.5 ACFM performance characteristics.

SUIT PRESSURE DROP SELECTION

ISSUES

- O EXTRAVEHICULAR LSS PENALTIES
- O VEHICLE CONTINGENCY LSS PENALTIES
- O AVAILABLE SUIT TECHNOLOGY

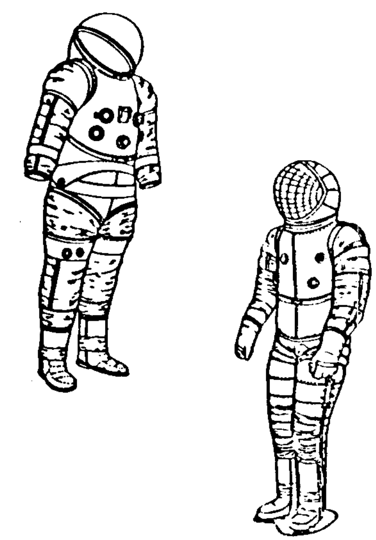


RECOMMENDED EVA & IV SUIT REQUIREMENTS
(EXCLUDING MALE INLET AND OUTLET CONNECTORS)

1.8 IN. H_2O ΔP @ 5.5 ACFM, 8 PSIA, 77°F

7.5 IN. H_2O ΔP @ 12 ACFM, 8 PSIA, 77°F

13.8 IN. H_2O ΔP @ 12 ACFM, 14.7 PSIA, 77°F



BASIS

- O AIRESEARCH AES SUIT TEST DATA
- O POTENTIAL VENT SYSTEM IMPROVEMENTS IDENTIFIED BY ILC

SPACE SUIT REQUIREMENTS

The selection of the 8 psia pressure will be covered in the section of the presentation titled Supporting Studies.

The specified leakage rate is estimated to be attainable by ILC Industries by incorporating hard waist disconnects, new attachment methods for bladder and restraint materials, elimination of friction dependent devices such as cables and the use of easily replaceable seals in waist, helmet and wrist closures as well as in all bearing and hard joints.

Quick donning is required to provide for emergencies requiring the wearing of space suits and for the efficient use of the crewman's time.

Useful life is a combination of shelf life and operational life. Some suit materials will be synthetic rubber, therefore the 8 year useful life in MSFC STD 105, Age Control of Synthetic Rubber, is specified.

The cycle life figures specified are approximately twice the number of cycles determined to be required by ILC Industries analysis. The factor of two is a common safety factor used in deriving design goal requirements.

The structural design factors are the same as used for Apollo and Skylab.

The pressure drop selection was just discussed and the contact surface temperatures are discussed in the section of the presentation titled Supporting Studies.

The suit interior surface temperatures specified is the range which a man can contact without having skin damage. 39° F lower limit from SP-3006 and 113° F upper limit from Orbiter RFP.

The suit mounted equipment is a combination of required operational and safety equipment.

SPACE SUIT REQUIREMENTS

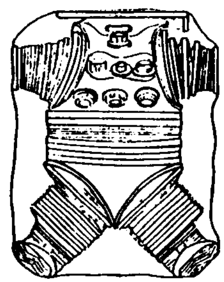
- OPERATING PRESSURE – 8 PSIA
- LEAKAGE RATE – 80 SCC/MIN AT 8 PSIA, MAX.
- MATERIALS – HIGH STRENGTH
NONFLAMMABLE IN ONE ATMOSPHERE AIR
- QUICK DONNING
- USEFUL LIFE – 8 YEARS
- JOINT CYCLE LIFE: UPPER TORSO JOINTS – 200,000 CYCLES
LOWER TORSO JOINTS – 100,000 CYCLES
- STRUCTURAL DESIGN FACTORS – DESIGN – 1.5 x 8.0 = 12 PSIG
PROOF – 2.0 x 8.0 = 16 PSIG
BURST – 2.5 x 8.0 = 20 PSIG
- VENT SYSTEM PRESSURE DROP – 1.8 INCHES OF H_2O MAX
AT 5.5 ACFM AND 8 PSIA
(EXCLUDING CONNECTORS)
- EVA/IVA SUIT MUST WITHSTAND CONTACT WITH SURFACES WITH A TEMPERATURE OF -263^oF TO $+285^oF$
- INTERIOR SURFACE TEMPERATURE RANGE: 39^oF TO 113^oF
- SUIT MOUNTED EQUIPMENT:
  - PRESSURE GAGE
  - HELMET/HELMET & TORSO VENT DIVERTER VALVE
  - ACTIVE RADIATION DOSIMETER (EVA/IVA SUIT ONLY)
  - FEED PORT IN HELMET
  - URINE TRANSFER DEVICE

SPACE SUIT STOWAGE REQUIREMENTS

The space suits may be stowed either in container or suspended at a donning station. The weights and volumes specified are estimates made by ILC Industries based on experience on Apollo and Skylab.

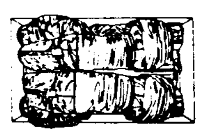
SPACE SUIT STOWAGE REQUIREMENTS
STOWAGE ENVELOPE & WEIGHT

EVA/IVA SUIT - 50 LBS. MAX.

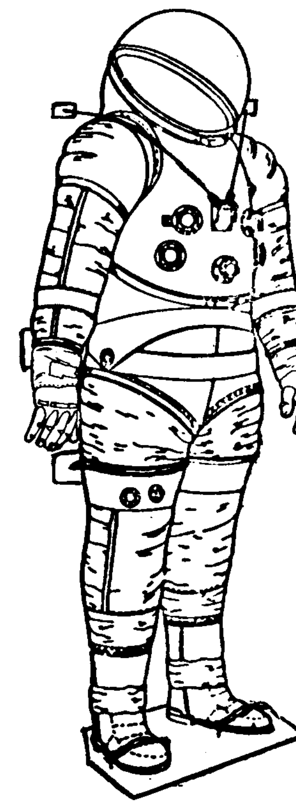


IN A CONTAINER
28½ X 23 X 15 INCHES

EMERGENCY IV SUIT - 17 LBS. MAX.



IN A CONTAINER
18 X 17 X 8 INCHES



SUSPENDED
79.5 X 31 X 20 INCHES

VISIBILITY REQUIREMENTS

It is difficult to establish specific requirements for visibility. The requirements are perhaps more useful when stated in terms of what a crewman must be able to do. These are examples of things the crewman must be able to do.

An EVA crewman commanding the motions and attitude of the Work Platform must be able to see where he wants to go in front of him, but he must also be able to turn and see directly behind him to be sure the manipulator arm does not strike something while responding to his commands. (As currently conceived, the manipulator will have no automatic system to prevent driving the arms into something.) The crewman must be able to bend over and see his toes while engaging the foot restraint.

An IVA crewman who is controlling the Orbiter while wearing an Emergency IV suit must be able to read all instruments and locate all controls required for his task.

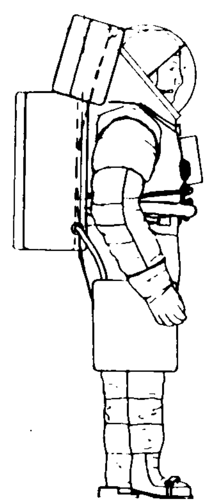
In the sketch the EVA crewman is shown replacing a solar cell assembly on an LST, utilizing a Work Platform end effector.

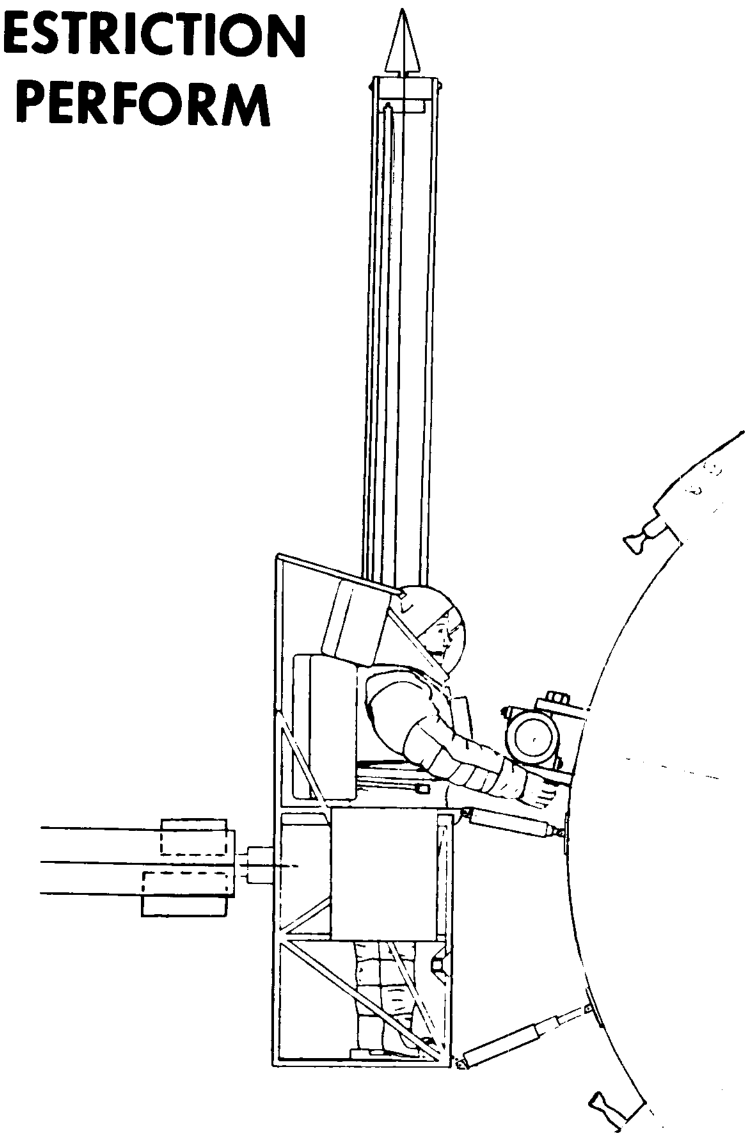
VISIBILITY REQUIREMENTS

VISIBILITY — SHALL NOT CAUSE A RESTRICTION IN THE CREWMAN'S CAPABILITY TO PERFORM REQUIRED TASKS.

EVA/IVA SUIT EXAMPLES: WHILE CONTROLLING A WORK PLATFORM END EFFECTOR, MONITOR MANIPULATOR ARM POSITION. WHILE ENTERING FOOT RESTRAINTS, BE ABLE TO SEE BOTH FEET.

EMERGENCY IV SUIT EXAMPLE: WHILE CONTROLLING THE ORBITER, BE ABLE TO SEE ALL CREW STATION CONTROLS AND DISPLAYS.



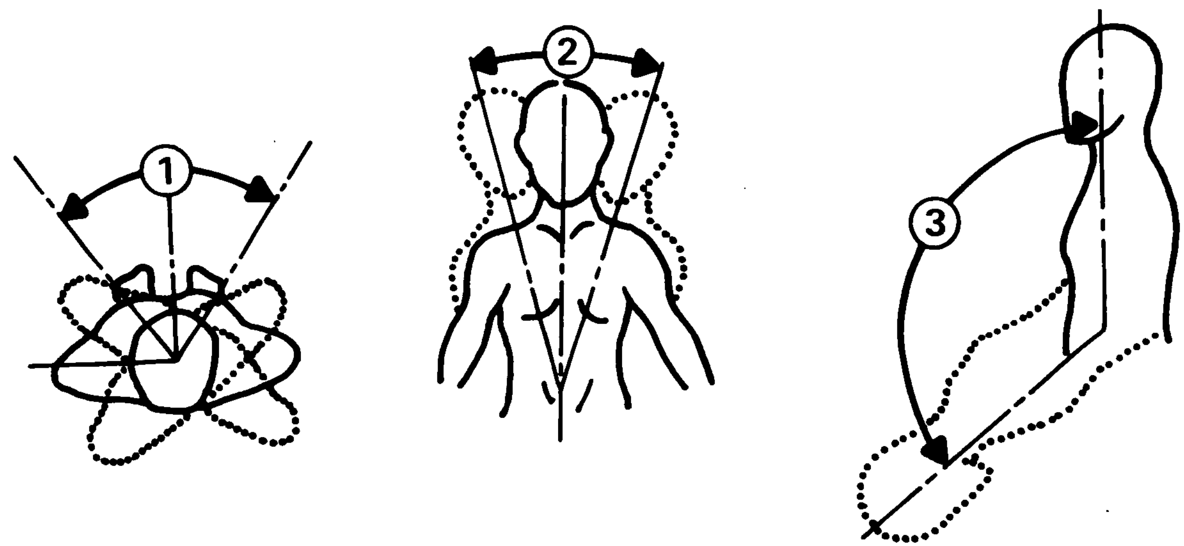


EXAMPLE MOBILITY REQUIREMENTS

Crewman mobility requirements have been established by ILC Industries for both the EVA/IVA Space Suit and the Emergency IV Suit. This is an example of the required mobility. These requirements were derived by the use of orbiter mockups at Rockwell and JSC combined with analysis of the representative EVA/IVA tasks presented earlier in this presentation. Complete data are given in Volume III.

EXAMPLE MOBILITY REQUIREMENTS

EXAMPLE: WAIST MOBILITY



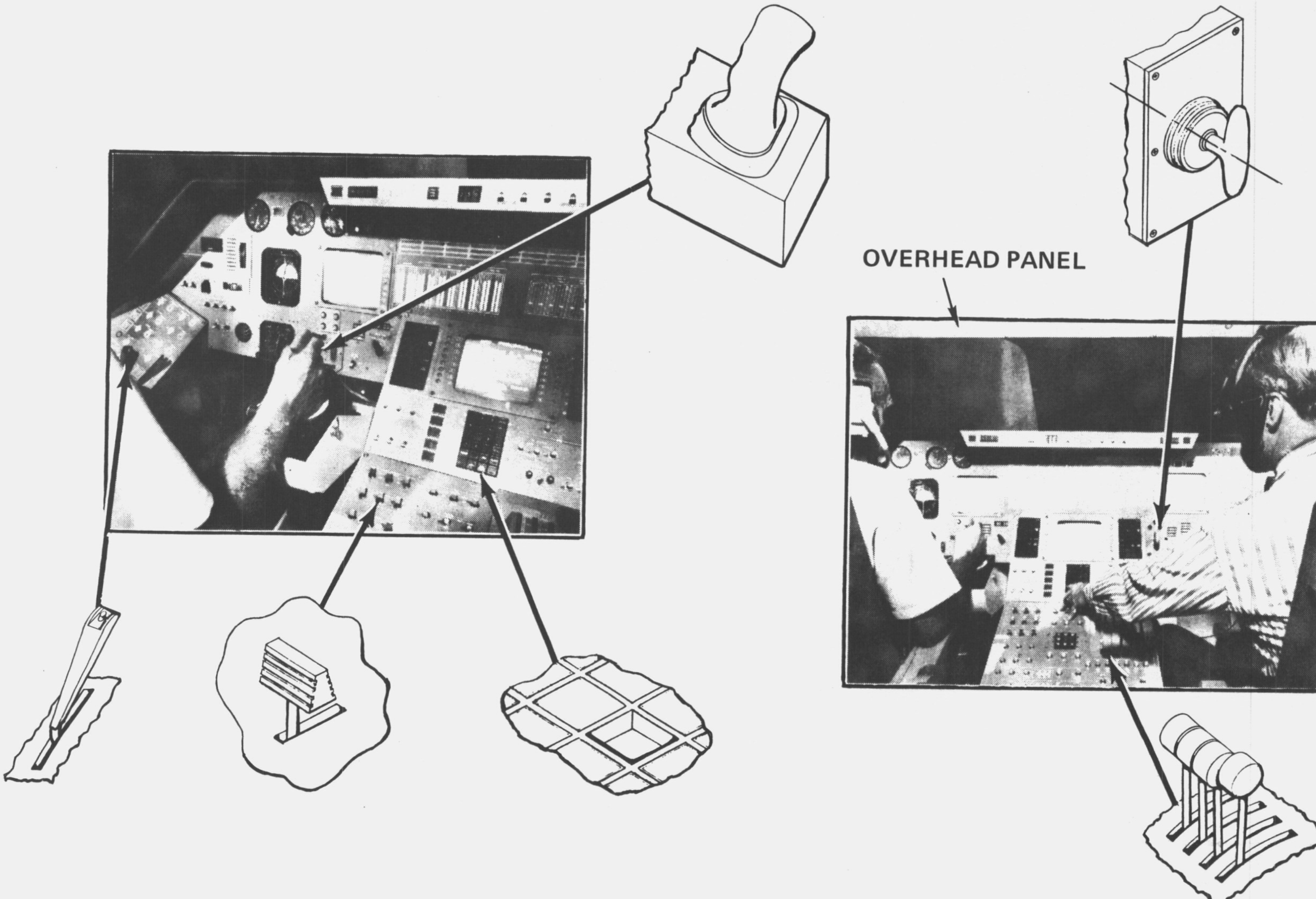
NO.	MOVEMENT	EVA/IVA	IV EMERGENCY
1	ROTATION, LEFT-RIGHT	90^o	NONE
2	FLEXION, LEFT-RIGHT	15^o	NONE
3	FLEXION FORWARD	45^o	25^o

COCKPIT-SUIT INTERFACE

This viewgraph shows the interior of the Rockwell Orbiter vehicle cockpit mockup. Several controls are detailed to show the dexterity which would be required of the pilot and commander wearing a pressurized IV suit and controlling the vehicle during an emergency re-entry and landing.

ILC engineers utilized this mockup to establish mobility requirements for the IV space suit. Some of these mobility requirements are shown on the next viewgraph.

COCKPIT - SUIT INTERFACES



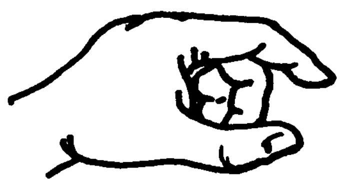
EXAMPLE DEXTERITY REQUIREMENTS

Required dexterity was derived coincidentally with the mobility requirements. This is an example of the dexterity requirements derived by ILC Industries.

EXAMPLE DEXTERITY REQUIREMENTS

EXAMPLE: HAND-FINGER OPERATIONS

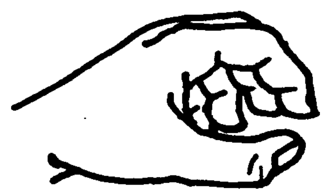
PALMAR



RELATED TASKS

1. WRITING
2. USING ROTARY
3. USING SMALL SCREWDRIVER

TIP



RELATED TASKS

1. PICKING UP SMALL OBJECTS
2. USING TWEEZER
3. WINDING ELECTRICAL INSULATING TAPE
4. USING TWINE OR HEAVY LACING TAPE

LATERAL

RELATED TASKS

1. USING ROTARY
2. USING TOGGLE SWITCH

GRASP

RELATED TASKS

1. USING PLIERS
2. USING WRENCHES
3. USING SCREWDRIVER
4. USING HANDLES AND LEVERS
5. USING HANDHOLDS AND HANDRAILS
6. INGRESS AND EGRESS OF SHUTTLE COUCH OR AIRLOCK
7. USING TORQUE WRENCH

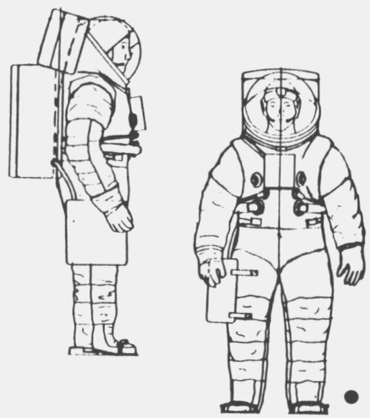
VI. LIFE SUPPORT SYSTEM

LIFE SUPPORT ISSUES

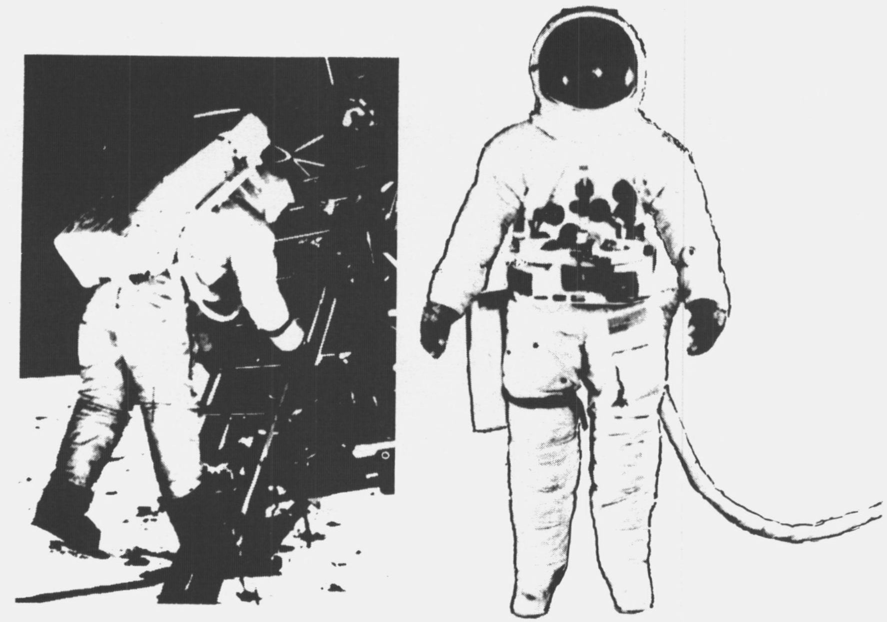
Some of the main questions considered in selecting the EVA/IVA life support system are illustrated. A fine balance is involved between capability of the system to effectively perform the projected tasks, the development costs and risks involved, and impact on other systems.

A very important consideration relative to effectiveness of the EVA/IVA system is whether an EVA can safely and effectively be performed by one man instead of two, especially in view of the EVA overhead issue. Another important consideration is payload contamination, as shown in the sections on Supporting Studies and Task Analysis. In contrast, concepts to eliminate EVA contaminant sources must not so encumber the crewman that maneuverability and task performance capability is severely compromised.

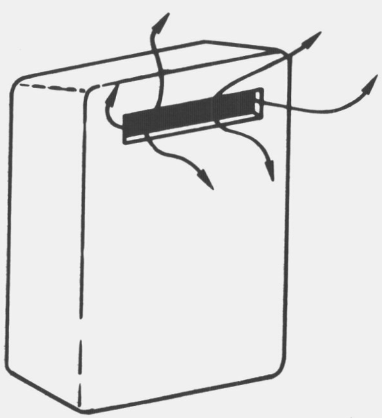
LIFE SUPPORT SYSTEM ISSUES



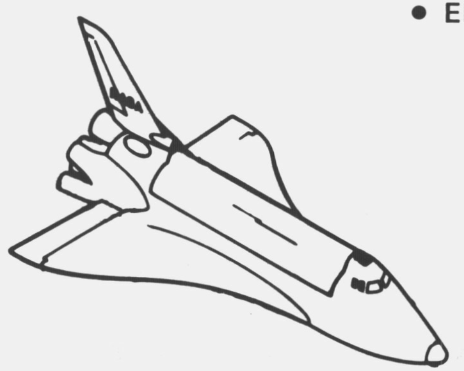
- ONE VS TWO MAN EVA
- MANEUVERABILITY
- TASK PERFORMANCE CAPABILITY



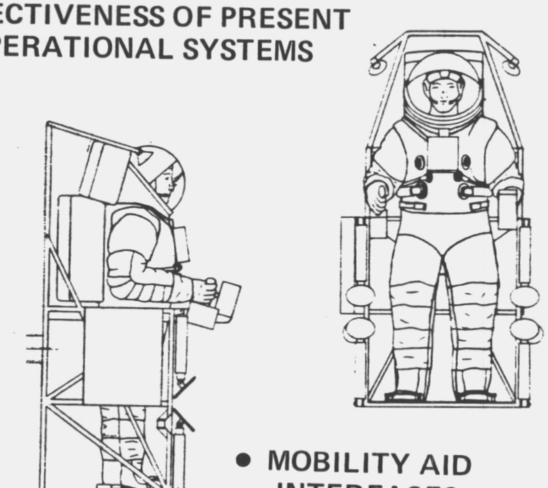
- EFFECTIVENESS OF PRESENT OPERATIONAL SYSTEMS



- CONTAMINATION



- VEHICLE IMPACT



- MOBILITY AID INTERFACES

LIFE SUPPORT SYSTEM REQUIREMENTS

The opposing chart summarizes the design requirements for the Extravehicular Life Support System (EVLSS) and Emergency Oxygen Pack (EOP). The various parameters are the results of timeline and task analyses, physiological considerations, subsystem level trade studies, and other considerations. (See Supporting Studies on the determination of operating pressure, flowrate, and heat leak.)

In addition to the requirements listed on the chart, a 240 pph liquid loop flowrate was determined (see Supporting Studies), and a non-venting and contaminant control capability was defined to ensure acceptable use around sensitive payloads.

LIFE SUPPORT SYSTEM REQUIREMENTS

EVLSS

1)	Duration	4.0 Hours
2)	Metabolic Rates	
	• Minimum	400 Btu/hr
	• Shuttle Flight EVA Avg.	800 Btu/hr
	• Single EVA/IVA Max. Avg.	1000 Btu/hr
	• Maximum for 1/2 Hour or Less	2000 Btu/hr
3)	Thermal Storage in Crewman	$\pm$100 Btu/hr
4)	Carbon Dioxide Partial Pressures	
	• Average	7.6 mm Hg
	• Maximum for Less Than 30 min.	15.0 mm Hg
5)	Ventilation Loop Flow Rate	5.5 ACFM
6)	Suit Pressure	8.0 Psia
7)	Communications	
8)	Multiple Use	
	o During a Shuttle Flight	
	o Multiple Shuttle Flights	
	o Different Crewmen	
9)	Environmental Heat Leak to EMU	+300 Btu/hr -375 Btu/hr
10)	Optional Non-venting Capability	1.0 Hour

EMERGENCY EVA/IVA LSS

1)	Reserve O_2 for Suit Leak	:	3.75 Lbm usable O_2
2)	CO_2 Level Inspired	:	15 mm Hg or less
3)	Metabolic Rate	:	1200 Btu/hr
4)	Environmental Heat Leak to Suit	:	+220 Btu/hr -280 Btu/hr
5)	Crewman Thermal Storage	:	$\pm$ 300 Btu/hr
6)	Failure In Any EVLSS Subsystem	:	Redundant Emergency Provisions
7)	Duration	:	24 Minutes
8)	Suit Pressure	:	8.0 psia

EVLSS SYSTEM LEVEL TRADES

Present operational systems were evaluated and found to be inadequate for shuttle EVA/IVA. Subsystem trade studies were conducted to evaluate the acceptability of current technology and the need for improvements. A closed loop ventilation loop with LiOH for CO_2 control, activated charcoal for trace contaminant control, and storage of waste water was recommended for all systems. Either high pressure storage or umbilical supply of oxygen was selected for make-up of metabolic consumption, leakage and service O_2 (for suit pressurization). The recommended power supplies for EVLSS subsystem were either Ag/Zn batteries or umbilical. A high effectiveness LCG with either an evaporative heat sink (typified by a flash evaporator) or umbilical or ice packs was selected for thermal control. Radio frequency communications were recommended for all systems to allow maximum EVA/IVA mobility.

The recommended subsystems were combined into the six systems listed on the opposite page, and system level trades were performed. Schematics and evaluations results are presented on the following pages for each of the six systems. Weights and volumes are also listed on each evaluation chart for a 4-hour total duration with a 1-hour minimum non-venting capability.

EVLSS SYSTEM LEVEL TRADES

ALL UMBILICAL

UMBILICAL/VENT

UMBILICAL/NON-VENTING

VENT/NON-VENT
(INTEGRAL)

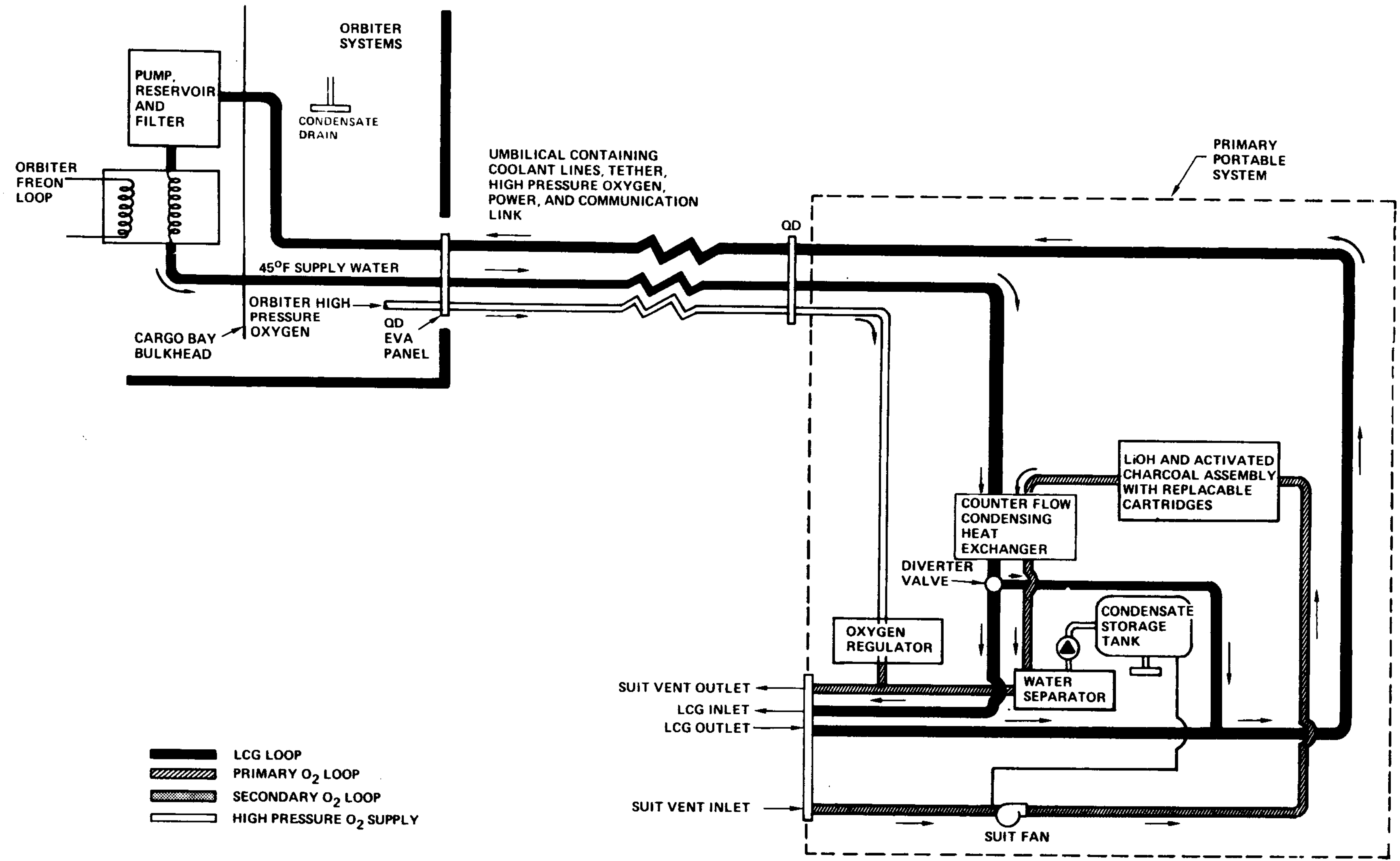
VENT/NON-VENT
(DETACHABLE)

MODULAR ICE PACK
NON-VENT (VENT)

SHUTTLE EVA/IVA LSS CONCEPT ALL UMBILICAL SYSTEM

The all-umbilical concept illustrated on the opposing chart is similar to the existing Skylab ALSA, only the oxygen system is closed by integration of a CO_2 and humidity control loop into the portable pack. In this way it avoids the payload contamination problem present with open-loop venting. The system is also excellent from the viewpoint of a small volume on the astronaut and only a modest vehicle impact for the umbilical system. It suffers from the encumbrance of the umbilical at all times. This will reduce EVA effectiveness, as shown on a previous chart in the Task Analysis section, and will prohibit conduct of tasks requiring an extremely long umbilical length, as also previously shown. In addition, a second crewman would always be required for umbilical management, causing the "EVA overhead" to be high.

SHUTTLE EVA/IVA LSS CONCEPT
ALL UMBILICAL SYSTEM



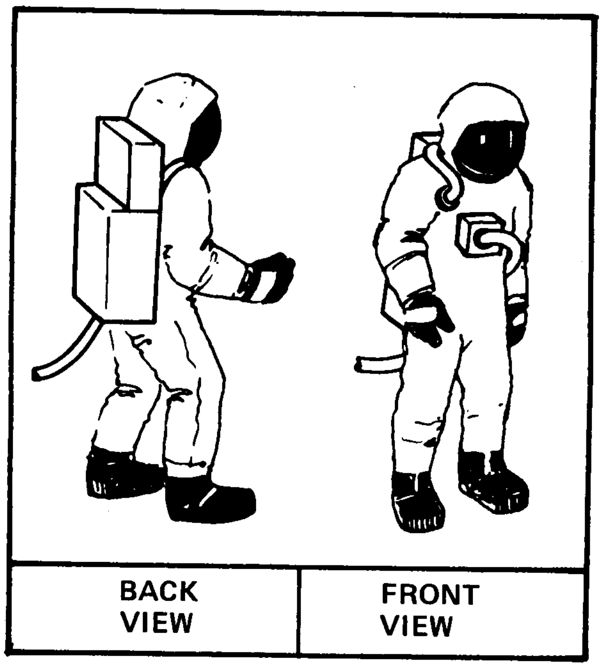
EVALUATION OF ALL UMBILICAL CONCEPT

The volume as a function of EVA duration is plotted, exclusive of the umbilical. In the current concepts study, umbilical weight and volume were added to the vehicle, as it does not represent a volume or weight constraint on the man at the worksite - it is more an encumbrance and management problem. A 70 ft umbilical, which probably would be selected, would weigh about 65 lbs and occupy a volume of about 2000 in^3. In order to do all the tasks, a prohibitively long umbilical would be required.

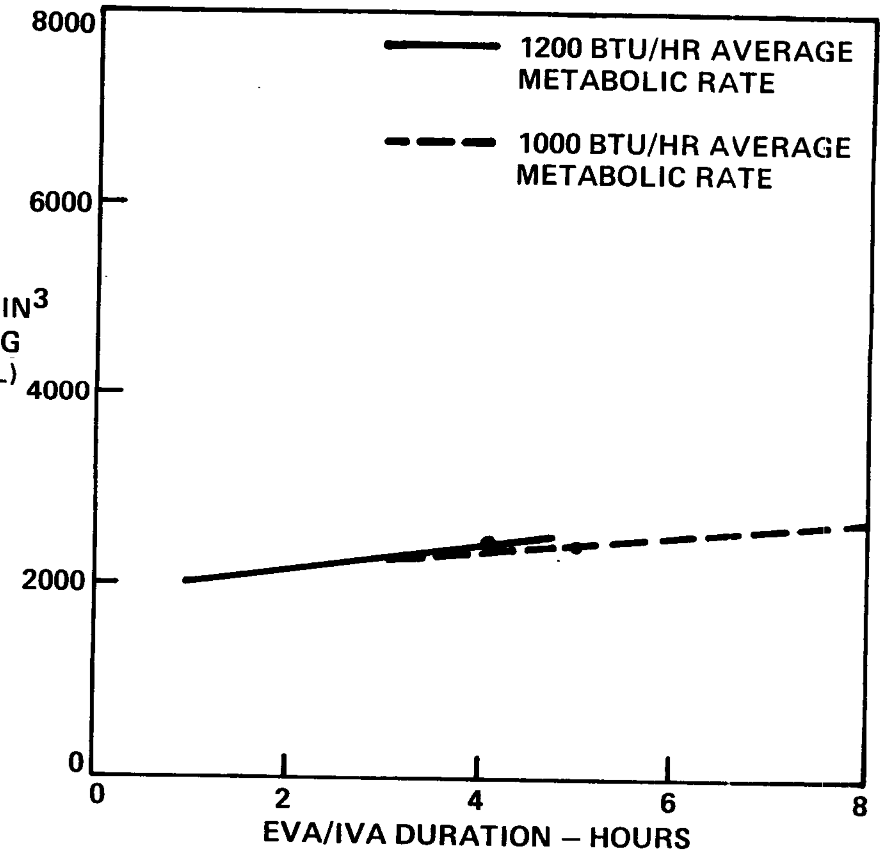
It is seen from the sketch and the parametric data that the portable pack is very small and relatively insensitive to EVA duration, all in its favor. This is to be contrasted against the disadvantages of umbilical systems.

The point weight and volume data tabulated on the chart are for the 4-hour design mission at the 1000 Btu/hr metabolic rate.

SHUTTLE EVA/IVA LSS CONCEPT
ALL UMBILICAL



2320 IN.^{3} 57.8 LBS
TASK EFFECTIVENESS: POOR



ALL UMBILICAL LSS

SHUTTLE EVA/IVA LSS CONCEPT HYBRID UMBILICAL AND VENTING PORTABLE SYSTEM

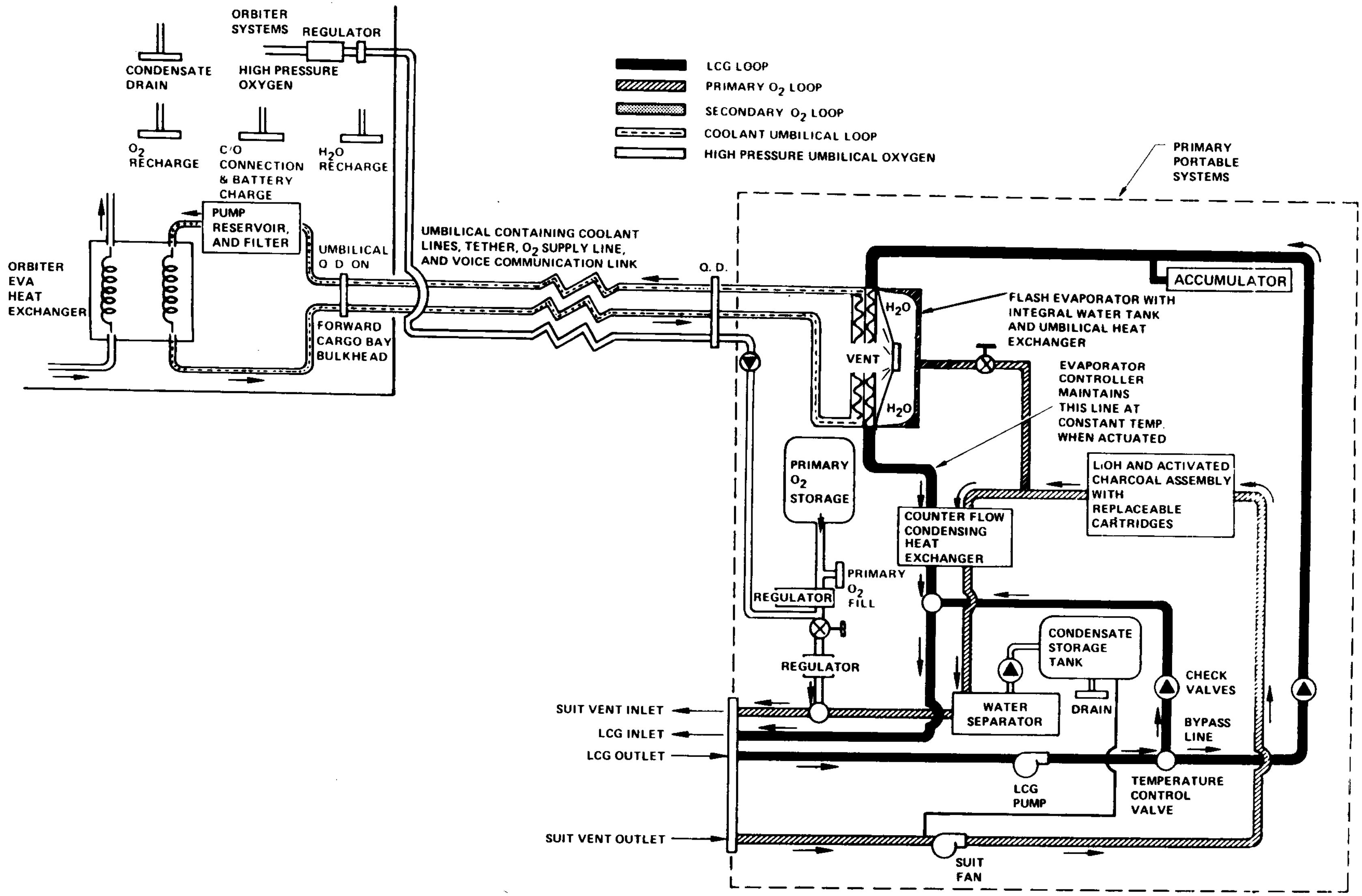
The concept of a hybrid umbilical and venting expendable concept is representative of adapting an existing Apollo PLSS type system to non-venting use near water vapor sensitive surfaces. A flash evaporator is shown to typify a long life version of an expendable concept.

The concept provides all necessary consumables in a portable form so that no critical vacuum disconnects are involved. Not shown is the necessary communications transmitter and battery, which must be included for non-umbilical operation.

The system is closely related to existing flight hardware and attractive from a volume and weight basis when detached, all in its favor. Vehicle interfaces are modest. Its big disadvantage is its limitation to the umbilical in the non-venting mode.

SHUTTLE EVA/IVA LSS CONCEPT

HYBRID UMBILICAL AND VENTING PORTABLE SYSTEM



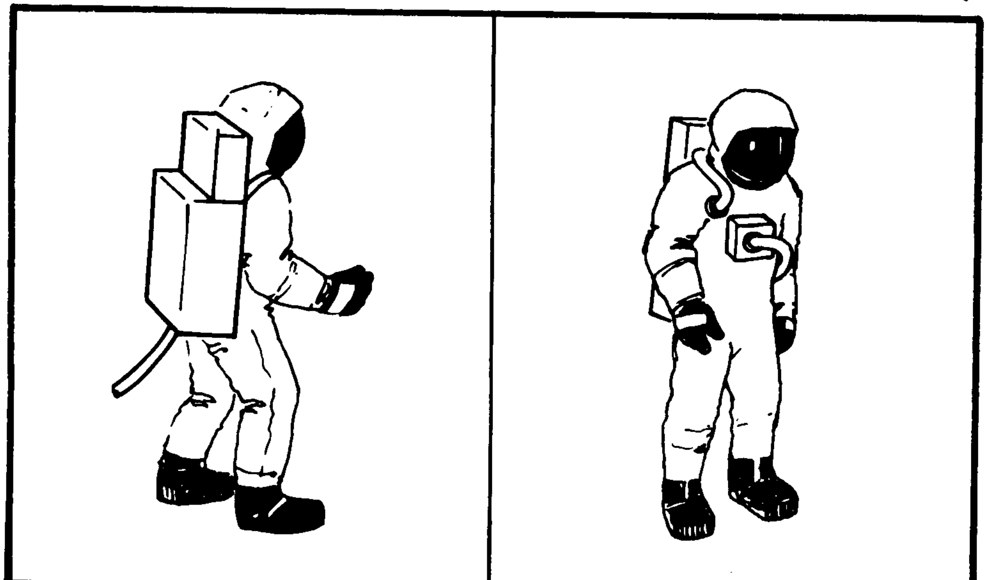
EVALUATION OF HYBRID AND VENTING PORTABLE SYSTEM

Quantitative parametric volume data are given on the opposing chart. The general arrangement is sketched. The plot of data volume as a function of oxygen storage pressure in the portable EVA system is general and applies to all hybrid concepts. All concepts were sized for 2100 psia, and these curves show the penalties/improvements corresponding to changes in charge pressure.

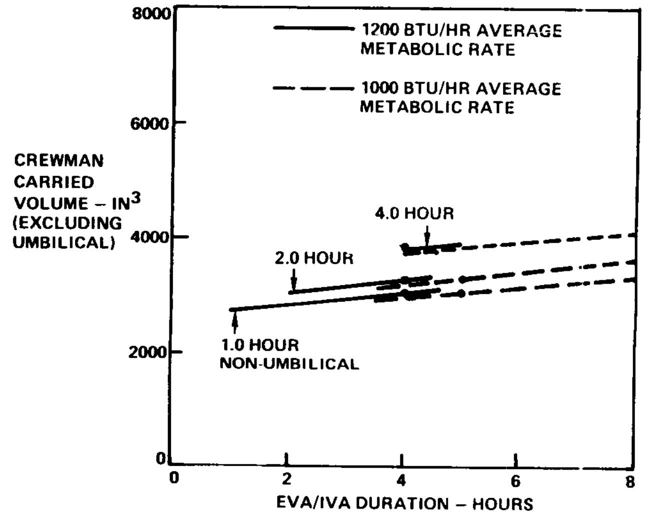
The tabulated data on the chart is for the point design mission (1000 Btu/hr metabolic), with up to 4 hours off the umbilical in the venting mode.

Parametric data shown are for variable total EVA duration, with 1, 2, or 4 hour capability off the umbilical. Volume data are given for both 1000 and 1200 Btu/hr average metabolic rates. Typically, for the case of 4 hours total duration and 1200 Btu/hr metabolic rate, the 2-hour non-umbilical case is 4 1/2 lb heavier than the 1-hour non-umbilical case, and the 4-hour non-umbilical case is 13 lb heavier than the 1-hour non-umbilical case.

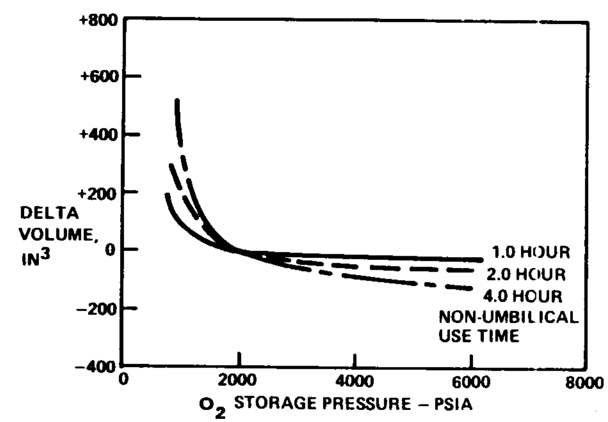
SHUTTLE EVA/IVA LSS CONCEPT
HYBRID/VENTING (UMBILICAL/FLASH EVAPORATOR)



BACK VIEW | FRONT VIEW



HYBRID LSS UMBILICAL/VENTING (FLASH EVAPORATOR)

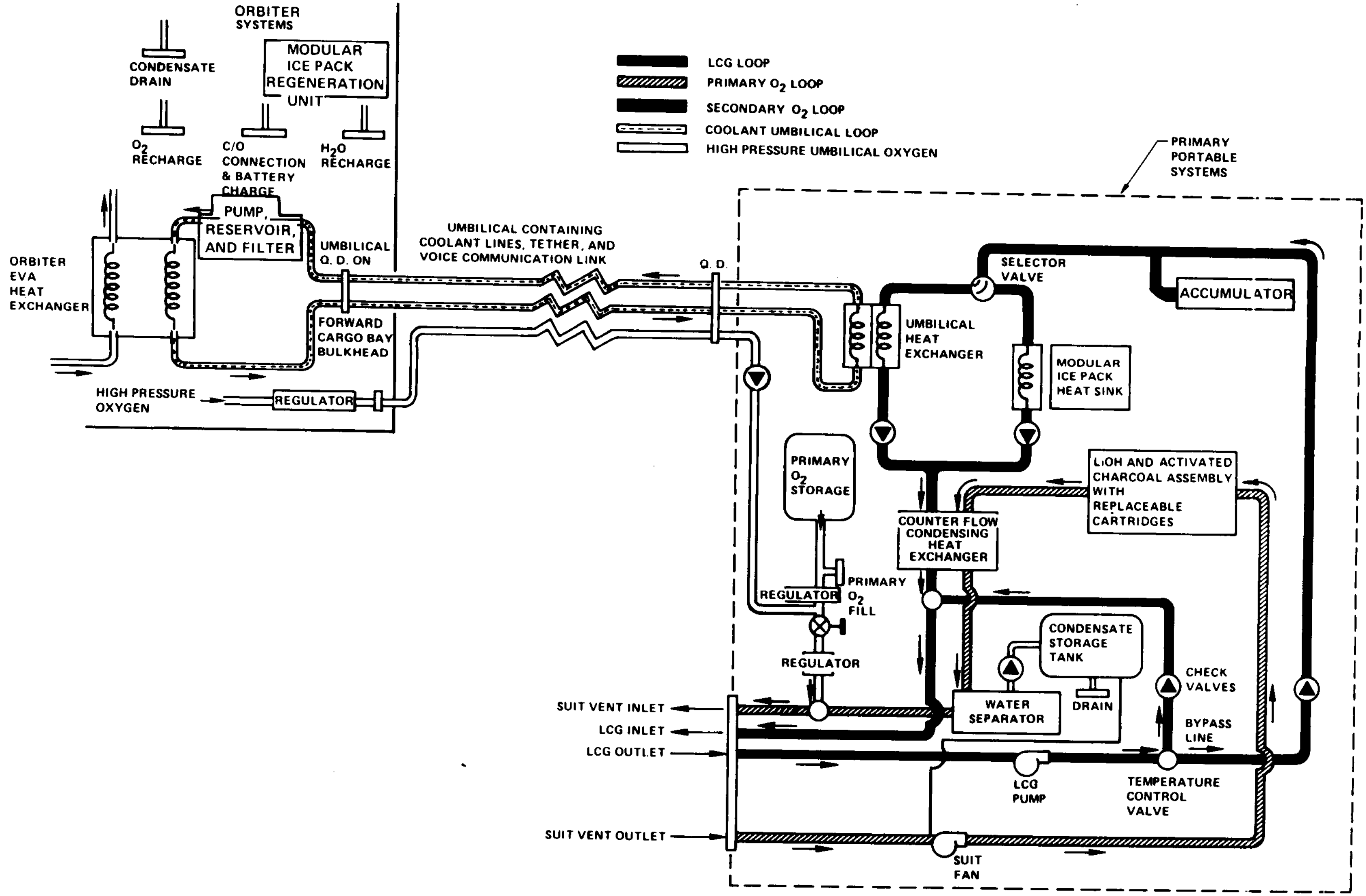


3750 IN.^{3} 90.4 LBS
TASK EFFECTIVENESS: FAIR

SHUTTLE EVA/IVA LSS CONCEPT
HYBRID NON-VENTING AND UMBILICAL SYSTEM

This concept eliminates venting entirely by using an umbilical/modular ice pack combination. Operationally, if sized properly, it can accomplish all tasks. In addition, on short duration EVA's, it can effectively operate in the one-man EVA mode without ever having to unstowe the umbilical. Vehicle interfaces, unfortunately, are the most complex of all.

SHUTTLE EVA/IVA LSS CONCEPT
HYBRID NON-VENTING AND UMBILICAL SYSTEM



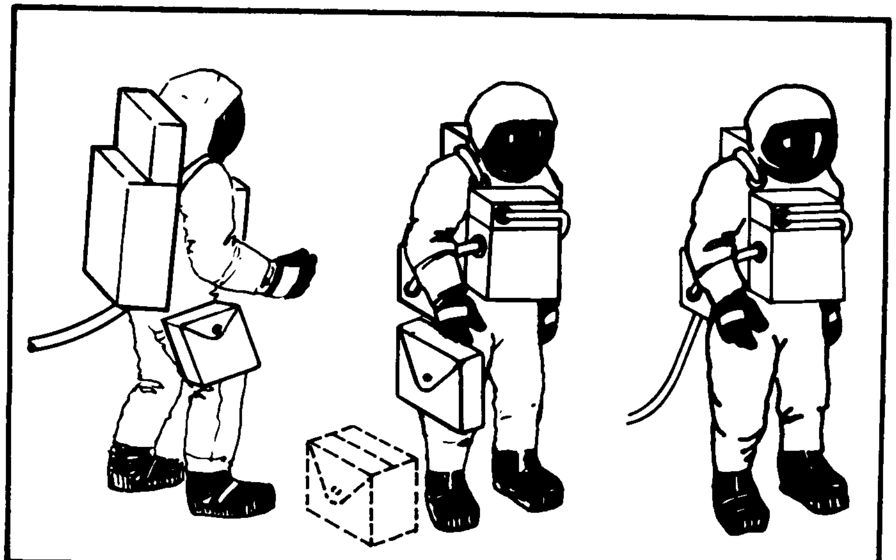
EVALUATION OF HYBRID NON-VENTING AND UMBILICAL SYSTEM

Volume, point design weight for a 4-hour/1-hour non-umbilical design, and configurational data are given on the opposing page. The concept is seen to be especially attractive for short non-umbilical times.

The parametric data for the 2-hour non-umbilical capability includes one leg-mounted replacement ice module and additional portable oxygen, resulting in a weight increase of about 27 lbs over the 1-hour non-umbilical capability (at 1000 Btu/hr metabolic rate). For the 4-hour non-umbilical capability, a separately transported package of two ice modules is required (about 50 lbs and 1070 in^3 for the 1000 Btu/hr metabolic rate), as illustrated in the center sketch, but is not included in the parametric curves. The 4-hour non-umbilical capability increases weight about 30 lbs (portable) above the 1-hour non-umbilical capability (at 1000 Btu/hr metabolic rate).

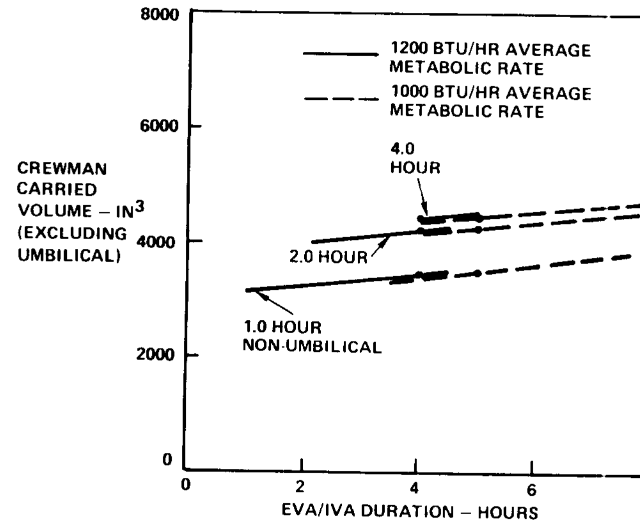
SHUTTLE EVA/IVA LSS CONCEPT

HYBRID/NON-VENTING (UMBILICAL/MODULAR ICE PACKS)

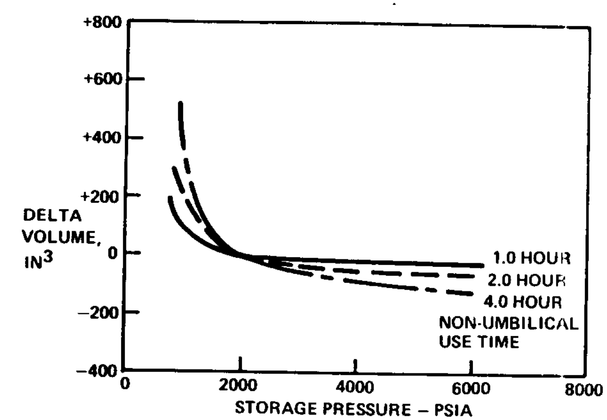


BACK VIEW	FRONT 2.0 HOUR	FRONT 1.0 HOUR

4150 IN.³ 106.4 LBS
TASK EFFECTIVENESS: GOOD



HYBRID LSS UMBILICAL/NON-VENTING (MODULAR ICE PACKS)

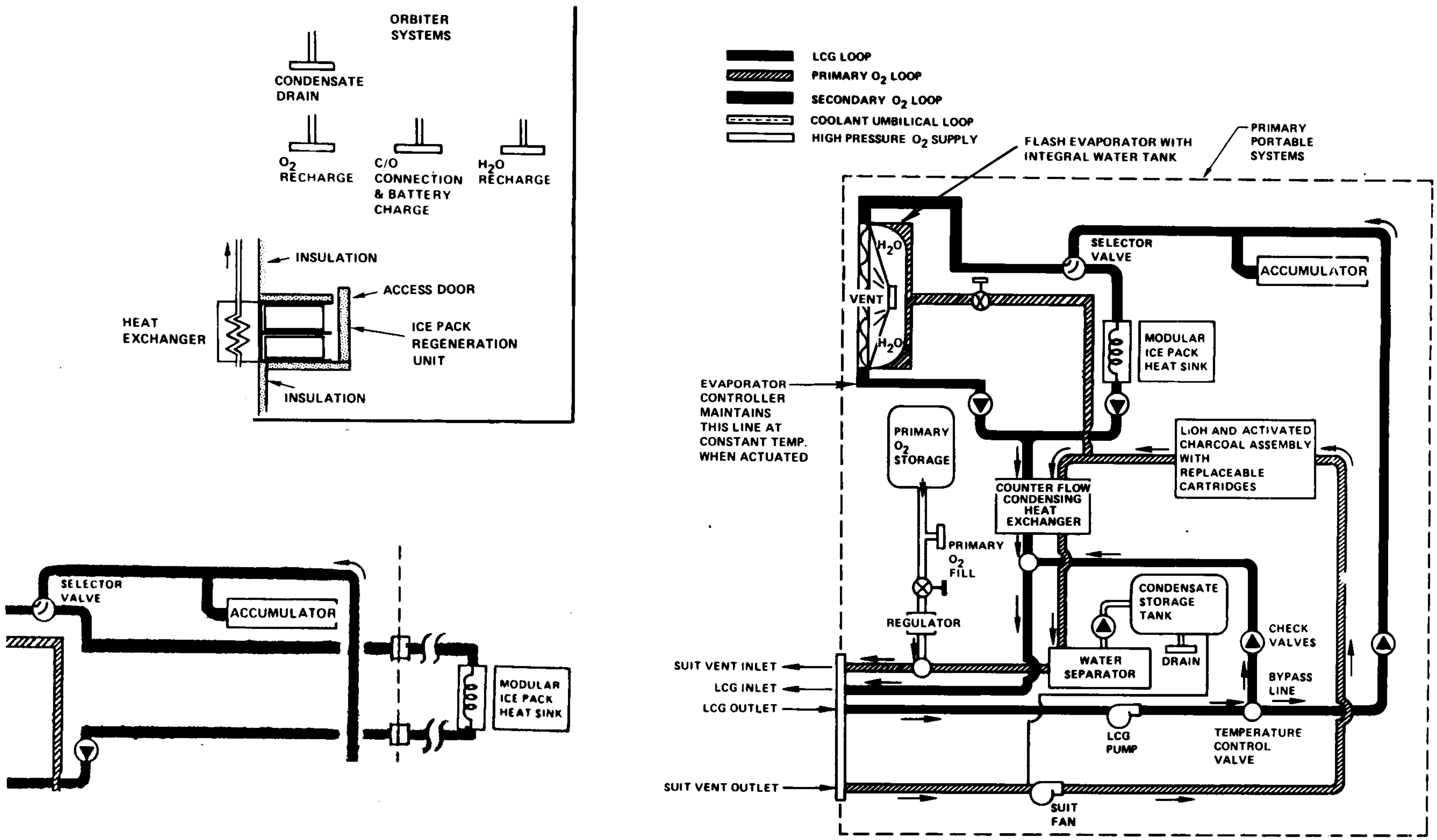


SHUTTLE EVA/IVA LSS CONCEPT
NON-VENTING/VENTING NON-UMBILICAL SYSTEM

This concept is similar to the Hybrid Umbilical and Venting Portable System, but replaces the umbilical with a modular ice pack. The increase in EVA/IVA effectiveness by removal of the umbilical is somewhat offset by added system complication and volume carried by the astronaut. The vehicle impact is now different, but of similar magnitude.

Two versions are shown - one with an integral (but replaceable) modular ice pack, and the other with a detachable modular ice pack, heat exchanger, and short umbilical connecting the ice pack and backpack. The detachable version has obvious advantages for EVA's not requiring non-venting, but is slightly heavier and more bulky due to the disconnects and short umbilical.

SHUTTLE EVA/IVA LSS CONCEPT
NON-VENTING/VENTING NON-UMBILICAL SYSTEM



(DETACHABLE)

(INTEGRAL)

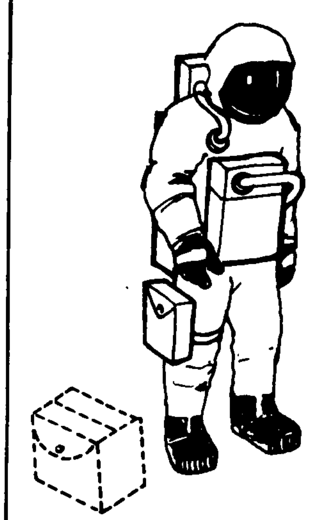
EVALUATION OF NON-VENTING/VENTING NON-UMBILICAL SYSTEM

Parametric volume data are given for the integral version of this system. The parametric data for the 2-hour non-venting capability includes one leg-mounted replacement ice module. The weight for the 2-hour non-venting capability (1000 BTU/hr) is about 25 lb. greater than for the 1-hour capability. For the 4-hour non-venting capability, a separately transported package of two ice modules (about 50 lb. and 1070 in^3 at the 1000 BTU/hr metabolic rate) is required, as illustrated in the center sketch, but is not included in the parametric curves. Point weight and volume data are listed for both the integral and detachable versions for the 4-hour/1-hour non-venting design mission (1000 BTU/hr metabolic). The sketch shows that the increased volume leads itself to a more favorable packaging arrangement, and retains good compactness. The illustrated location of the modular ice pack is shown on the chest. Other candidate locations are the sides (under lower arms) and on the legs.

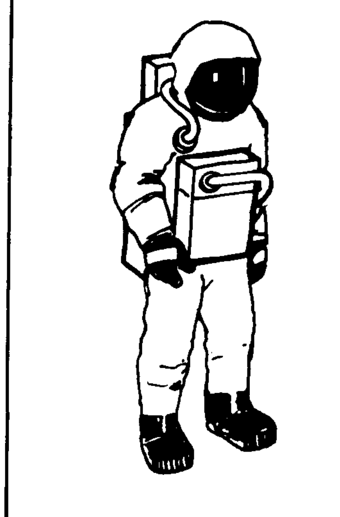
The delta volume effect of oxygen storage pressure at other than 2100 psia is also shown, and is common to all completely portable concepts.

SHUTTLE EVA/IVA LSS CONCEPT
NON-VENTING/VENTING NON-UMBILICAL SYSTEM

BACK VIEW



FRONT 2.0 HOUR



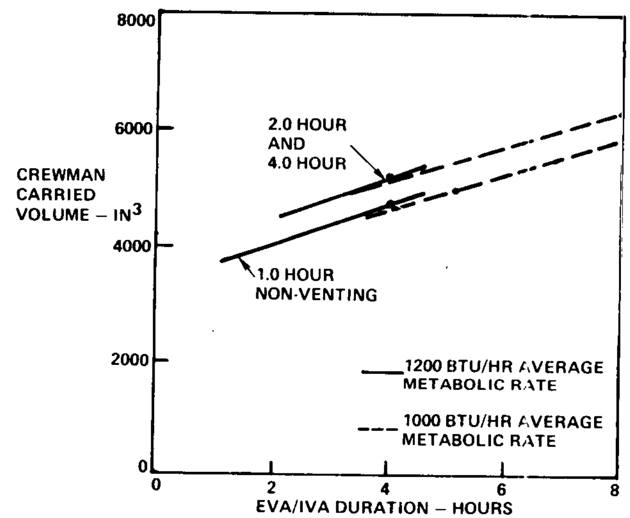
FRONT 1.0 HOUR

(INTEGRAL)

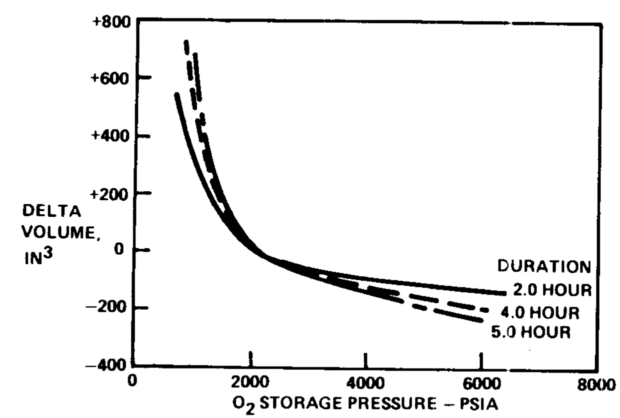
4530 IN.^{3} 123.0 LBS
TASK EFFECTIVENESS: GOOD

(DETACHABLE)

W/O ICE PACK: 3640 IN.^{3} 91.0 LBS
ICE PACK: 4480 IN.^{3} 124.0 LBS
TASK EFFECTIVENESS: GOOD



ALL PORTABLE LSS VENTING/NON-VENTING
(FLASH EVAPORATOR AND MODULAR ICE PACKS)

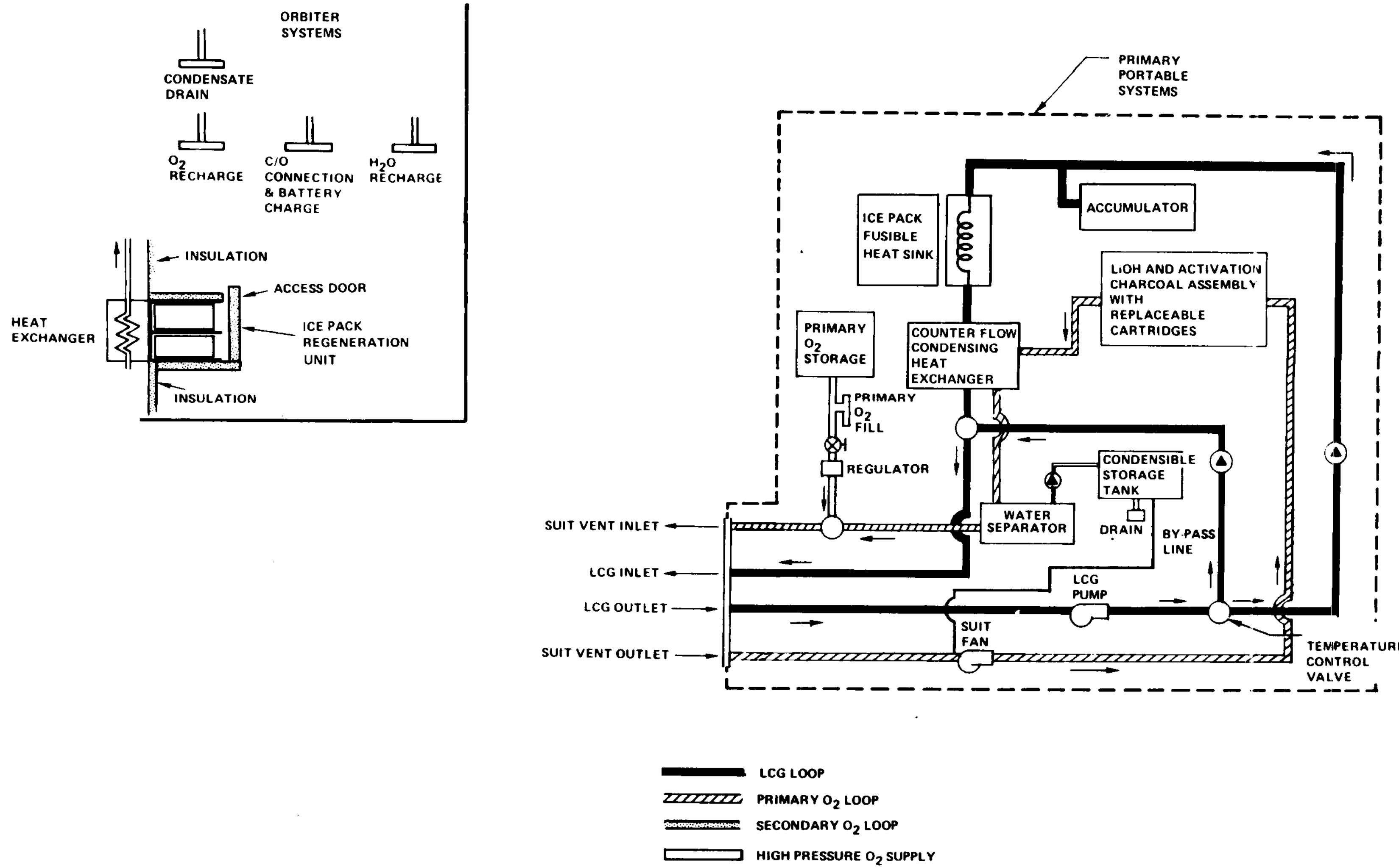


SHUTTLE EVA/IVA LSS CONCEPT NON-VENTING NON-UMBILICAL SYSTEM

The advantages of the Hybrid Non-Venting and Umbilical System for short duration detached operation, plus the complication of both an umbilical and a modular rechargeable ice pack, suggest elimination of the umbilical. This system is illustrated by the opposing schematic. It can operate both in the thawing module and in the venting mode once the ice is melted. Also, as a higher development risk item, it could operate either in the venting or non-venting mode prior to complete ice thawing.

SHUTTLE EVA/IVA LSS CONCEPT

NON-VENTING NON-UMBILICAL SYSTEM

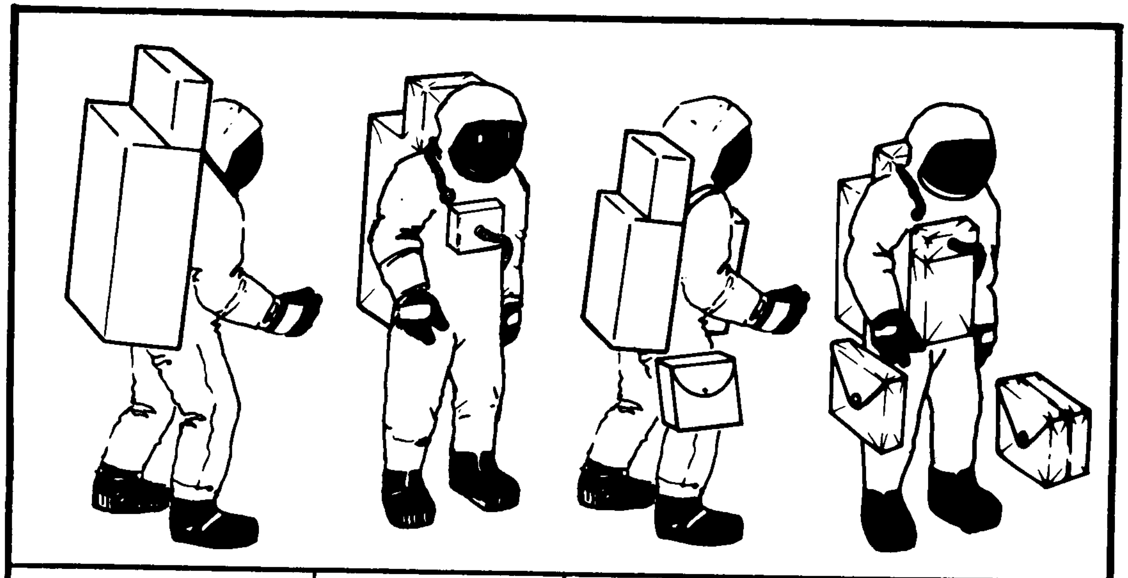


EVALUATION OF NON-VENTING NON-UMBILICAL SYSTEM

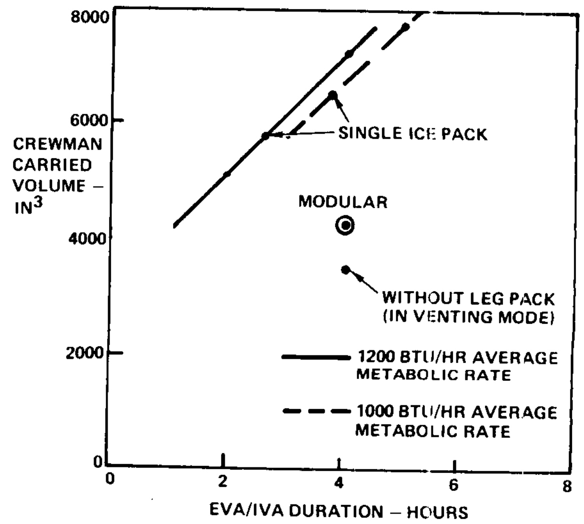
The parametric volume trade curves show that this concept is very sensitive to duration if a single ice pack module is carried. However, by breaking the packs into 1-hour modules and recognizing that they can be mounted or transported separately, the concept becomes more attractive. The sketches illustrate leg-mounting a replacement module, which is the same order of size as the Skylab SOP. Vehicle interfaces are now modest, about equivalent in complexity to an all-umbilical system. Interfaces with a manipulator work platform are greatly simplified.

Typical weights for a 1200 btu/hr metabolic rate system designed for a 4-hour duration are 172.8 lbs for a single ice pack system and 128.4 lbs for a modular ice pack system (about 60 lbs and 1280 in^3 separately transported). The tabulated data are for the design mission (1000 btu/hr metabolic rate) for the modular system with one ice module only. This system assumes the ice pack can be operated, at will, in either a venting or non-venting mode, and thus represents a high development risk.

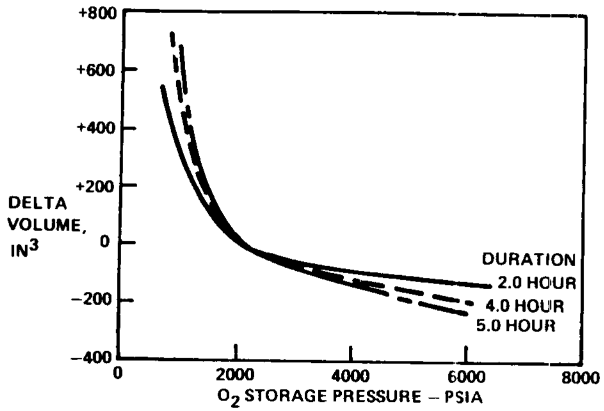
SHUTTLE EVA IVA LSS CONCEPT
NON-VENTING, NON-UMBILICAL SYSTEM



BACK VIEW	FRONT VIEW	BACK VIEW	FRONT VIEW
PORTABLE SINGLE ICE PACK		PORTABLE MODULAR ICE PACK	



ALL PORTABLE LSS NON-VENTING



3630 IN^3 97.8 LBS
TASK EFFECTIVENESS: GOOD

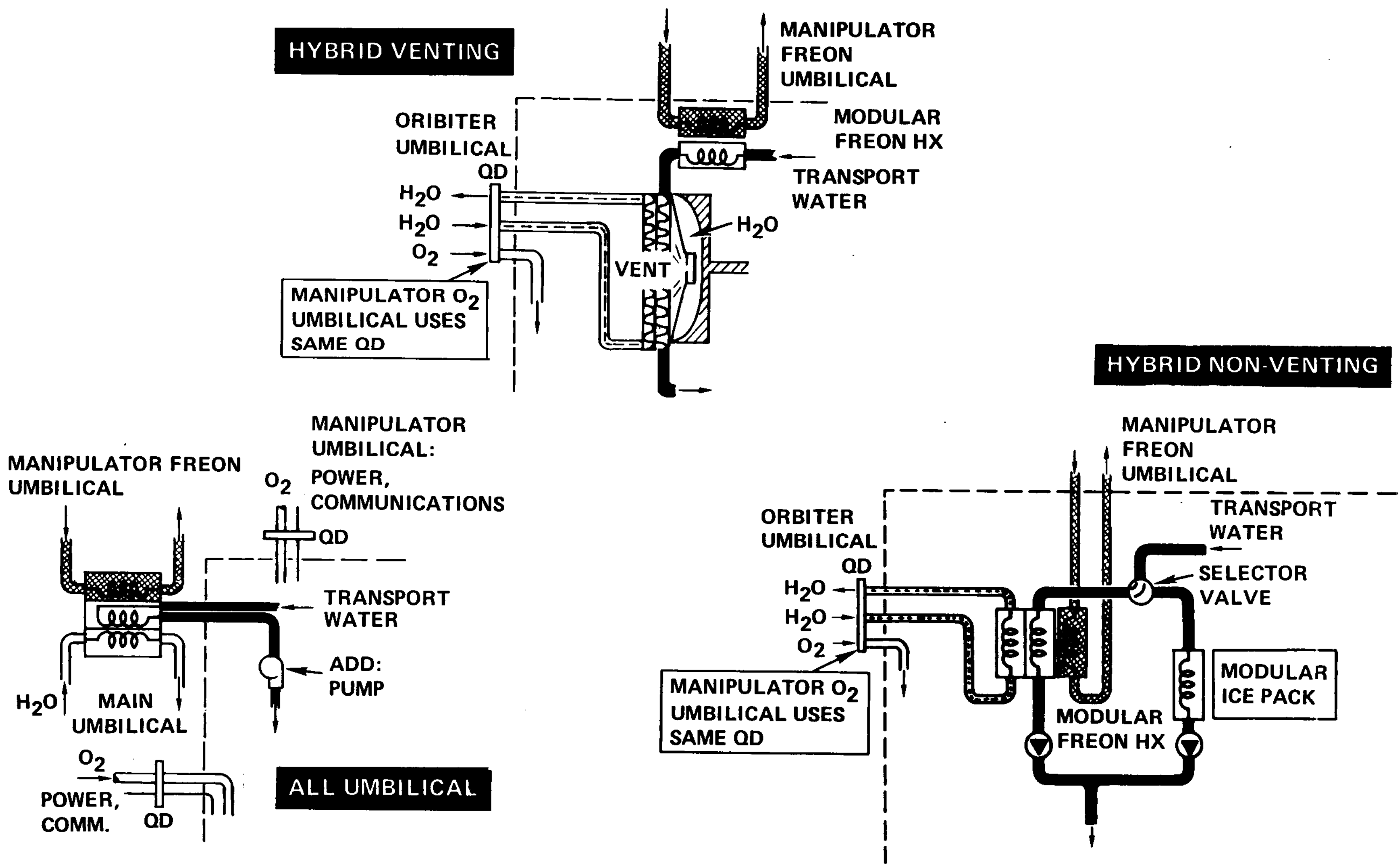
UMBILICAL CONCEPT MODIFICATIONS TO INTERFACE MANIPULATOR WORK PLATFORM

Since working with the manipulator is expected to be highly advantageous with any concept, it is important to not impede this capability by umbilical management problems. The opposing concepts were generated for this purpose.

A freon loop and oxygen hose are integrated into the manipulator boom. They terminate in a short umbilical with an oxygen Q.D. and a freon contact heat exchanger. This design avoids vacuum disconnects of critical liquid systems.

The hybrid non-venting concept could be used with only the short manipulator umbilical, as the crewman could translate to the work platform in the detached non-venting mode. Where venting was permitted, the same procedure could be used with the hybrid venting concept.

UMBILICAL CONCEPT MODIFICATIONS TO INTERFACE MANIPULATOR WORK PLATFORM



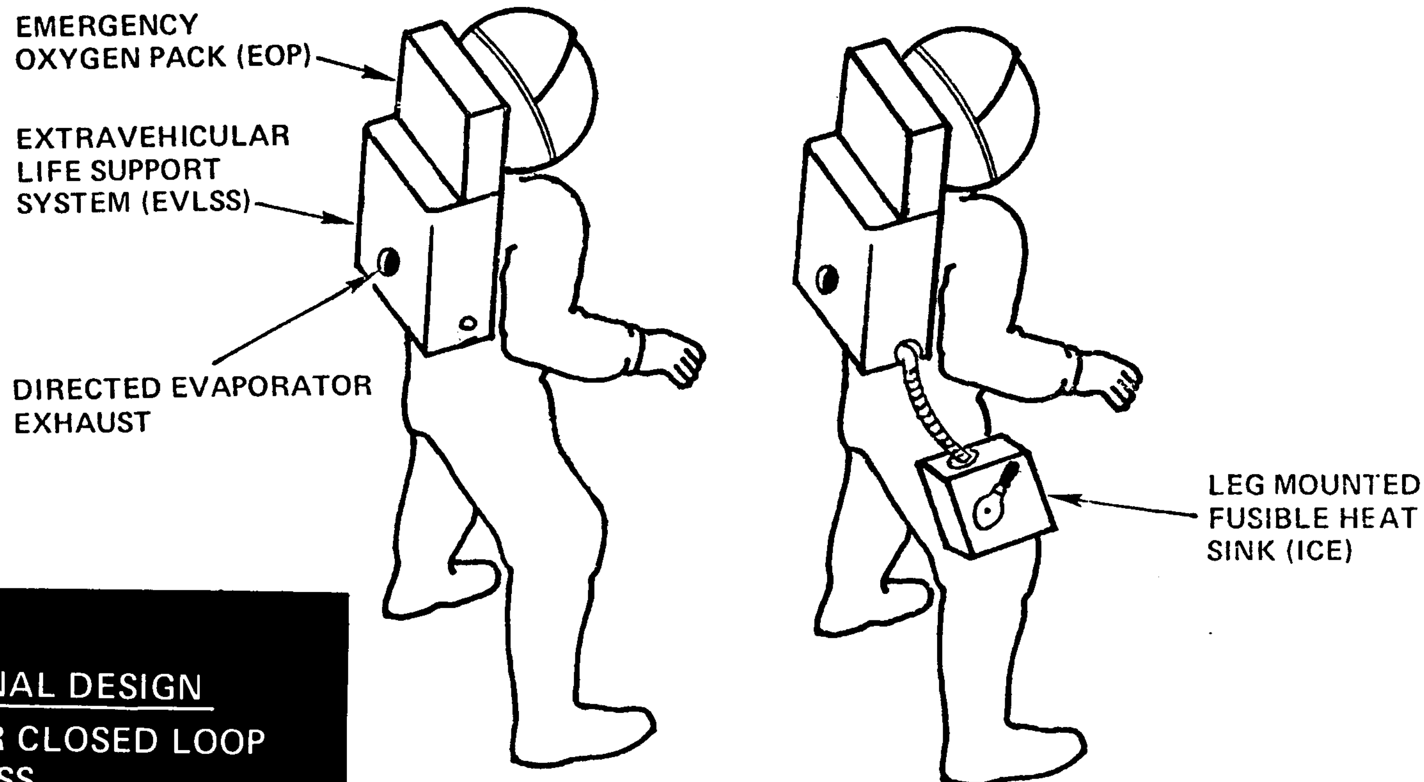
SELECTED EVA SYSTEM

The selected EVA system uses the EVLSS as a venting heat sink. For payloads requiring non-venting, the modular ice pack is added and its associated refreezer unit is carried aboard. Each modular ice pack is sized for one hour duration. For more than one hour non-venting, and up to 4 hours, separately transported spare ice packs are carried and replaced during the EVA. When the ice pack is attached, the EVLSS permits switching between the venting and non-venting modes at any time. In the venting mode, the evaporator exhaust is directed to minimize water vapor hazards to sensitive payloads (see Supporting Studies).

A unique advantage of the selected EVA/IVA system is the capability for one man activities. Costly EVA/IVA man-hour requirements can be minimized (see Task Analysis) because umbilical management problems are eliminated. When two men can effectively supplement each other, two-man EVA/IVA's would be conducted.

When conducting one-man EVA/IVA a second crewman may be required for a rescue capability, at least during early phases of the program. The rescue crewman monitors the first and is free to do other tasks during stand-by. He is in an unpressurized space suit, helmet and gloves off. His life support system is donned and checked out but not active. During stand-by duty cooling is provided by the liquid cooling loops, which are also used for EMU donning. Since the airlock must be free for use by the first EVA crewman, the cooling must be provided inside the cabin. The umbilical length must be sufficiently long to allow limited mobility in the cabin as well as use in the airlock during donning. For comfort the standby crewman is also vented, using the Drying Station umbilicals with the suit diverter valve in the IV vent mode position.

EVA SYSTEM



WITHOUT ICE PACK

WITH MODULAR ICE PACK

NOMINAL DESIGN

- 4 HR CLOSED LOOP EVLSS
- 1 HOUR NON-VENTING CAPABILITY
- REPLACEABLE ICE MODULES

EVLSS FUNCTIONAL DIAGRAM

The selected EVLSS provides a control system, closed gas ventilation loop, recirculating liquid coolant loop, oxygen supply, contaminant control, power supply, R.F. communications, alarms, and heat sinks. The baseline configuration heat sink is a flash evaporator using water as the expendable. The ice pack module provides a non-venting capability for activities near water sensitive experiments. Temperatures in the system are shown with the ice pack in use. The ice pack is not normally launched; the modules and refreezer are carry-on items and charged to payload when required.

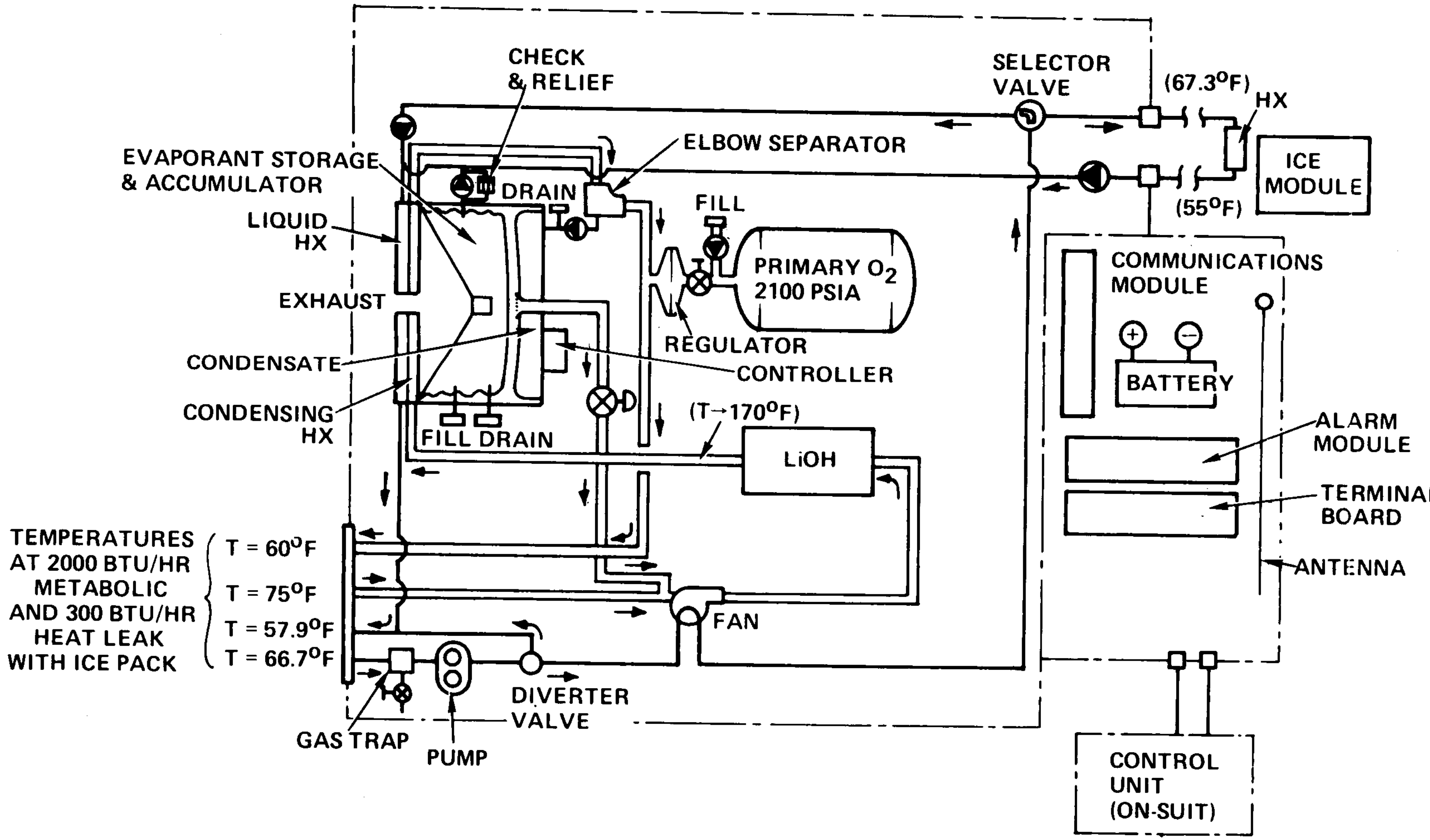
The flash evaporator is integrated with the evaporant storage tank to minimize the packaged volume. The condensate is also stored in the storage tank but separated from the evaporant to minimize potential contamination of experiments. For non-venting activities, part of the evaporant is drained from the storage tank to provide the volume required for this condensate.

Sensors are required for checkout and safety. They have been excluded from the functional diagram in the interest of clarity. The sensors which are integrated into the EVLSS are:

- CO_2 Partial Pressure
- Ventilation Flow Rate
- High O_2 Flow Rate
- Primary O_2 Pressure
- Battery Current
- Battery Voltage
- LCG Temperature (T)
- LCG ΔT
- Vent Flow Temperature (T)
- Suit Pressure
- Feed Water Pressure
- RF Contact

A unique advantage of this system is the capability to employ an umbilical as an alternate non-venting heat sink. In this case the umbilical replaces the ice pack with no impact on the EVLSS, and can be used to potential advantage in an alternate IVA servicing configuration illustrated on a subsequent chart.

EVLSS FUNCTIONAL DIAGRAM



EVLSS PACKAGING

The opposite page presents a preliminary layout of the EVLSS. The overall dimensions are 23.4" x 16" x 9.4", on the back pack. A control unit 7" x 6-1/2" x 2-1/2" is mounted on the chest of the suit. The leg mounted ice pack is 13-1/2" x 13-1/2" x 4-1/2". The total weight and volumes are as follows:

		Total Without Ice Pack	Modular Ice Pack
Weight	:	91 lbs	33 lbs
Volume	:	3635 in^3	890 in^3

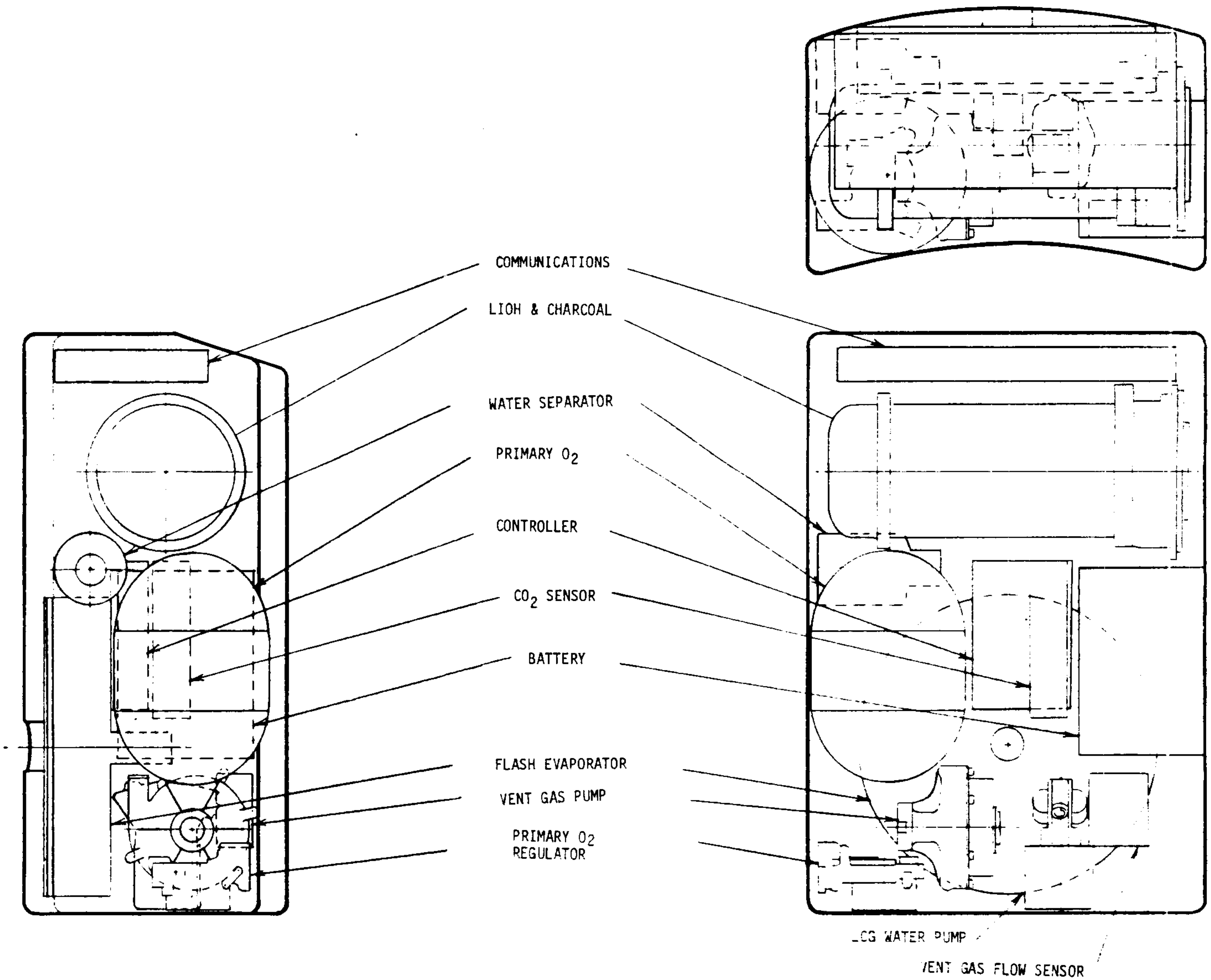
2100 psi O_2 storage is recommended to minimize the EVLSS volume. 900, 2100, and 6000 psi storage were considered; 900 psi provided the lowest scar and 6000 psi the highest. 2100 was recommended since the increased scar was small (5 lbs) and volume reduction in the EVLSS is significant (approximately 600 in^3 packaged). The change in EVLSS weight is not significant (less than 0.1 lbs).

The EVLSS control unit is mounted on the chest of the space suit. Visual displays (lights or flags) and a warning tone are provided for the following:

- o Low Suit Pressure
- o High CO_2
- o Low Vent Flow
- o High O_2 Flow
- o Low Primary O_2 Pressure
- o Loss of RF Signal

In addition the primary O_2 storage pressure and available EVA/IVA time are visually displayed on the control unit. Total elapsed time may be provided either on the control unit or the suit.

EVLSS PACKAGING



EMERGENCY LSS CONCEPTS

Based on subsystem and system trades conducted under previous studies ("Advanced Extravehicular Protective Systems", J. L. Williams, B. W. Webbon, and R. J. Copeland, CR114832, March 1972) emergency system concepts were devised.

Eight concepts for emergency EVA/IVA LSS were considered. Each was compared against the requirements for the Shuttle EVA/IVA. Since one man activities can significantly reduce the man-hour requirements, the capability to conduct one-man EVA was specified as a requirement. The duration was determined from timeline analyses as 0.4 hours (24 minutes) including a reserve to safe/secure experiments.

A weight and volume trade-off was ocnducted for all concepts. Based on human factors, technical risk, one-man EVA capability, weight and volume considerations, the EOP and IRHS were selected for more detail evaluation.

EMERGENCY LSS COMCEPTS

SYSTEMS CONSIDERED

- EOP BLOW DOWN O_2 (OPS TYPE)
- BLOW DOWN O_2 WITH INTEGRATED HEAT SINK (IRHS)
- BREATHING VEST (CTS)
- BREATHING VEST AND BUDDY LIQUID COOLING UMBILICALS
- BLOW DOWN O_2 (OPS & BSLSS) AND BUDDY LIQUID COOLING UMBILICALS
- BUDDY UMBILICALS FOR ALL LSS FUNCTIONS
- INTEGRATED REDUNDANCY (PECS TYPE)
- COMPLETELY SEPARATE LSS (SLSS)

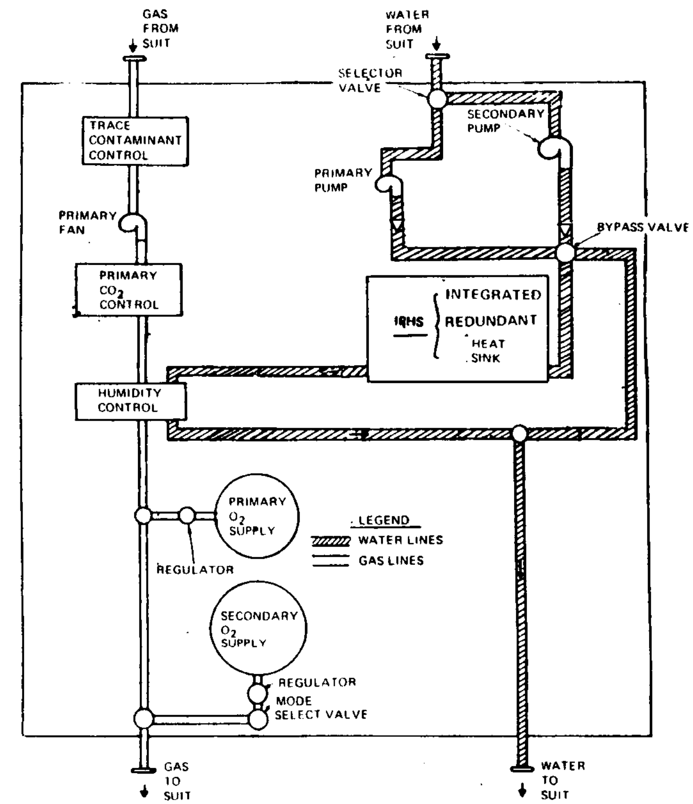
EMERGENCY EVA/IVA LSS

The opposing schematic ciagrams illustrate the two emergency concepts selected for final evaluation. The IRHS saves weight and volume by redundant design, integral packaging, and a lower secondary (emergency) oxygen requirement. In the emergency mode cooling is still provided by the water loop which inforporates a redundant pump and redundant (integrated) heat sink. The secondary oxygen system is a blowdown system, but flowrate is low because it is not required to cool the astronaut. The EOP is extremely sinple, but required more oxygen since both cooling and breathing/CO_2 washout are provided by blowdown. Either concept can be adapted to automatic initiation.

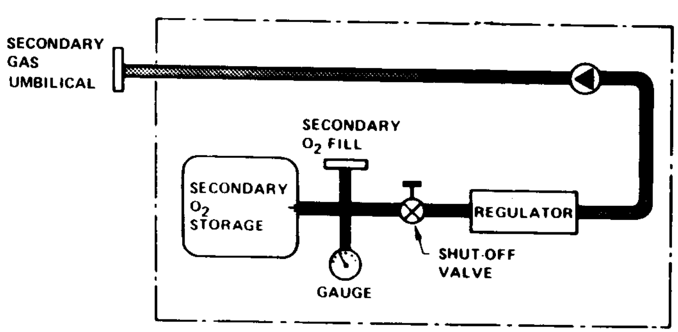
The EOP can be used to conduct an EVA contingency transfer following an IV emergency. However, the IRHS concept requires increased vehicle launch penalties to be used in contingency trades. The option to develop both concepts (with EOP delivered by a rescue crewman) is not considered viable due to increased program cost.

The EOP was selected based on its simplicity, capability for separate packaging, and potential commonality of uses.

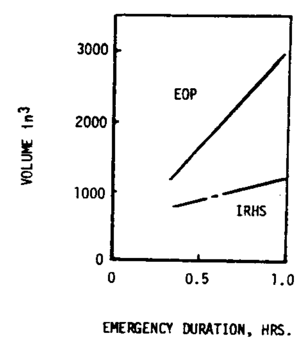
EMERGENCY EVA/IVA LSS

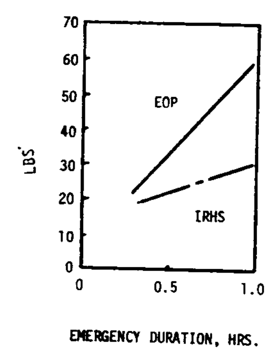


INTEGRATED REDUNDANT HEAT SINK (IRHS)



EMERGENCY OXYGEN PACK (EOP)





- COMMONALITY
- PACKAGING
- SIMPLICITY

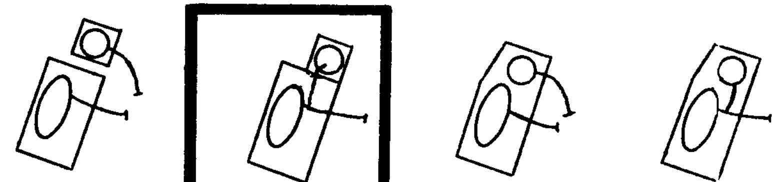
SELECTION

- EOP

EOP PACKAGING EVALUATION

The EOP has a number of potential used, discussed in various parts of this report. Separate packaging with sharing of the suit supply oxygen live with the primary EVLSS is recommended.

EOP PACKAGING EVALUATION



EOP USES	EOP CONFIGURATIONS			
EVA SAFETY	BEST	OK	BEST	OK
EVA WEIGHT AND VOLUME	OK	GOOD	BETTER	BEST
CONTG. EVA. X-FER	GOOD	GOOD	POOR	POOR
IVA SERVICING ALT. CONFIG. (NON-EMERGENCY)	GOOD	GOOD	N/A	OK IF AUTOMATIC
PORTABLE FACE MASK O_2 SOURCE	GOOD	GOOD	POOR	POOR
SUPPLEMENTAL CABIN OXYGEN SOURCE	GOOD	GOOD	GOOD	GOOD

RECOMMEND
- COMMONALITY
- EVA EFFECTIVENESS

EMERGENCY OXYGEN PACK

The selected Emergency Oxygen Pack (EOP) concept is a combined EVA emergency LSS system and a portable contingency transfer LSS for IV emergencies. In comparison with existing blow-down emergency systems, the volume of the Apollo OPS is about 1470 in^3 and the Skylab SOP is about 700 in^3.

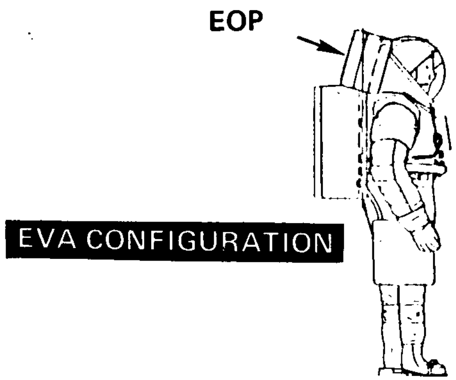
For worst case orbiter EVA emergency locations, a duration of 20 minutes is estimated for return and airlock repressurization, and 4 minutes has been reserved for contingency safeing/securing of the payload/experiment being worked on. The timeline analysis supporting this is:

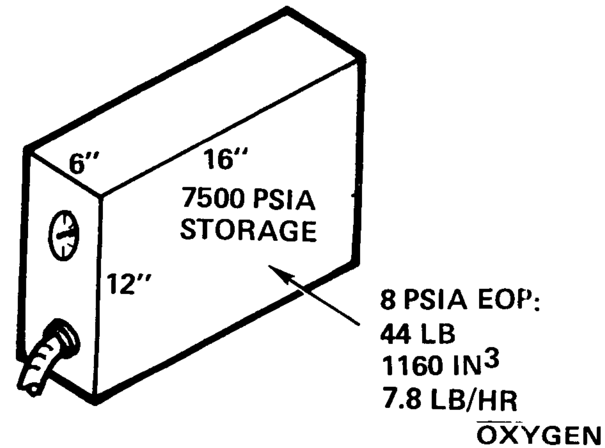
	TIME (MIN : SEC)		
TRANSLATION RATE (FPS)	DISTANCE (FT)		
	35	60	220
0.2	8:25 (8:45)*	10:50 (11:50)	22:20 (25:40
0.5	6:40 (7:00)	7:50 (8:50)	14:20 (17:40) → Value Used
2.5	5:44 (6:04)	6:14 (7:14)	8:28 (11:48)

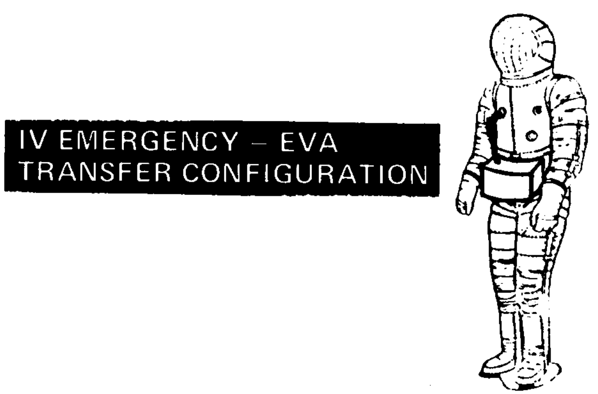
* Slow tether management

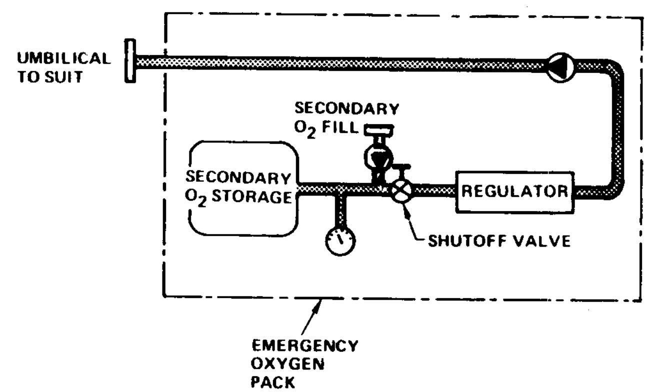
The indicated value of 17:40 was used and rounded upward to 20 minutes as a realistic worst case.

EMERGENCY OXYGEN PACK









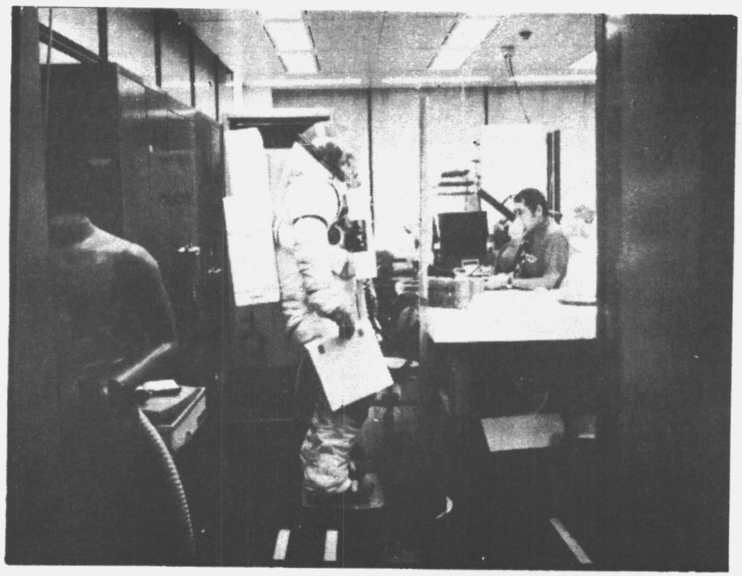
SUIT EVLSS INTEGRATION TEST

Three ice pack locations on the suit evalutaed as follows:

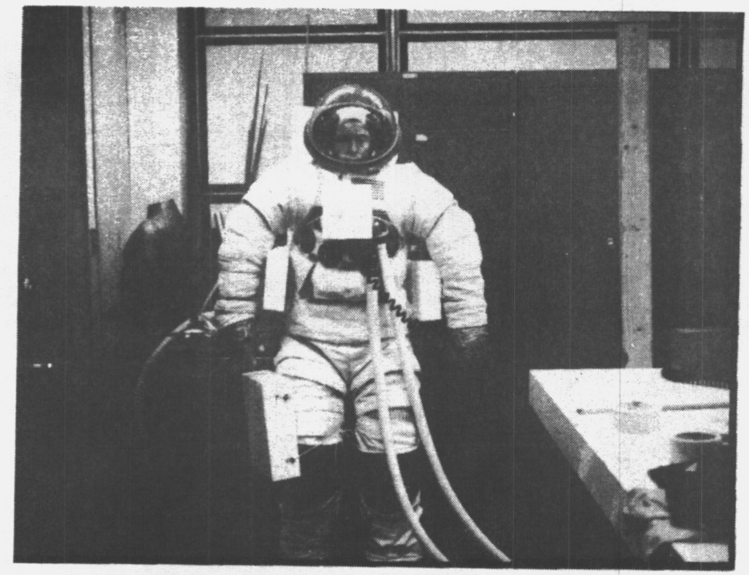
- o Chest pack
- o Side packs (two sizes)
- o Leg pack

Tests were conducted with the Litton Advanced Extravehicular Space Suit at NASA-JSC and mock-ups of the ice packs, back-pack, EOP and control unit. All three locations were found to be feasible. However, the leg mounted location is the simplest approach for a detachable ice pack.

SUIT EVLSS INTEGRATION TEST



BACKPACK PLUS 3¾ x 12½ x 4 CONTROL AND 13 x 12½ x 4 ICE PACK ON CHEST AND 13 x 12½ x 4 ICE PACK ON LEG



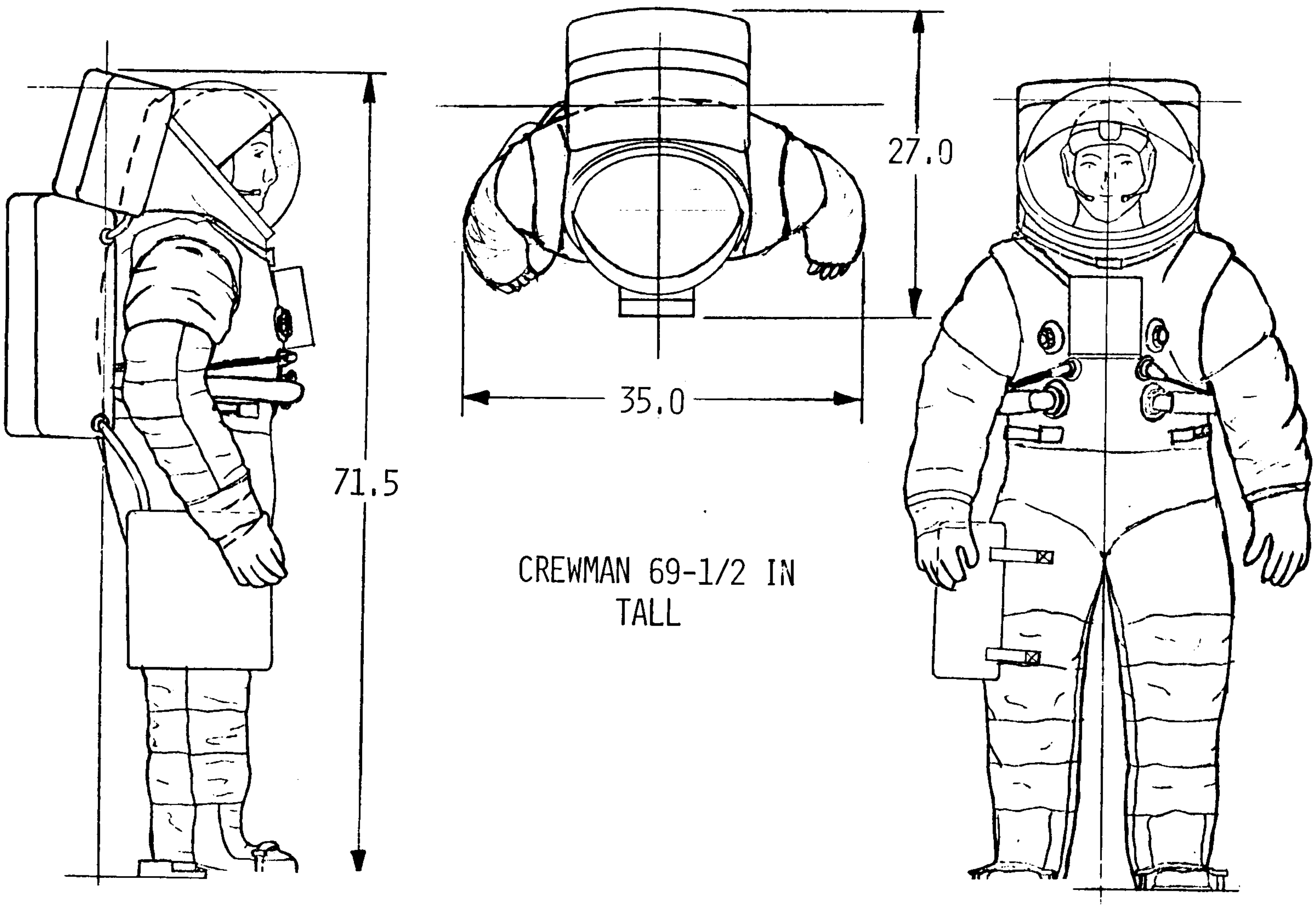
BACKPACK WITH 8½ x 21 x 3 ICE PACK ON EACH SIDE PLUS SMALL (6½ x 7 x 2½) CONTROL ON CHEST AND 13 x 12½ x 4 ICE PACK ON LEG

SPACE SUIT AND EV LIFE SUPPORT SYSTEM

The dimensions of the space suit and EVLSS are shown on the scale drawing on the opposite page. All items are included except a small tether.

The ice pack is shown mounted on the crewman's right leg, the same location as the Skylab SOP. Mounting on either leg is acceptable and mounting on the left leg may be more preferred.

SPACE SUIT AND EV LIFE SUPPORT SYSTEM



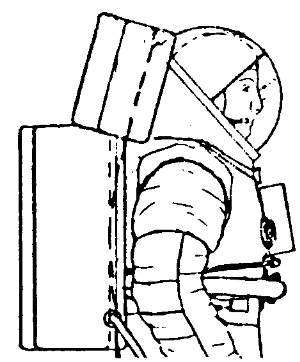
EVLSS CHECKOUT REQUIREMENTS

The EVLSS must be verified to be in proper operating condition prior to all EVA/IVA. The opposite page presents all items which must be measured. The performance items are measured and recorded prior to all activities. If an anomaly occurs during the activity, a second checkout is performed immediately afterwards to determine the cause. Safety items are measured before and during all activities. These latter items are required to determine the existence of a hazardous condition during the EVA/IVA. In the event of an emergency a warning tone alerts the crewman of an immediate danger which he would not otherwise be aware of.

EVLSS CHECKOUT REQUIREMENTS

SAFETY ITMES[1]

- CO_2 PARTIAL PRESSURE
- VENTILATION FLOWRATE
- O_2 FLOWRATE
- COMMUNICATIONS
- BIOMEDICAL, HEART RATE[3]
- PRIMARY O_2 PRESSURE
- TIME
- BATTERY VOLTAGE
- SUIT PRESSURE



PERFORMANCE ITEMS[1, 4]

- LCG T
- LCG ΔT
- BATTERY CURRENT
- VENT FLOW T
- EOP STORAGE PRESSURE
- EOP REGULATED PRESSURE[2]

NOTES:

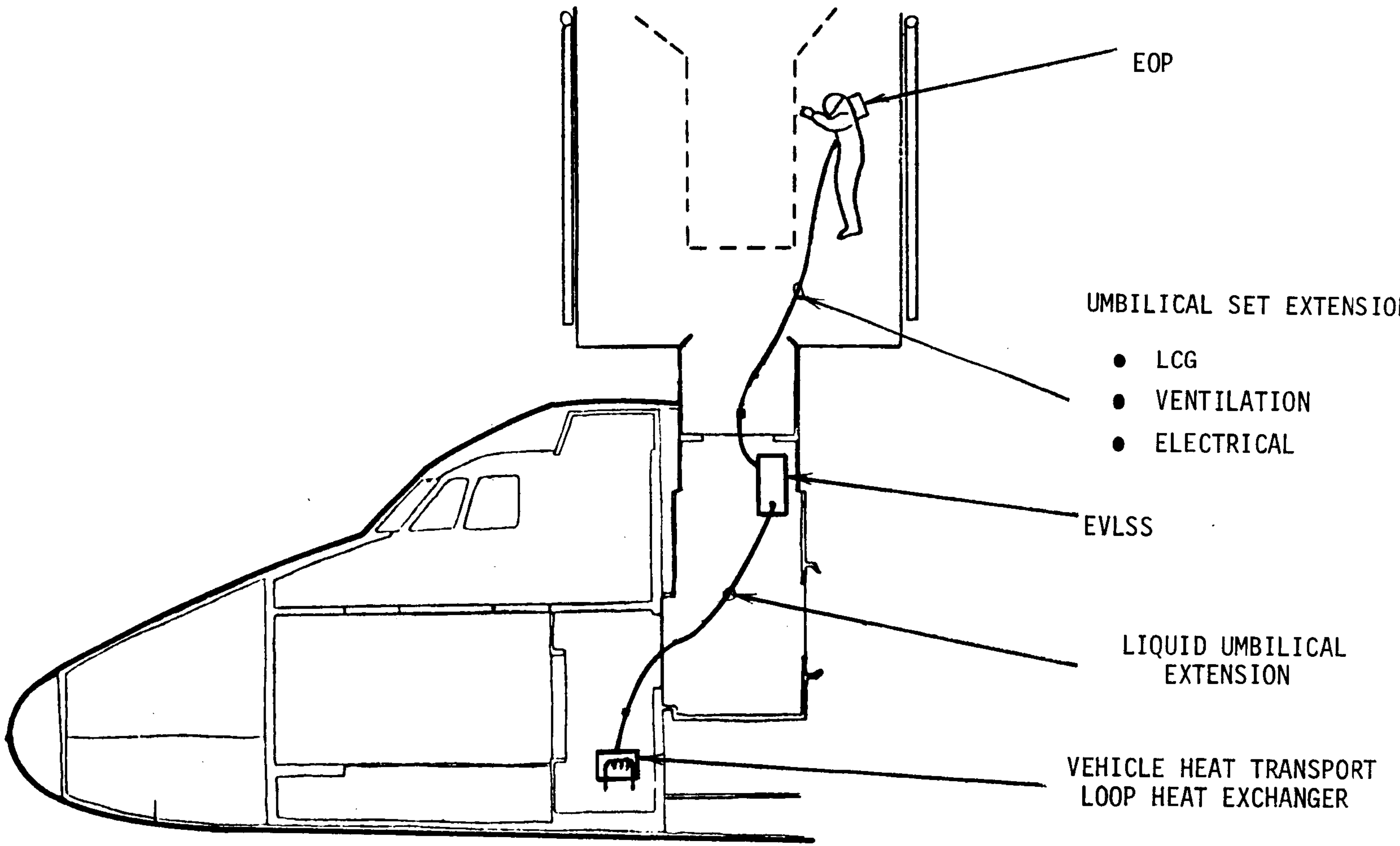
1 SENSOR ON EVLSS UNLESS NOTED
2 SENSOR ON EOP CHECKOUT STATION
3 CARDIO-TACH ON MAN
4 MEASURED PRIOR TO EVA/IVA ONLY

IVA SERVICING CONFIGURATION

IVA servicing can impose a requirement for non-venting operation. In some cases with very restricted space it may be desirable to doff the EVLSS and work with life support provided by umbilicals.

The opposite page presents a concept for IVA servicing employing the EVLSS and umbilical set extension. The EVLSS is shown stowed in the docking module; alternatively it could be in the work area or the airlock. A liquid umbilical extension provides cooling to the EVLSS and crewman. The liquid line interfaces with the EVLSS at the ice pack connectors. The vehicle heat transport provides the heat sink through the LCG loops required for suit donning. All other life support functions are provided by the EVLSS.

ALTERNATE
IVA SERVICING CONFIGURATION CONCEPT

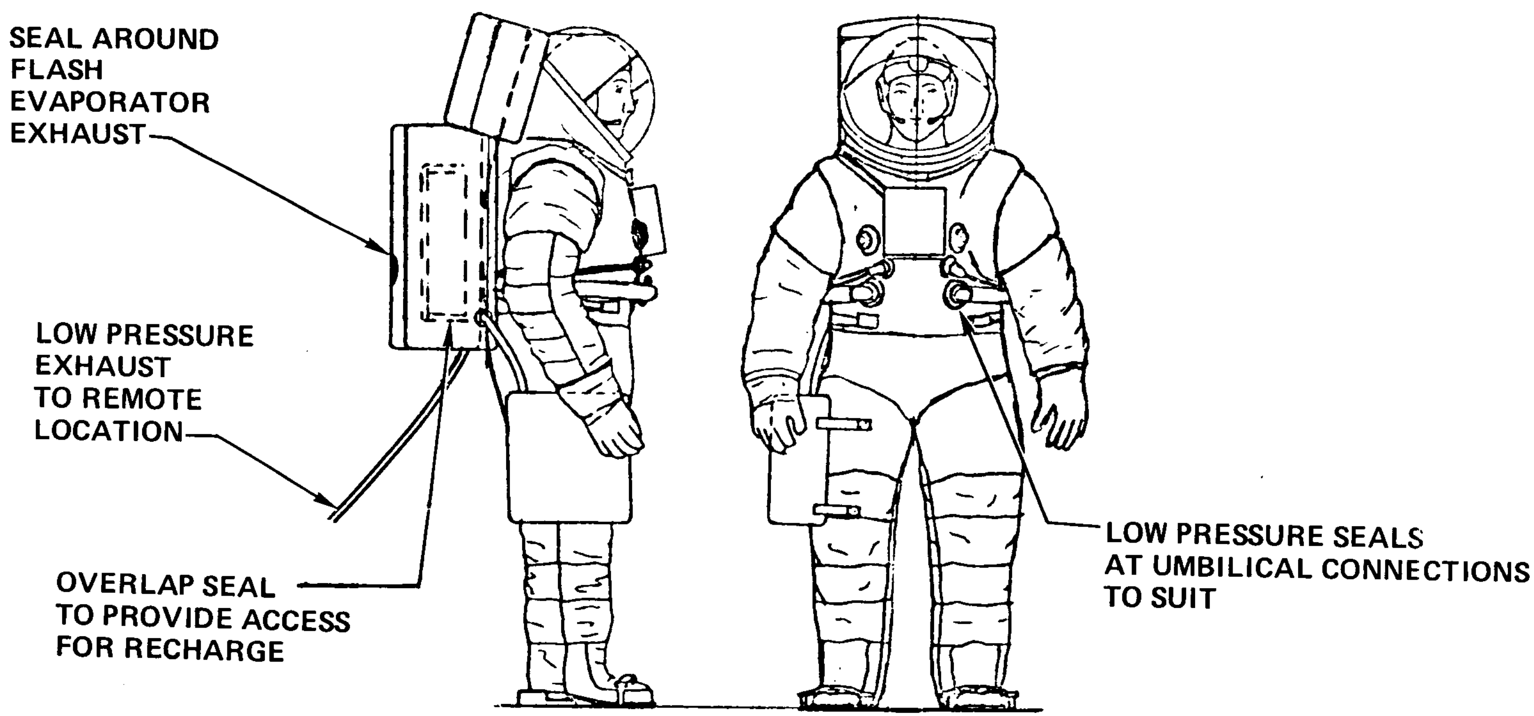


EVLSS CONTAMINATION AVOIDANCE CONCEPT

Leakage of ventilation gas internally from the EVLSS is a source of contamination. The gas will contain water vapor and organic materials. Other sources of contamination are off gassing from seals and insulation in the EVLSS. In order to contain these gasses and any lint which may be present, a barrier can be placed over the EVLSS. Low pressure seals would be placed at all umbilical connections and openings in the EVLSS. The flash evaporator exhaust would remain open to allow use of the venting mode.

Excess pressure caused by leakage would be ducted to a remote location and exhausted. The EVLSS barrier would be used with the suit contamination barrier garment previously described, and a common exhaust duct would be employed.

EVLSS CONTAMINATION AVOIDANCE CONCEPT

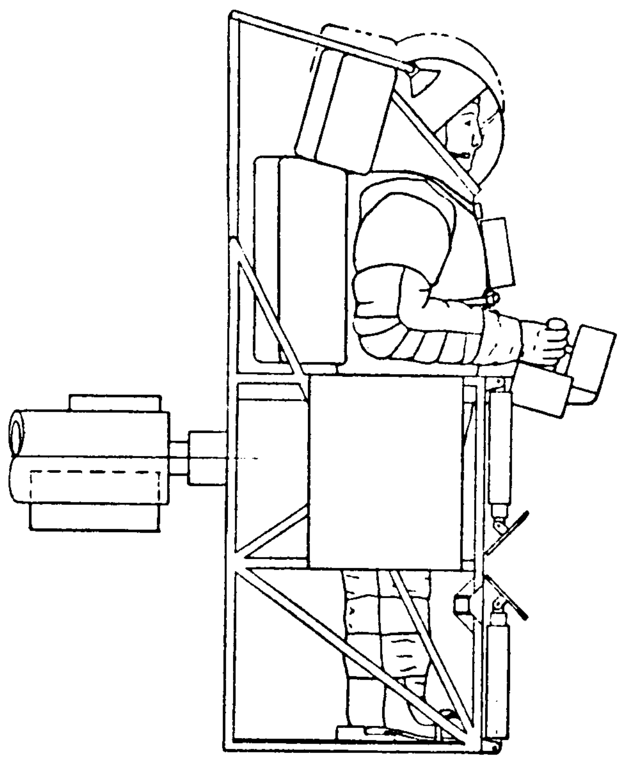


WORK PLATFORM INTERFACES

The selected EVLSS concept does not require hardline connections from the work station. Ingress/egress from the work platform may be conducted at any point during the activity, and complex umbilical management problems are avoided.

Sufficient volume is required in the work station to provide stowage and replacement of ice packs. A tether is required to provide a secure restraint for the crewman. Additional requirements for the work station are discussed in the next section.

WORK PLATFORM INTERFACES WITH EMU



- EMU WITH ICE PACK
- STOWAGE OF SPARE ICE PACKS
- PROVISIONS FOR REPLACEMENT OF ICE PACK
- INGRESS/EGRESS WORK PLATFORM WITH ICE PACK ON SUIT
- TETHER STOWAGE AND ATTACH POINTS

MANIPULATOR WORK PLATFORM

VII. MOBILITY AIDS

MOBILITY AIDS

The mobility aids are; 1) translational devices to assist crewmen in moving from place to place and in moving equipment packages (cargo) from place to place; 2) restraint devices for crewmen at the worksite to prevent undesired induced motion between the crewman and the worksite while he performs tasks; and 3) other necessary worksite provisions.

EVA/IVA task requirements for mobility aids and candidate concepts for satisfying these requirements are presented. Then recommendations and equipment requirements are presented.

MOBILITY AIDS

TRANSLATIONAL DEVICES

WORKSITE RESTRAINTS

WORKSITE PROVISIONS

TRANSLATIONAL DEVICES EVA/IVA TASK REQUIREMENTS

These requirements were derived from the representative scenarios presented eariler:

- Surface Path Length -

  30 Ft. - minimum distance required for sortie lab IVA in the Plasma Wake Experiment

  220 Ft. - path covered to reach the end instruments on the 150 ft. Plasma Wake Experiment boom

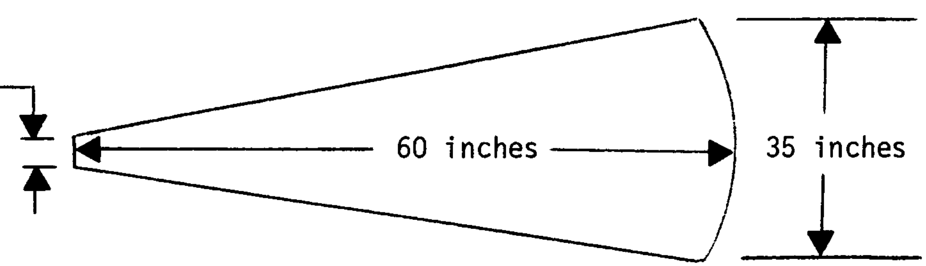
- Minimum Passageway - sketch is for one section of the Environmental Protection Doors on the LST

- Premanent installation must be avoided on the Orbiter exterior due to aerodynamic and heating considerations and inside the LST Telescope tube due to optical considerations.
- Contamination monitoring gage is smallest, lightest component and has least moment of inertia.
- A segment of the 30 ft dia. antenna is the largest component.
- Solar cell array assembly for large observatories has largest moment of inertia.
- Scintillation counter in X-ray observatory is heaviest component.

TRANSLATIONAL DEVICES EVA/IVA TASK REQUIREMENTS

- SURFACE PATH LENGTH - 30 TO 220 FEET AND RETURN
- MINIMUM PASSAGEWAYS - AIRLOCK OR DOCKING MODULE OPENING 40 x 40 INCH

OR



- PERMANENT INSTALLATION OF MANUAL DEVICES CANNOT BE MADE ON ORBITER VEHICLE EXTERIOR OR LST TELESCOPE TUBE INTERIOR
- CARGO CHARACTERISTICS

	SIZE (INCHES)	WEIGHT (POUNDS)	MOMENT OF INERTIA (SLUG-FT^2)
MINIMUM	1.3 DIA. x 3.5	.5	<1
MAXIMUM	114 x 180 x 18	286	21

TRANSLATIONAL DEVICES CONCEPTS

- Single Handrails have been successfully used on Gemini and Apollo and will be used on Skylab for crew transfer. Standardized physical characteristics were established on Apollo and used on Skylab.

- Dual Handrails have been evaluated by the NASA Langley Research Center and were found to be very useful when manually moving cargo with a moment of inertia over 15 slug-ft^2 or a weight of over 300 pounds.

- Electroadhesive Devices have been evaluated by the NASA Langley Research Center and were found to have a potential of assisting EVA and IVA crewmen in translating, cargo handling, worksite restraint and workstie equipment retention.

- Manipulator Arm End Effectors are presently being considered for payload and cargo handling. Crew transfer and work platforms end effectors appear to be quite desirable as aids to EVA.

- Free Flying Maneuvering Units have been evaluated on Gemini and in various frictionless platform facilities. These evaluations and additional studies have identified several maneuvering unit concepts, some of which will be evaluated on Skylab. Also two Technology Sorties are planned for the Orbiter to evaluate strap-on maneuvering units and maneuvering work platforms. Free flying maneuvering units are required for EVA involving translation between unattached spacecraft in orbit.

- Tethers attached to the space suit have been used on Gemini and Apollo as cargo transfer aids. Extendable booms, endless clothesline devices, and pallets will be used on Skylab as cargo transfer aids. The utility of each device has been proven in actual or simulated zero-g.

- Burnoff handholds were designed for the Apollo programs, and are a viable candidate for emergency use on the orbiter exterior. Futher evaluation is needed.

TRANSLATIONAL DEVICES CONCEPTS

- SINGLE HANDRAILS
- DUAL HANDRAILS
- ELECTROADHESIVE DEVICES
- MANIPULATOR ARM END EFFECTORS
- FREE FLYING MANEUVERING UNITS
- CARGO TRANSFER AIDS
- POCKETS ON SPACE SUIT

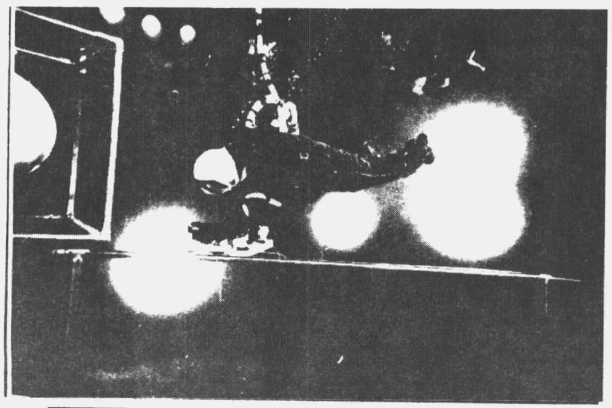
ELECTROADHESIVE DEVICES

Electroadhesive devices produce electrostatically induced attractive forces between surfaces. Recent studies by Chrysler Corp.,* LRC, MSFC and the Air Force have shown that forces up to 30 psi can be produced and maintained in a vacuum. The devices have been tested as handholds and for attachment to boot soles. The schematic shown is for a handhold device.

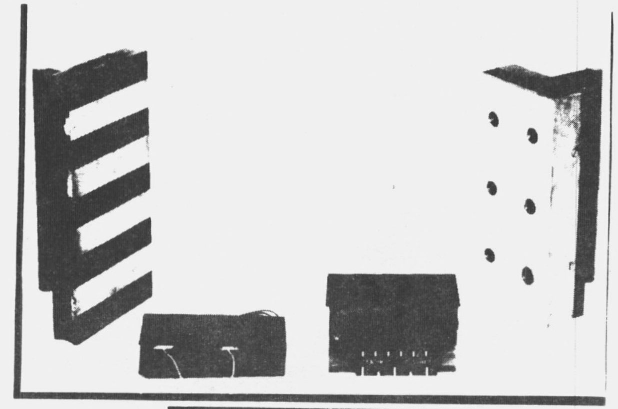
A restriction to the electroadhesive concept is that the spacecraft surface must be electroconducting. Numerous spacecraft meet this requirement. Indications are that the orbiter thermal protection system exterior coating will also, and electroadhesive devices should be evaluated further as a potential emergency handhold for orbiter exterior mobility.

* Reference: "Applications Study of Electroadhesive Devices", Richard P. Krape, NASA CR 1211, Oct. 1968.

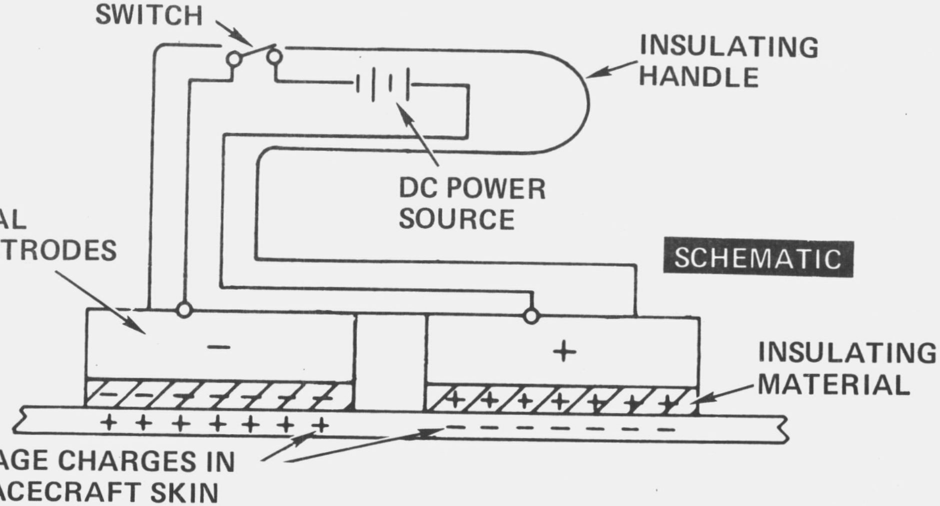
ELECTROADHESIVE DEVICES



SIMULATED ELECTROADHESIVE HANDHOLDS TESTS



ELECTROADHESIVE HANDHOLDS



SCHEMATIC

FROM:

DEVELOPMENT OF ELECTROADHESIVE DEVICES FOR ZERO-g INTRA/EXTRAVEHICULAR ACTIVITIES
NASA LANGLEY – AIAA/ASMA
MEETING AUG 1971

MANIPULATOR ARM AND EFFECTORS CONCEPTS

The manipulator end effectors can take on a number of forms, four are shown here.

The first is a single grappler with lighting and a TV camera to aid in remote control. This end effector is the simplest to control but has the least utility. It can grasp things and move them from place to place. Placement tolerance must be large. Working with this end effector the EVA crewman could do the detailed, precision work and the manipulator could do the gross moving and positioning.

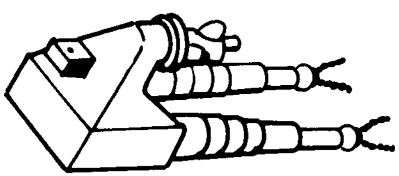
The next end effector has another grappler plus two articulated arms added to simulate human arms. There is also stowage space for spare parts and tools. This end effector is more complex to control but has more utility. Using one arm to restrain itself relative to a worksite the other arm could do much closer tolerance work then the single grappler version. It could not only move things and position them fairly accurately, it could do some things an EVA crewman could do. An EVA crewman would be a backup to this end effector.

The third end effector is a partial enclosure to move an EVA crewman, tools, spare parts, portable lights, etc. One of the manipulator arms could have this crew translation end effector and the other a simpler end effector to move cargo or hold payloads, etc. Handrails could be eliminated but worksite crewman restraint and provisions would still be required for EVA. The manipulator arm would need to be longer than planned (max. 50 ft) in order to reach the desired worksites (approx. 70 ft).

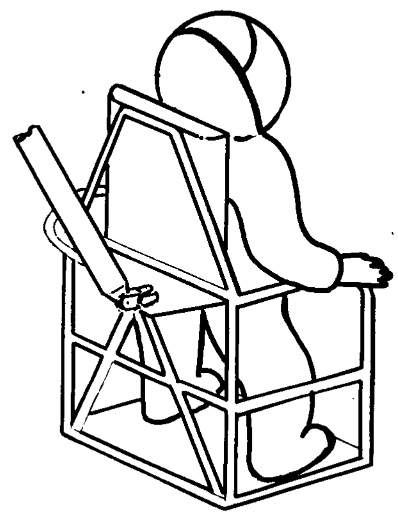
The last is a work platform which can be used for crew translation as well as providing him a stabilized work platform from which to work, thereby eliminating the need for handrails, crewmen restraint and worksite provisions. With the manipulator controls on the work platform the EVA crewman can position himself as he desires, without depending upon remote control, making him more versatile. In addition to the additional length required by the crew translation end effector, another joint would be required to position the work platform.

MANIPULATOR ARM END EFFECTORS

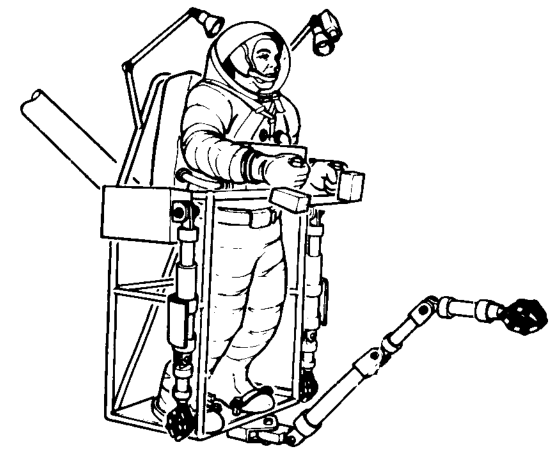
GRAPPLER
LIGHTING
TV CAMERA



DUAL ARMS WITH GRAPPLERS
LIGHTING
TV CAMERA
STOWAGE SPACE FOR SPARE PARTS



SPACE FOR CREWMAN
SPACE FOR SPARE PARTS
SPACE FOR TOOLS & LIGHTS
SPACE FOR TV CAMERA
CREWMAN RESTRAINT



SPACE FOR CREWMAN
SPACE FOR LIFE SUPPORT EQUIP
END EFFECTOR POSITION CONTROLS
LIGHTING
TV CAMERA
SPACE FOR SPARE PARTS
SPACE FOR TOOLS
CREWMAN RESTRAINT
ARMS WITH GRAPPLERS

TRANSLATIONAL DEVICES RECOMMENDATIONS

A work platform end effector combines all mobility aids into one device. It would reduce the impact on the payloads to providing attachment points for stabilizing the work platform. The work platform end effector is particularly attractive for unscheduled EVA since a worksite and manual translation path cannot be prepared in advance.

Handrails are a proven means of crew and cargo translation. They provide for the capability of one man EVA/IVA as opposed to utilizing powered cargo transfer devices, like Skylab, where a "sending" and "receiving" crewman are required.

Electroadhesive devices could eliminate the need for handrails by allowing the man to adhere to any conductive surface and hand over hand or step by step translate across the surface. These devices would be particularly useful for use in attaching the work platform end effector to each worksite.

As pointed out in the EVA/IVA task requirements some cargo packages are quite small. The manipulator end effectors will be much more useful if it can handle relatively small packages. Pockets on the space suit for small packages will be very useful also.

A maneuvering work platform requirement does not exist at this time for the shuttle program.

TRANSLATIONAL DEVICES RECOMMENDATIONS

- A WORK PLATFORM END EFFECTOR BE DEVELOPED AS THE PRIMARY TRANSLATIONAL DEVICE FOR CREW AND CARGO
- HANDRAILS FOR EVA CREW AND CARGO TRANSFER BEYOND MANIPULATOR REACH AND FOR IVA
- DUAL HANDRAILS FOR EVA BEYOND MANIPULATOR REACH AND IVA CARGO TRANSFER FOR CARGO PACKAGES WHICH WEIGH OVER 300 POUNDS OR HAVE A MOI > 15 SLUG-FT^2
- MANIPULATOR PROGRAM DEMONSTRATE CARGO HANDLING OF PACKAGES AS SMALL AS 125 IN^3 AND 1 POUND
- POCKETS BE PROVIDED ON SPACE SUITS FOR CARGO PACKAGES SMALLER THAN 125 IN^3 AND 4 POUNDS
- ELECTROADHESIVE DEVICES FOR CREW TRANSLATION CARGO TRANSFER AND WORK PLATFORM ATTACHMENT BE PURSUED
- MANEUVERING WORK PLATFORM BE DEVELOPED IF CONTAMINATION BY ORBITER EFFLUENTS IS SHOWN TO BE A PROBLEM OR OTHER REQUIREMENTS FOR A FREE-FLYER EVOLVE

WORKSITE RESTRAINT EVA/IVA TASK REQUIREMENTS

These requirements will be different for each worksite and are dependent upon the tasks to be accomplished.

Until the specific worksite tasks are defined, the requirements for motions and forces are considered to be the crewman's capability in the shuttle EVA/IVA space suit.

WORKSITE RESTRAINT EVA/IVA TASK REQUIREMENTS

- MOTIONS
  - WHOLE BODY -
  - LIMBS -
  - EXTENT -

  } CAPABILITY IN SHUTTLE EVA/IVA SPACE SUIT OR THAT NECESSARY FOR SPECIFIC WORKSITE TASKS

  - FREQUENCY - THAT NECESSARY FOR SPECIFIC WORKSITE TASKS

- FORCE
  - MAGNITUDE -
  - DIRECTION -

  } CAPABILITY IN SHUTTLE EVA/IVA SPACE SUIT OR THAT NECESSARY FOR SPECIFIC WORKSITE TASKS

  TYPE (SUSTAINED OR IMPULSE) - THAT NECESSARY FOR SPECIFIC WORKSITE TASKS

WORKSITE RESTRAINT CONCEPTS

- Foot Restraints were utilized on Gemini and Apollo and will be used on Skylab. The early Gemini devices were undesirable. However the later versions on Gemini and Apollo were better and lead to the design to be used on Skylab.

- Waist Tethers were evaluated on Gemini and found to be useful in counteracting some applied forces at worksites and in preventing the astronaut from drifting away when not holding onto the spacecraft.

- Handholds have been utilized on Gemini and Apollo and will be used on Skylab at worksites to assist the crewman in maintaining his position and in counteracting applied forces. Standardized physical characteristics were established on Apollo and used on Skylab.

WORKSITE RESTRAINT CONCEPTS

- FOOT RESTRAINTS
- WAIST TETHERS
- HANDHOLDS

TETHER DYNAMICS

Tether dynamics analyses were conducted in conjunction with the Air Force AMU experiments which were to have been conducted on the Gemini program. These analyses indicated that situations could exist such that attempting to recover an astronaut whose AMU had failed in free flight by use of a tether would be very dangerous to the astronaut. Due to orbital dynamics the tether, with the astronaut on the end away from the spacecraft, could wrap or bounce around the spacecraft causing large forces and rotation rates to build up relative to the spacecraft. The astronaut could slam into the spacecraft with such force as to cause injury, if the tether didn't break first. The figure shows one such computed trajectory. Several recovery techniques were tried but none was found which was satisfactory all the time.

The AMU range was about 2000 ft and the analyses indicated retrieval problems at lengths much less than that. It was shown that tethers up to 25 feet in length created no damaging dynamics.

The AMU experiment was designed to utilize a safety tether, starting with short ones and working to longer ones as the experiments showed retrieval capability. These experiments were not however conducted.

With tether and umbilical management to restrict free length to less than 25 feet there would be no tether dynamics problems during orbiter operations.

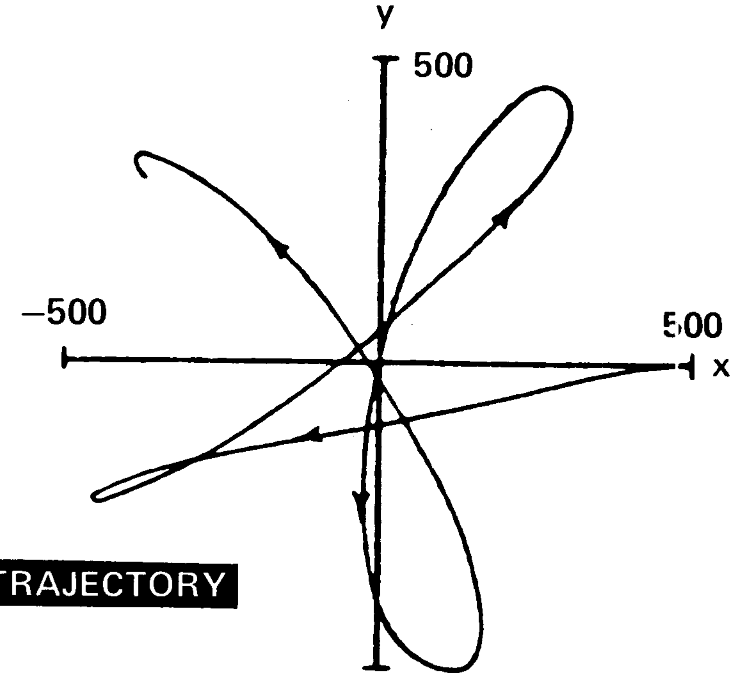
TETHER DYNAMICS

AMU ANALYSIS

- POINT MASS WORK
- VMSC ANALYSIS
- AF ANALYSIS
- NASA ANALYSIS
- SIMULATIONS

CONCLUSIONS

- MAX SAFE FREE LENGTH – 25 FT.
- UMBILICAL MANAGEMENT DRIVER



TRAJECTORY

RESTRAINT DEVICES RECOMMENDATIONS

Skylab mission simulations have shown that the foot restraints give adequate body restraint for accomplishing the required tasks. It is therefore recommended for use at all EVA/IVA worksites.

Waist safety tethers are desired for EVA in order to prevent a crewman from drifting away from the spacecraft and allow him to let go and rest occasionally while manually translating.

Handholds are required at some worksites for body positioning. Since handrails sometines are at worksites they can occasionally be used as handholds also. It is preferrable to have permanently mounted or deployable handholds, mechanically attaching and detaching a portable handhold was found to be difficult on Gemini.

Electroadhesive devices would provide a simple means of providing portable handhold. Hand held devices used for maunal translation could be used as handholds.

A maximum free tether length of 25 feet is recommended. Crew tethers should be capable of restraining two crewmen, including miscellaneous equipment in pockets, to allow for a rescue mission. This is estimated at 1000 lbs mass.

RESTRAINT DEVICES RECOMMENDATIONS

- SKYLAB TYPE FOOT RESTRAINTS AT ALL PLANNED WORKSITES
- WAIST TETHERS BE UTILIZED FOR SAFETY
- HANDHOLDS BE PROVIDED AT PLANNED WORKSITES AS REQUIRED
- HANDRAILS BE USED AS HANDHOLDS WHERE POSSIBLE
- HANDHOLDS BE PERMANENTLY MOUNTED WHERE POSSIBLE
- ELECTROADHESIVE HANDHOLDS BE PURSUED

EVA/IVA TASK WORKSITE PROVISIONS REQUIREMENTS

Worksites can be either prepared or unprepared. A prepared worksite is one in which the site location and the EVA operations to be performed at the site are established during equipment design. The site contains all provisions required by the crewman to perform worksite tasks. Unprepared sites are locations where an astronaut terminates translation activities to perform an unscheduled or contingency EVA task. The location of the unprepared site is determined after equipment and spacecraft design, possibly immediately prior to or during EVA.

Equipment retention will allow the crewman to use both hands to accomplish the tasks and also relieve him from worry about unrestrained items drifting away.

EVA/IVA TASK WORKSITE PROVISIONS REQUIREMENTS

- TYPE WORKSITE
  - PREPARED (PLANNED EVA AND IVA)
  - UNPREPARED (UNSCHEDULED AND CONTINGENCY EVA AND IVA)
- LIGHTING
  - FOR MANUAL TRANSLATION PATH ILLUMINATION
  - FOR WORKSITE ILLUMINATION
- EQUIPMENT RETENTION
  - UMBILICAL, TOOLS, SAMPLES, DATA-RECORDING, SPARE PARTS AND CHECKOUT EQUIPMENT

WORKSITE PROVISIONS CONCEPTS

- On Skylab, lighting will illuminate the route to each work-site with a minimum of 2.0 ft-Lamberts. Worksites will be illuminated with a minimum of 5.0 ft-Lamberts. A light assembly was selected and a number of fixed light assemblies used as required to obtain the desired illumination level. Portable light assemblies could be utilized instead of fixed light assemblies at some worksites, particularly unprepared worksites.

- Equipment Retention at worksites is by solid mounting on Sky-lab. Lanyards and pockets on the space suit have been utilized on Gemini and Apollo for small equipment retention.

WORKSITE PROVISIONS CONCEPTS

- LIGHTING
  - FIXED
  - PORTABLE
- EQUIPMENT RETENTION
  - SOLID MOUNTING
  - LANYARDS
  - POCKETS ON SPACE SUIT

WORKSITE PROVISIONS RECOMMENDATIONS

Permanent lighting relieves the crewman of the task of locating portable lighting assemblies for good illumination. However, in the case of unscheduled EVA permanent lighting cannot be easily provided, therefore portable lighting is recommended. The use of a work platform end effector will allow fixed lighting at all worksites, planned or unscheduled, within reach of the manipulator.

Solid mounting retention of equipment at the worksites will keep drifting equipment from interferring with the crewman in the accomplishment of tasks and keep the equipment readily available. Tether retention should be used when solid mounting cannot be provided and should provide for equipment weights up to about 300 lbs. A free tether maximum length of 25 ft is recommended. Here again the work platform end effector can provide solid retention of equipment at all worksites, planned or unscheduled, within reach of the manipulator.

WORKSITE PROVISIONS RECOMMENDATIONS

- PERMANENT LIGHTING FOR ALL PLANNED EVA/IVA WORKSITES AND MANUAL TRANSLATION PATHS AT LEVELS USED ON SKYLAB
- PORTABLE LIGHTING FOR UNSCHEDULED EVA/IVA WORKSITES
- SOLID MOUNTING RETENTION OF EQUIPMENT AT ALL PLANNED EVA/IVA WORKSITES WHERE POSSIBLE
- TETHER RETENTION OF EQUIPMENT WHERE SOLID MOUNTING NOT POSSIBLE
- RETAIN SKYLAB TOOL KIT AT WORKSITES WHERE REQUIRED TOOLS CANNOT BE PREDETERMINED
- PROVIDE POCKETS OR POUCHES ON SPACE SUIT TO RETAIN SMALL NUMBER OF PREDETERMINED TOOLS

RECOMMENDED MOBILITY AIDS BASELINE

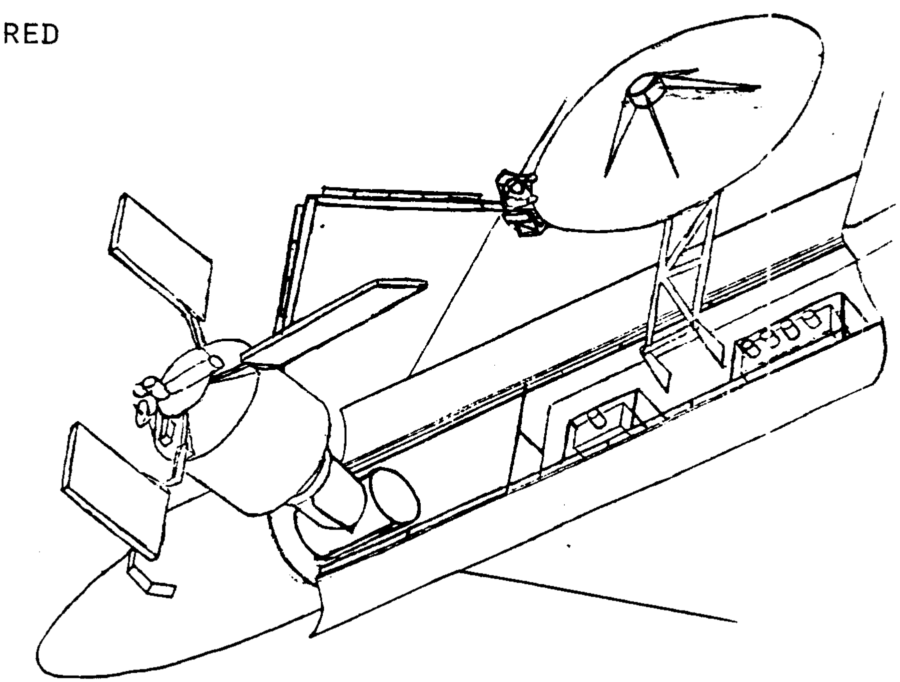
This then is the Mobility Aids baseline. It is the combination of the recommendations made in the three catagories.

The illustration is for the Earth Observation Sortie. An EVA crewman is shown, in the Work Platform End Effector, working on the dish antenna. Permanent handrails are shown in the payload bay. These include handrails around the periphery of the cargo bay, on the docking module, and on the exterior of the sortie module. Handrails, for the mission, are across the front of the pallet and around the cameras. Emergency handrails are shown on the manipulator arms and on the docking module.

Requirements have been established for the baseline equipment and are presented next.

RECOMMENDED MOBILITY AIDS BASELINE

- MANIPULATOR WORK PLATFORM END EFFECTOR
- PERMANENT HANDRAILS IN ORBITER PAYLOAD BAY
- SPECIFIC MISSION HANDRAILS AS REQUIRED
- EMERGENCY HANDRAILS AS REQUIRED
- DUAL HANDRAILS FOR DIFFICULT TO HANDLE CARGO
- PERMANENT LIGHTING IN ORBITER PAYLOAD BAY
- PERMANENT LIGHTING FOR PLANNED EVA/IVA
- PORTABLE LIGHTING FOR UNSCHEDULED EVA/IVA
- SKYLAB FOOT RESTRAINTS
- WAIST SAFETY TETHERS
- HANDHOLDS AT PLANNED WORKSITES AS REQUIRED
- SOLID WORKSITE EQUIPMENT RETENTION
- SPACE SUIT POCKETS FOR SMALL CARGO



WORK PLATFORM END EFFECTOR REQUIREMENTS

A minimum stowage volume and weight are required. The values shown for these characteristics were derived from a conceptual design of the work platform end effector. That design is presented in the next two figures.

Mechanical and electrical connections must be made and broken at the interface with the manipulator arm under remote control from the AMS* control station. The electrical power required is for lighting and any powered devices on the end effector such as stabilization devices.

Manipulator controls are for the EVA crewman to use in commanding end effector motion and attitude.

The recommended EVA/IVA space suit, EVLSS and EOP are defined elsewhere in this presentation. The end effector must be sized to allow the crewman to perform his EVA tasks without interference.

Representative parts and a tool kit have been identified and are presented as equipment retention requirements later. Samples, data recording and checkout equipment have not been defined.

A means of stabilizing the work platform relative to the worksite must be provided. This stabilization must counteract loads induced by the crewman while performing his tasks.

For access to certain payloads using the work platform, an extension of about 30 feet to the manipulator boom would be desirable. This was evaluated by Rockwell and found to be feasible.

* AMS - Attached Manipulator System.

WORK PLATFORM END EFFECTOR REQUIREMENTS

- STOWAGE VOLUME - 53 X 32 X 14 IN
- WEIGHT - 40 POUNDS
- INTERFACE WITH ATTACHED MANIPULATOR SYSTEM (ARMS) -
  - REMOTE ATTACHMENT AND DETACHMENT
  - ELECTRICAL POWER
  - SIGNALS BETWEEN END EFFECTOR CONTROLS AND ARMS CONTROL ELECTRONICS
- MANIPULATOR CONTROLS - MOTION AND ATTITUDE CONTROLS ON END EFFECTOR
- CREWMAN - WEARING EVA/IVA SPACE SUIT, EVLSS AND EOP
- CREWMAN RESTRAINT - SKYLAB FOOT RESTRAINT
- EQUIPMENT RETENTION - SPARE AND REPLACED PARTS, TOOL KIT, TOOLS SAMPLES, DATA RECORDING AND CHECKOUT EQUIPMENT
- STABILIZATION - HOLD WORKSITE FIRMLY RELATIVE TO END EFFECTOR

WORK PLATFORM END EFFECTOR

The Work Platform End Effector conceptual design, shown here, will fold up into a compact package for stowage.

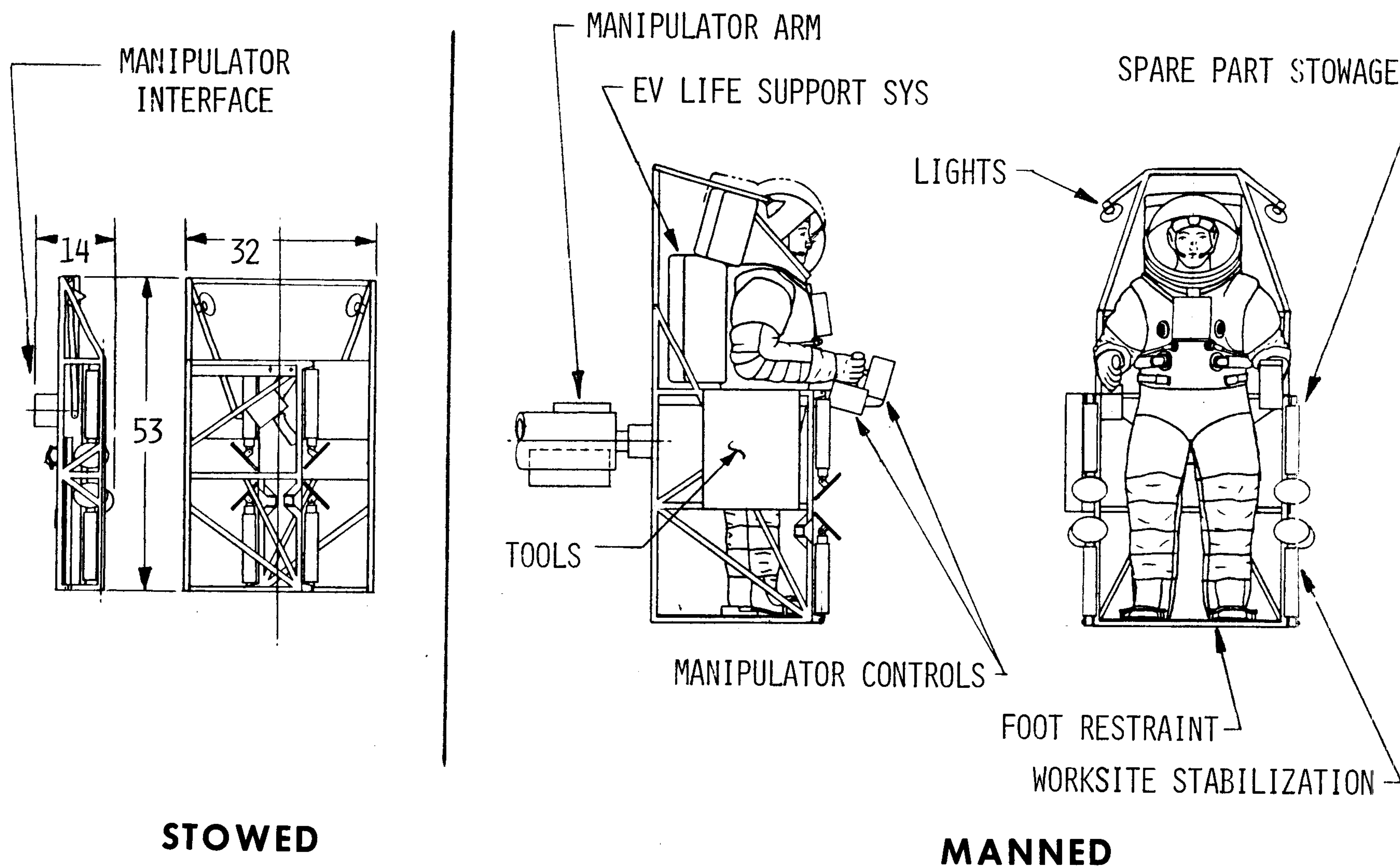
The crewman shown is wearing the recommended EVA/IVA space suit, EVLSS and EOP. His boots are in the Skylab foot restraint. The controllers shown are the Apollo LM controllers. The tool kit has the same volume as the Skylab kit but would have only two drawers each which could be pulled up and rotated out for access to the tools.

The structure is of a truss type constructed of tubing.

The four worksite stabilization devices are conceived as telescoping tubes with electroadhesive devices on the ends. The telescoping tubes could have grapplers for attaching to the worksite if electroadhesive devices are not suitable.

Spare parts and other equipment would be attached to the side of the Work Platform on the crewman's left.

WORK PLATFORM END EFFECTOR



WORK PLATFORM END EFFECTOR USAGE

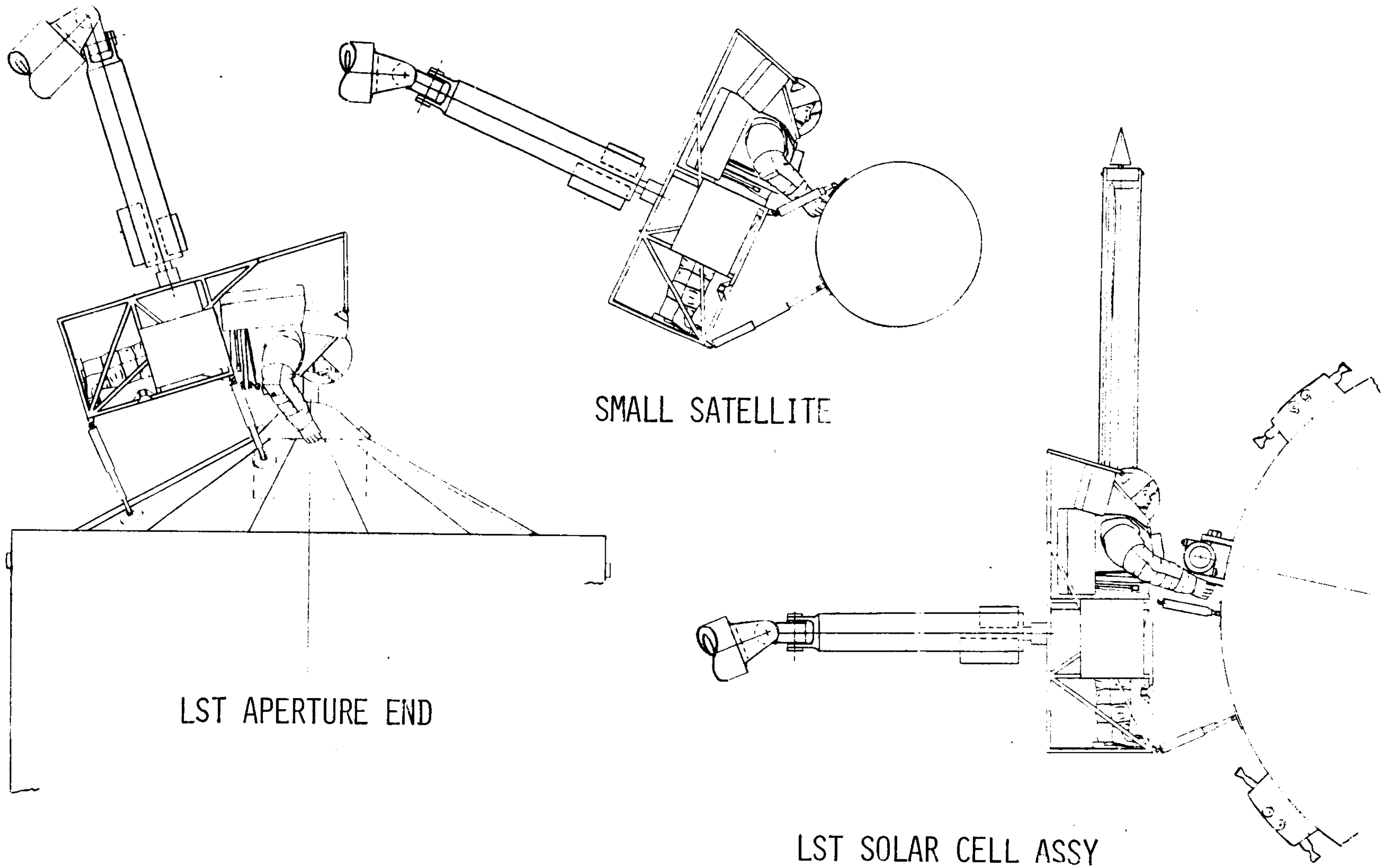
This shows three examples of the Work Platform End Effector usage. They illustrate worksite positioning and relative sizes of the equipment.

The crewman at the LST Aperture End is preparing to replace the Secondary Mirror Module on the General Dynamics LST configuration.

The small satellite shown is 3 1/2 feet in diameter. The crewman could be replacing a component or solar cell panel on the size of the satellite.

The crewman replacing the LST Solar Cell Assembly, on the General Dynamics LST configuration, has the spare solar cell assembly attached to the left side of his work platform.

WORK PLATFORM END EFFECTOR USAGE



HANDRAIL AND HANDHOLD REQUIREMENTS

The requirements for single handrails are those established from experience on Gemini Program and adopted as standards on Apollo and Skylab.

The dual handrail spacing was established during water immersion tests at Langley.

HANDRAIL & HANDHOLD REQUIREMENTS

- GRIP CROSS SECTION - RECTANGULAR 1.25 x .62 IN. .25 CORNER RADIUS*
- LOAD LIMITS - 600 LBS*
- TYPE LOAD - HANDHOLD, CONCENTRATED
  HANDRAILS, CONCENTRATED ON MOST CRITICAL 2 IN. OF MEMBER*
- LOAD DIRECTION - ANY POSSIBLE*
- ALLOWABLE DEFLECTION - HANDHOLD, 0.5 IN.
  - HANDRAIL, 1.0 IN.*
- HANDHOLDS MUST HAVE 5.5 IN. STRAIGHT GRASPING SURFACE*
- HANDRAILS SHOULD HAVE 2.5 IN. STAND-OFF FOR GLOVE CLEARANCE*
- DUAL HANDRAILS - 18" SEPARATION**

* FROM MATRIX EVA GUIDELINES AND DESIGN CRITERIA 12 JAN 72

** FROM LANGLEY REPORT NO. NASA TND-6774 APRIL 1972

LIGHTING REQUIREMENTS

General Specification SC-1-0002 is current, applicable specification giving EVA and other spacecraft lighting requirements. This specification, combined with the Skylab illumination levels shown, complete the Shuttle EVA lighting requirements.

LIGHTING REQUIREMENTS

- FUNCTIONAL DESIGN REQUIREMENTS FOR LIGHTING MANNED SPACECRAFT AND RELATED FLIGHT CREW EQUIPMENT, NASA MSC SC-1-0002, JULY 25, 1972

- ILLUMINATION LEVELS -

TRANSLATION PATH	2.0 FT LAMBERTS
WORKSITES	5.0 FT LAMBERTS

EQUIPMENT RETENTION REQUIREMENTS

These are the physical characteristics of representative parts and the Skylab tool kit which must be retained at worksites.

The characteristics of other equipment such as samples, checkout and data recording equipment have not been determined.

EQUIPMENT RETENTION REQUIREMENTS

- PARTS - SIZE: MIN. 1.3 IN DIA X 3.5 LONG
  MAX. 114 IN X 180 IN X 18 IN

  WEIGHT: MIN. 0.5 LB
  MAX. 286 LB

  MOMENT OF INERTIA: MIN. <1 SLUG-FT^2
  MAX. 21 SLUG-FT^2

- TOOLS - MIN. SINGLE TOOLS
  MAX. 9.60 IN X 10.84 IN X 15.90 IN

SPACE SUIT CARGO POCKETS REQUIREMENTS

These requirements are what could reasonably be expected to be done using space suit pockets. They are proposed as guides rather than absolute limits.

SPACE SUIT CARGO POCKETS REQUIREMENTS

- CONTENTS - ONE OR SEVERAL CARGO PACKAGES WITH A TOTAL WEIGHT OF 4 LB MAX.
- VOLUME - 125 IN^3 MAX
- NUMBER PER EVA/IVA SPACE SUIT - 6 MAX.

MANEUVERING WORK PLATFORM

Free flying maneuvering units generally take on two forms; they are either worn (backpacks) or they are ridden on (work platforms). A free flying maneuvering work platform (MWP) offers the most utility for use on Shuttle missions.

The maneuvering unit must contain the total impulse necessary to translate approx. 2000 ft. It must not contaminate the satellite with water vapor, particles, greases, etc. In order to meet these requirements the propulsion system would be a cold gas system. A backpack propulsion system with a 2000 ft range would take up approx. 4 ft^3, the volume of the Gemini AMU. By the time that volume is integrated with life support, stabilization and control, power and communications systems it would be very large for a backpack.

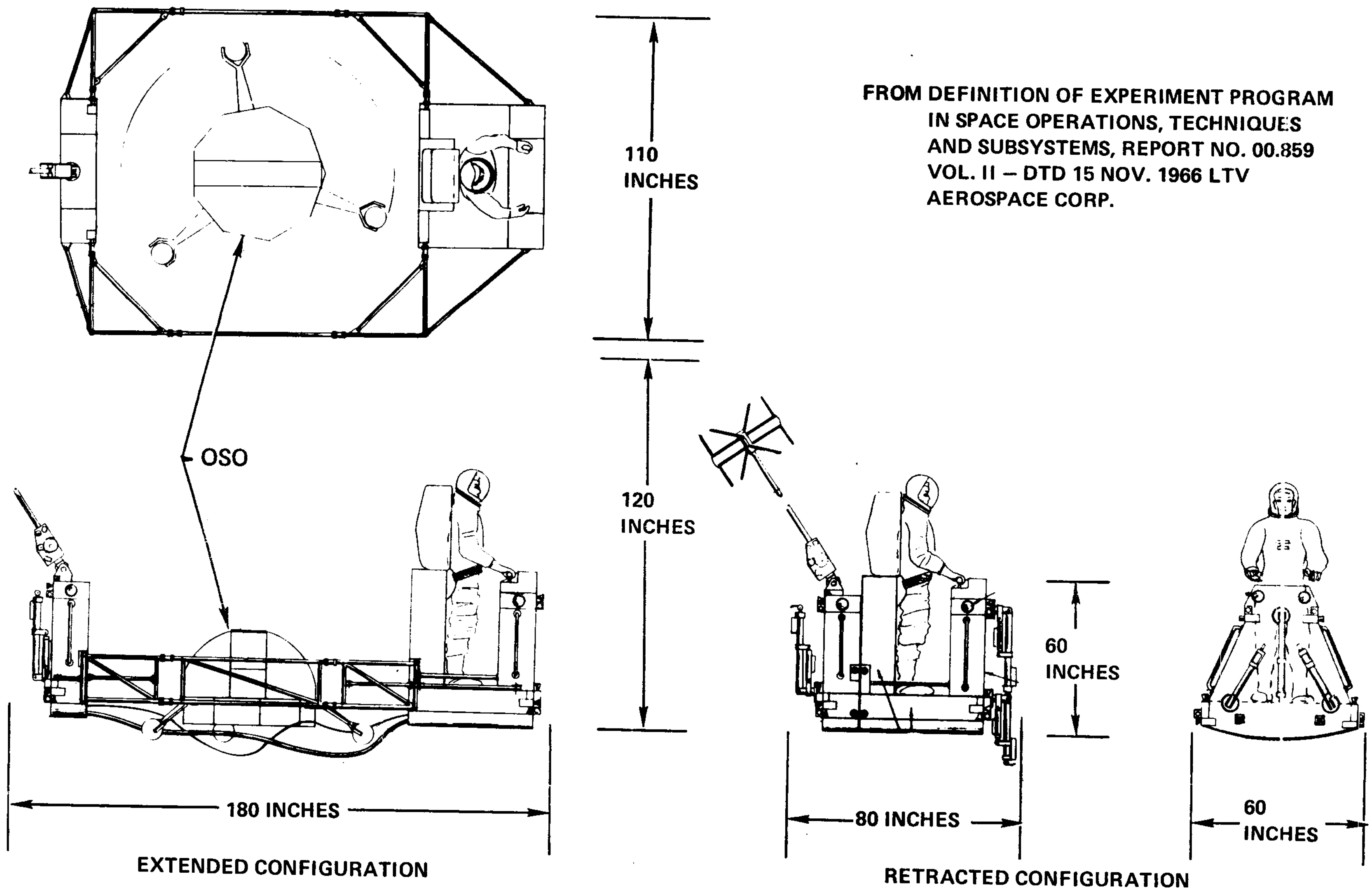
A maneuvering work platform could provide volume for the required contamination free systems plus tool stowage, spare part stowage, and devices for restraining the satellite while the EVA crewman works on it.

The work platform would also provide a base which could be more easily seen at a distance in addition to providing space for redundant systems and rescue aids for safety.

Although the present study has not derived any firm requirements, the opposing design is illustrated as a representative free-flying MWP should such a requirement envolve.

MANEUVERING WORK PLATFORM

FROM DEFINITION OF EXPERIMENT PROGRAM IN SPACE OPERATIONS, TECHNIQUES AND SUBSYSTEMS, REPORT NO. 00.859 VOL. II – DTD 15 NOV. 1966 LTV AEROSPACE CORP.

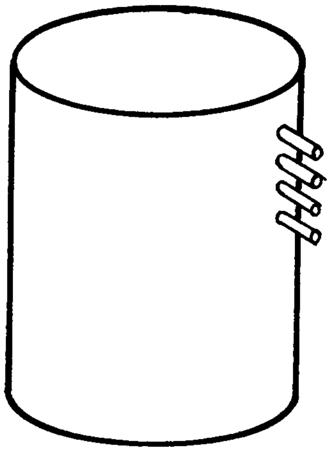


VIII. VEHICLE INTERFACES

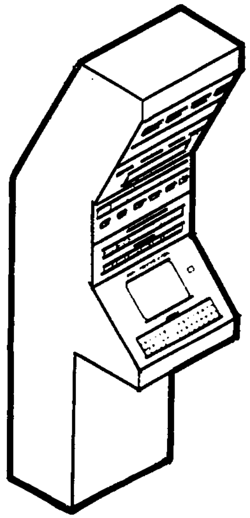
VEHICLE INTERFACES ISSUES

Several of the central issues associated with vehicle support provisions are pictorially illustrated on the opposing page. It is clear that there is a strong interaction between vehicle interfaces, each of the elements of the EVA/IVA system, and IV emergency requirements. Appropriate reference will be made to other sections of this presentation as the individual interactions are discussed.

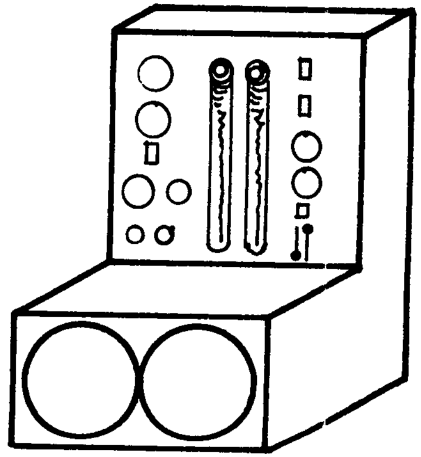
VEHICLE INTERFACE ISSUES



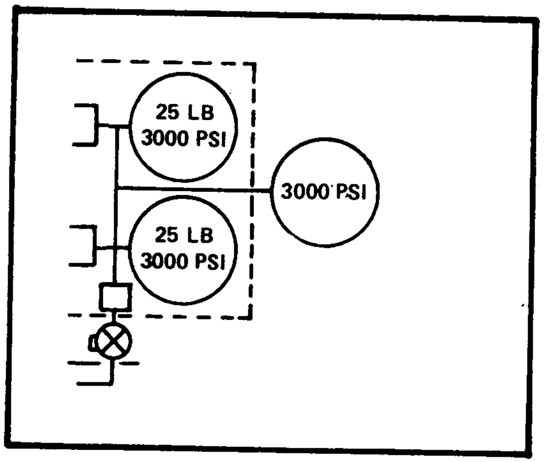
AIRLOCK



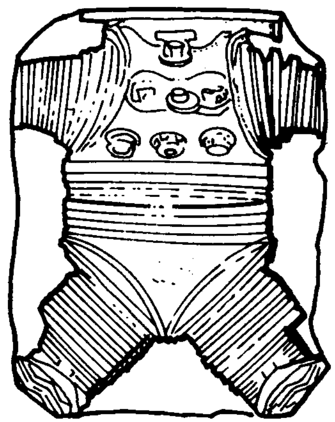
COMM & MONITORING



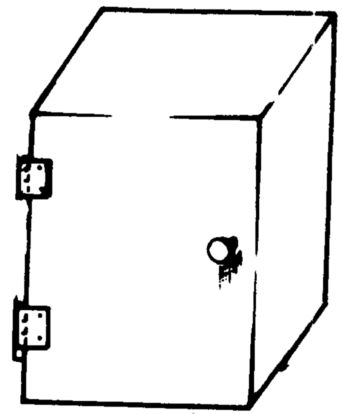
RECHARGE STATION



EVA OXYGEN



STOWAGE AND DRYING



ICE MODULE
REGENERATION

PROVISIONS FOR EVA/IVA

The capability for two EVA's (16 man-hours) is recommended on all shuttle flights. One is for unscheduled repair of the payload (cost savings) and the other is for emergency repair of the shuttle. Two EVA systems are required and associated support equipment. The required mobility aids are discussed in that section. Items required for emergencies affecting the EVA system are discussed in that section. The interfaces described in this section are for normal (planned or unscheduled) EVA/IVA and are consistent with the emergency requirements.

PROVISIONS FOR EVA/IVA

PROVIDED ON ALL FLTS :	TWO EVA'S (4 HOURS EACH, TWO MEN) • ONE UNSCHEDULED • ONE CONTINGENCY*
REQUIRED ON ALL FLTS :	EVA SUITS, 2 EVLSS AND EOP, 2 (LAUNCHED FULL) RECHARGE STATION EXPENDABLES FOR ONE RECHARGE EVA CREWMAN COMMUNICATIONS AND MONITORING SYSTEM
REQUIRED ON FLTS WITH PLANNED EVA/IVA :	CARRY-ON EXPENDABLES FOR PLANNED ACTIVITIES; ICE PACK HEAT SINKS AND REFREEZER, IF REQUIRED; SPECIAL EQUIPMENT FOR THE PLANNED ACTIVITY

* Contingency EVA/IVA interfaces are described in the Emergencies Section

COMMUNICATIONS REQUIREMENTS

Two way voice communications to/from the EVA crewman and the vehicle provides each crewman with the capability of independent conversations. Hands free operation is obtained, economizing EVA time. Continuous telemetry is provided by sub-carriers on the voice channels.

Relay of communications to the ground and other spacecraft can be accomplished through data links in the baseline orbiter. IV observation is provided by cameras in the payload bay and manipulator end-effectors currently baselined.

Alerts are provided in the shuttle cabin to warn shuttle personnel of EVA/IVA emergencies. A loss of RF contact warning is given simultaneously to the EVA crewman and shuttle personnel, since rescue may be needed for one man activities. Re-establishment of contact will distinguish between an equipment failure and blockage of the RF signal.

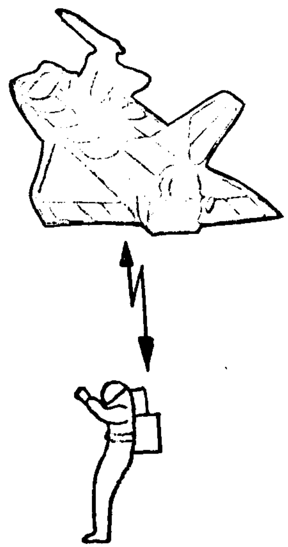
Ground communications provide permanent recording of data and advice to the EVA/IVA crewman during the performance of special tasks (e.g., unscheduled repairs).

COMMUNICATIONS REQUIREMENTS

<u>EVLSS</u>

VOICE,
DUPLEX

TELEMETRY,
SUBCARRIER ON VOICE CHANNELS



<u>VEHICLE</u>

VOICE,
DUPLEX,
RELAY TO GROUND

DATA DISPLAY,
RECORDING,
AND RELAY

ALERTS

- EQUIPMENT FAILURES
- LOSS OF RF CONTACT

TV OBSERVATION OF EVA

<u>GROUND</u>

VOICE

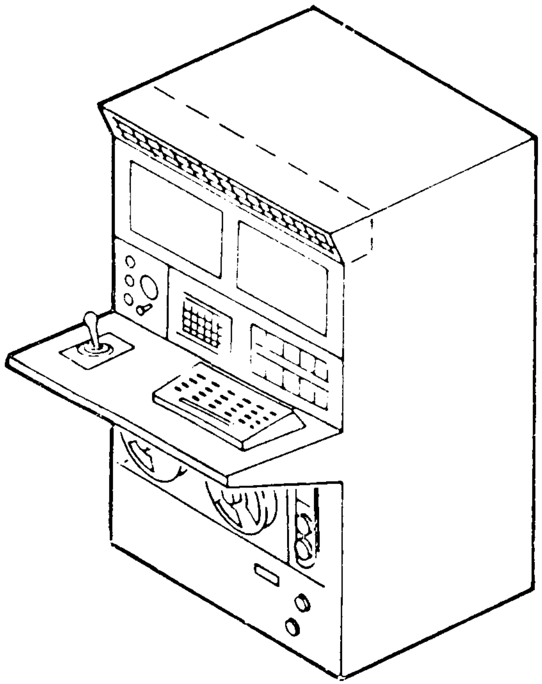
DATA DISPLAY
RECORDING

EVA/IVA MONITORING REQUIREMENTS

The opposing chart presents the items which are monitored and recorded by the shuttle. Safety items are monitored continuously and recorded during all EVA/IVA activities. Displays are also provided on the EVA equipment for the C & W safety items. Performance items are monitored and recorded only during checkout. A second check, following the EVA, is employed in conjunction with the continuously monitored data for equipment anomaly assessment.

The payload specialists station console is a general and special purpose unit. All of the basic requirements can be provided by this unit; data channels in the station will be available during EVA and IVA since experiments would not normally be active.

EVA/IVA MONITORING REQUIREMENTS



PAYLOAD SPECIALIST STATION CONSOLE

MONITORED AND RECORDED BY SHUTTLE

	CHECKOUT PRIOR & POST EVA/IVA [1]	DISPLAYED & RECORDED DURING ACTIVITY [1]	WARNINGS AND CAUTIONS
SAFETY ITEMS	CO_2 PARTIAL PRESSURE	CO_2	WARNING
	VENTILATION FLOWRATE	VENT FLOW	WARNING
	O_2 FLOWRATE	O_2 FLOWRATE	WARNING
	COMMUNICATIONS	VOICE & RECORD TRANSMISSION	CAUTION ON LOSS OF SIGNAL
	BIOMEDICAL, HEART RATE [3]	HEART RATE [3]	-
	PRIMARY O_2 PRESSURE	PRIMARY O_2 PRESSURE	CAUTION
	TIME	TIME	-
	-	ICE PACK TIME AVAILABLE	CAUTION
	BATTERY VOLTAGE	BATTERY VOLTAGE	-
	SUIT PRESSURE	SUIT PRESSURE	WARNING
PERFORMANCE ITEMS	LCG T	-	-
	LCG ΔT	-	-
	BATTERY CURRENT	-	-
	VENT FLOW T	-	-
	EOP STORAGE PRESSURE	-	-
	EOP REGULATED PRESSURE [2]	-	-

1 SENSOR ON EVLSS UNLESS NOTED

2 SENSOR ON EOP CHECKOUT STATION

3 CARDIO-TACH ON MAN

EVLSS RECHARGE STATION

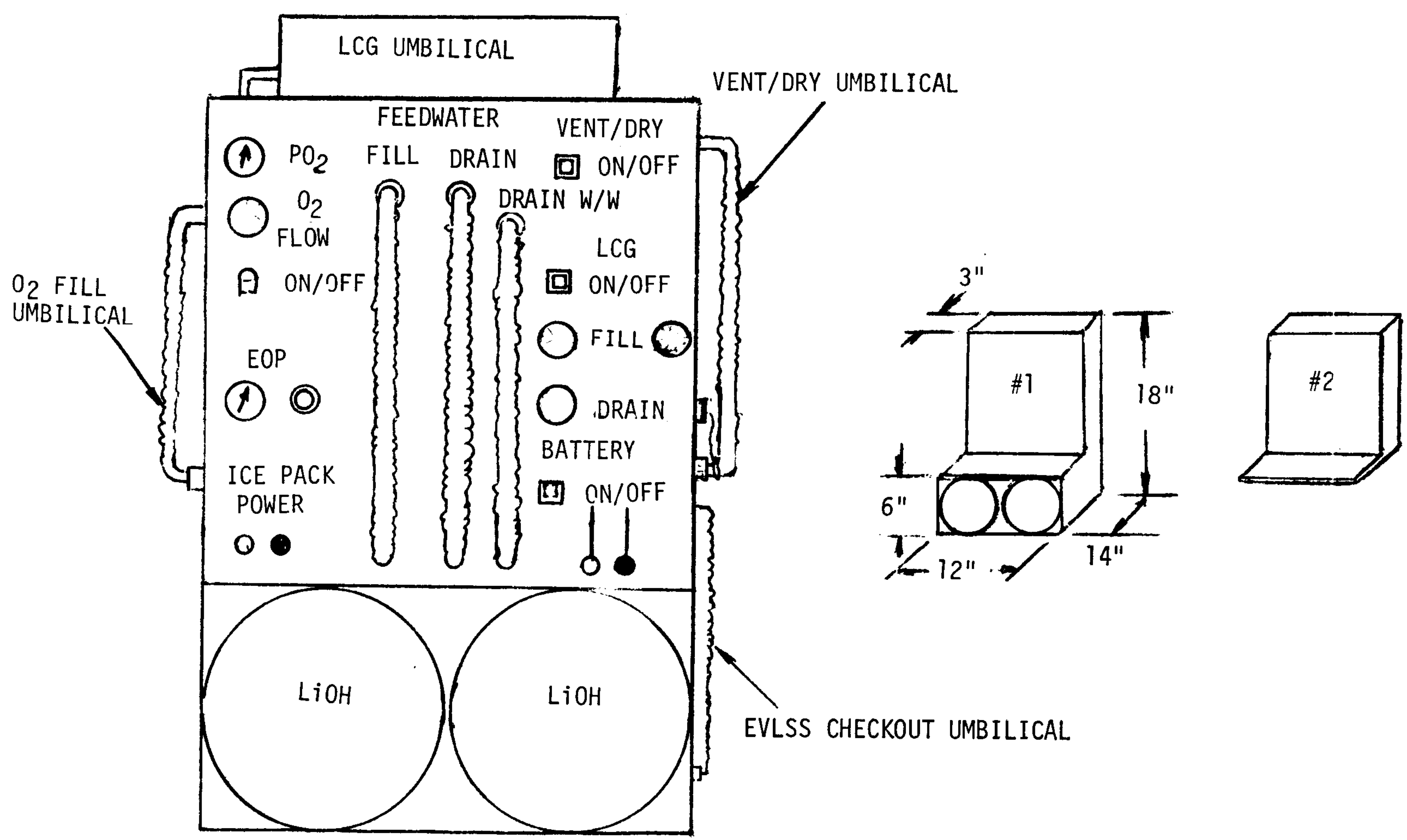
The EVLSS must be recharged after every planned and unscheduled EVA/IVA. A recharge station which includes the items presented on the opposite page is necessary. One unit with sequential recharging of two EVLSS's is the minimum requirement. However, that procedure is consumptive of man-hours. In addition, one unit is required in the airlock for one-man IVA servicing, and cooling is required in the cabin for the standby rescue crewman. Consequently, two EVA recharge stations are recommended and one may be located in the cabin if convenient.

The second recharge station may be identical to the primary, but it is recommended that the second unit be different to minimize launch penalties, thereby eliminating an extra set of the following:

- o Battery Recharger
- o Ice Pack Power Supply Outlet
- o Primary O_2 On/Off Valve

The LiOH storage canisters are shown stored in the recharge station for convenience. However, the LiOH may be stored at any location in the Shuttle.

EVLSS RECHARGE STATION



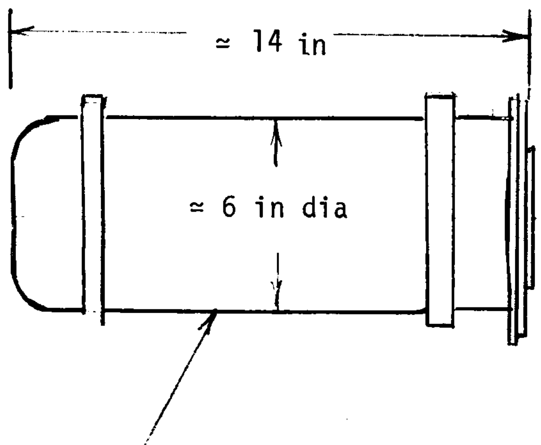
LiOH/CHARCOAL REPLACEMENT

LiOH and activated charcoal are selected for contaminant control in the EVLSS. Replacement cartridges are stored in air tight storage canisters to prevent pick-up of cabin contaminants.

The lunar module and PLSS employed a common LiOH cartridge size. The same approach can be used with the shuttle and the EVLSS. However, a major modification to the baseline vehicle ECS and/or EVLSS would be required to make the two compatible. A small savings in vehicle penalties (approximately 10 lbs) would result.

The dimensions and weight shown on the opposite page are representative, and for the purpose of defining a typical vehicle interface.

LIOH/CHARCOAL REPLACEMENT



REQUIREMENTS

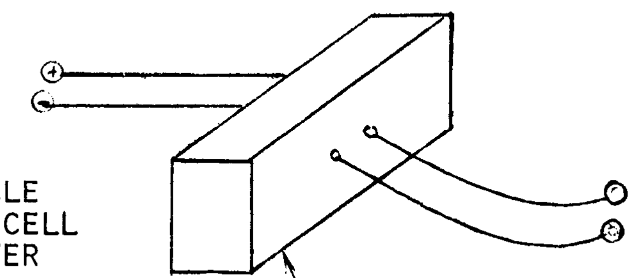
- AIR TIGHT STORAGE CANISTER: WITHSTAND 14.7 PSI PRESSURE DIFFERENTIAL, EITHER AS INTERNAL OR EXTERNAL PRESSURE
- ONE STORAGE CANISTER PER MAN PER EVA/IVA
- 5.8 LBS TOTAL INCLUDING LIOH AND ACTIVATED CHARCOAL CARTRIDGE

BATTERY RECHARGE

Recharge of the EVLSS batteries using vehicle fuel cell power was selected to minimize launch penalties. The recharge requirements are presented on the opposite page.

The baseline orbiter provides 28 VDC regulated. Current EVA Life Support Systems (PLSS) technology employs 16.8 VDC batteries. A step-down power conditioner or higher voltage EVLSS components are required to make the systems compatible.

BATTERY RECHARGE



REQUIREMENTS PER MAN

- EVA/IVA USABLE POWER (66 WATTS) : 264 WATT-HOURS (4 HOURS)
- EVA/IVA BATTERY (AG/ZN) : 10.0 LBS* 190 IN^3
- RECHARGER : 4.2 LBS 230 IN^3
- RECHARGE POWER : 90 WATT-HOURS / MAN-HOUR EVA
- RECHARGE TIME : APPROXIMATELY 2.5 X USE TIME
- RECHARGE PENALTY : FUEL CELL REACTANTS 1.54 LBS/KWH

* CARRY-ON FOR BACK-TO-BACK ACTIVITIES

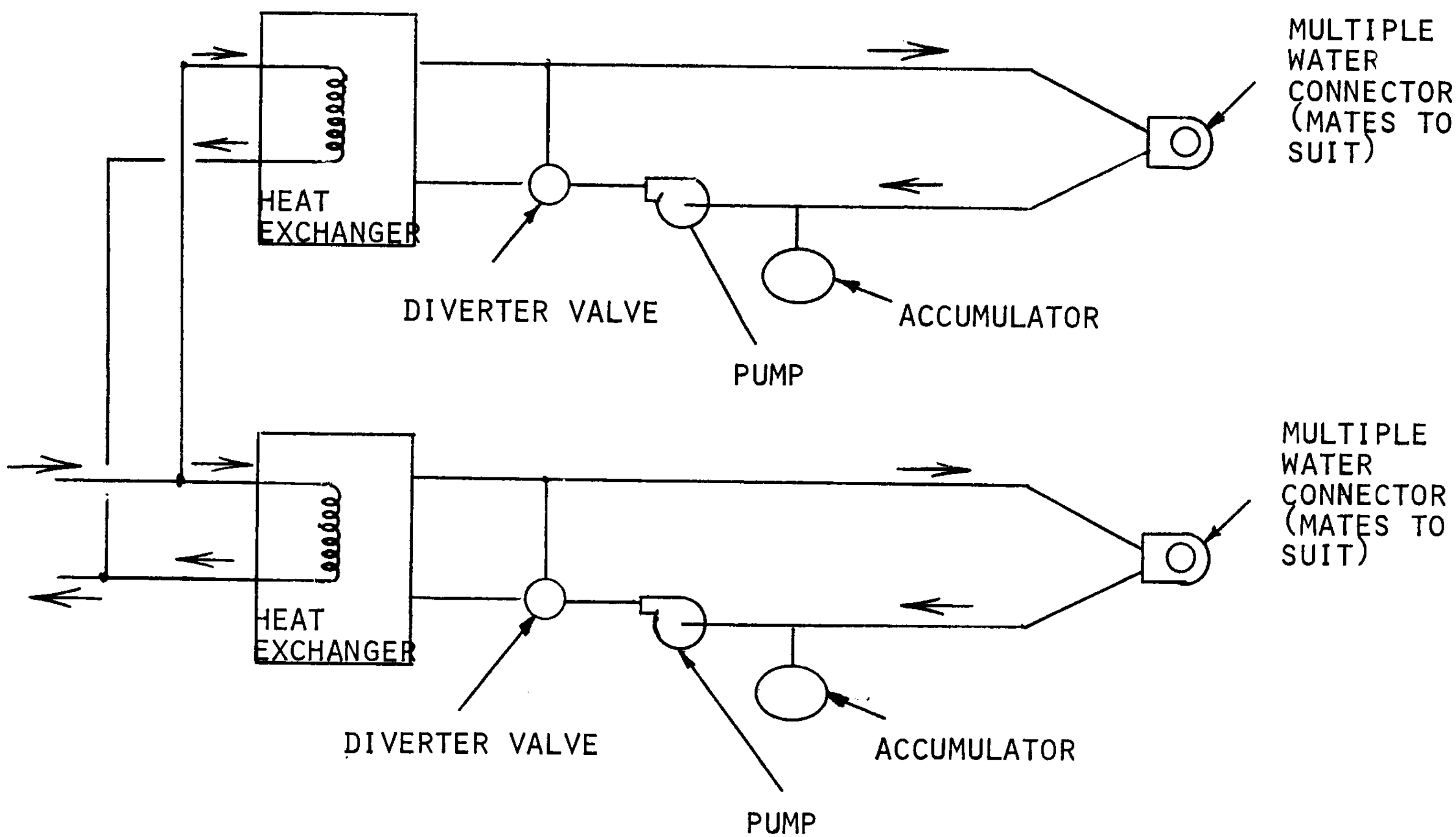
AIRLOCK LCG COOLANT LOOP

A coolant loop is required in the EVLSS recharge station. There are three uses for this loop. The primary use is to cool the crewmen during donning and doffing of the EMU. Secondary uses are a heat sink for the ice pack refreezer and a heat sink for an umbilical during EVA servicing (as an alternate configuration). Both liquid cooling loops and ventilation gas loops were evaluated. Gas cooling is marginally acceptable and will not satisfy the IVA servicing requirement. Liquid cooling with use of the LCG during don/doff is acceptable for all requirements.

The schematic of the selected system is presented on the opposite page. The multiple water connectors mate to the suit, ice pack refreezer and umbilical. Diverter valves provide individual LCG temperature control by the crewman. Although the freon loop provides a somewhat lower temperature, it is recommended that the airlock liquid cooling loop interface with the cabin water loop to avoid the pressure shell penetrations.

Alternately, the airlock water loop could mate the EVLSS at the ice module umbilical plug-in and use the EVLSS pump for circulation. The slight flow reduction should not be serious.

AIRLOCK COOLING LOOP



VEHICLE LAUNCH WIEGHT AND SCAR HEAT REJECTION SUBSYSTEMS

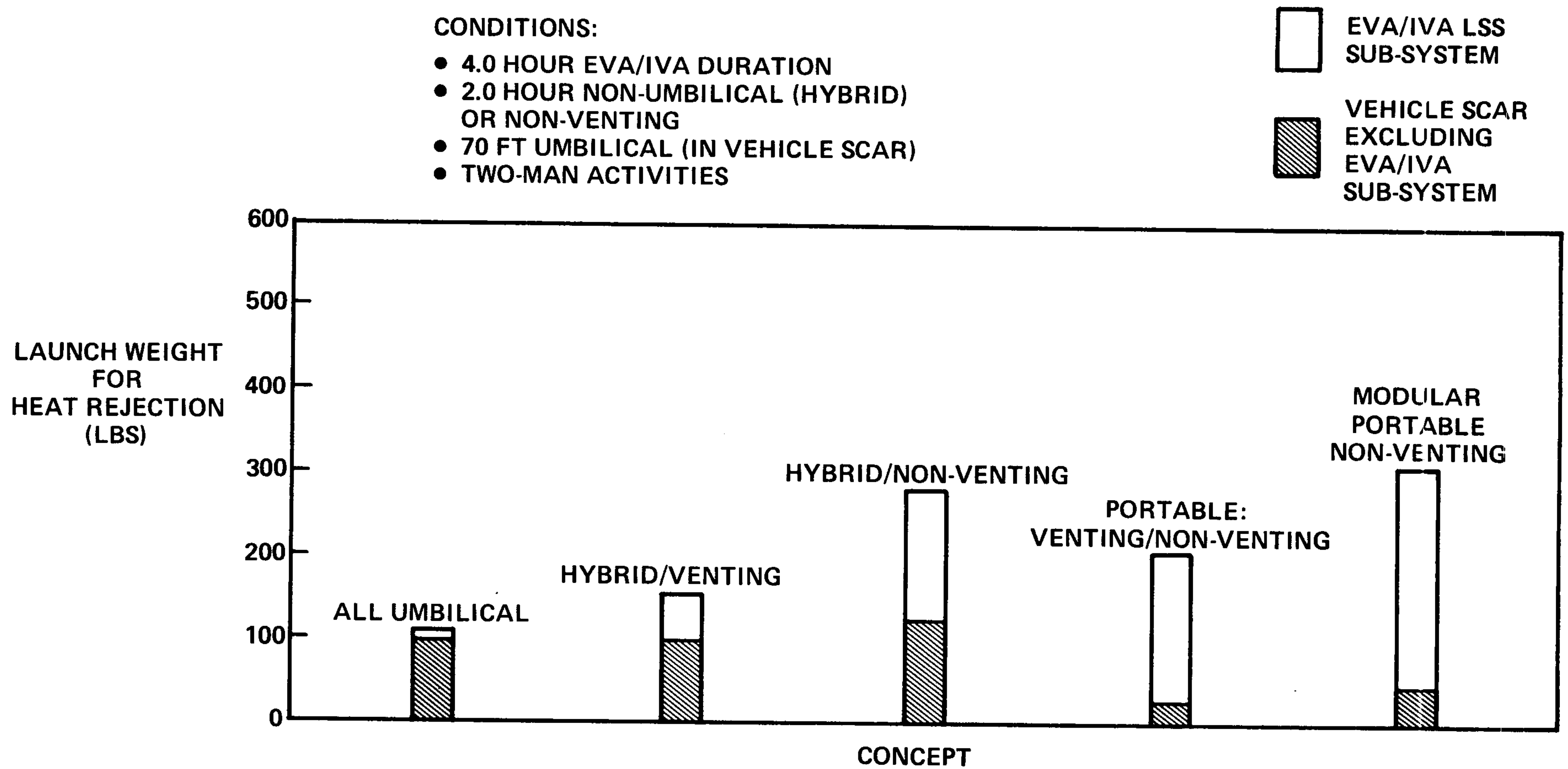
The alternate EVA/IVA LSS heat rejection subsystem concepts were evaluated for launch weight and permanent vehicle scar penalties in the course of selecting the recommended EVA heat rejection system. The opposing chart presents the results. The selected portable venting/non-venting system has the smallest vehicle scar.

VEHICLE LAUNCH WEIGHT AND SCAR

HEAT REJECTION SUBSYSTEMS

CONDITIONS:

- 4.0 HOUR EVA/IVA DURATION
- 2.0 HOUR NON-UMBILICAL (HYBRID) OR NON-VENTING
- 70 FT UMBILICAL (IN VEHICLE SCAR)
- TWO-MAN ACTIVITIES



ICE PACK REFREEZER

The ice pack refreezer is a simple thermoelectric unit. Vapor compression refrigeration and the use of cold radiator return fluid (upstream of the mixing valve) were also evaluated. The thermoelectric refrigerator was selected as the minimum launch weight system with an assured low temperature heat sink. The expendables (fuel cell power) plus equipment are a minimum with this system.

Heat is extracted from the ice pack modules during refreeze and is transferred to the liquid water coolant loop which is required in the airlock for cooling of the crewman during donning and doffing.

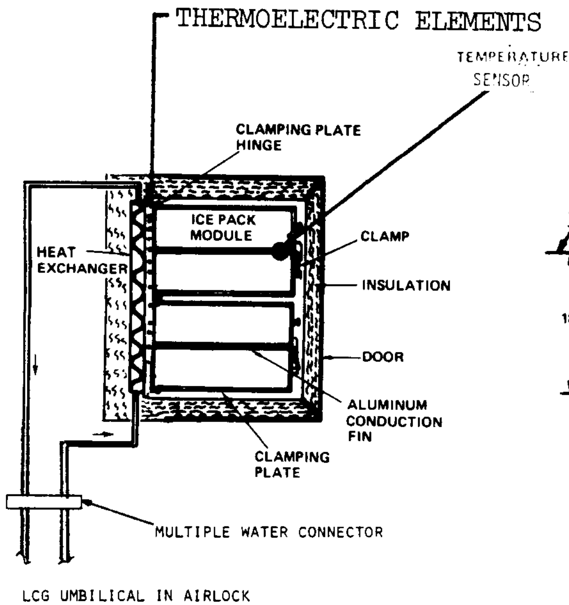
An active controller activates the thermoelectric elements as required. A temperature sensor mounted on the aluminum conduction fin is the control point; the controller measures this temperature and compares it with the allowable deadband (approximately 27° to 29°F). When the temperature is less than the minimum (indicative of frozen ice packs) the refrigerator and LCG pump are deactivated. Because of the thermal resistance increase as the ice is frozen, the controller will reactivate the refrigerator prior to freezing all of the ice. When the temperature is raised above the maximum set point (due to time lag in freezing or heat leak into the unit), the controller reactivates the refrigerator and LCG pump.

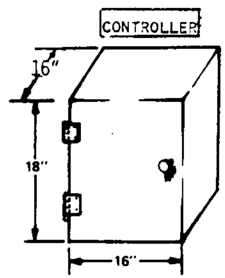
The ice pack refreezer and spare ice packs are carry-on items. The nominal design is for a 4 module unit to refreeze between EVA/IVA's. This design provides one man with four hours of non-venting capability or two men with 2 hours non-venting capability. Back-to-back 4 hour non-venting EVA/IVA's with two men are very rare, but when required either a second refreezer or additional spare ice packs can be employed.

The requirements listed reflect ice modules sized for a 120 btu/hr average metabolic rate, and would be scaled lawn appropriately for the final design value of 1000 btu/hr.

Although the recommended baseline system uses the water loop as a heat sink, studies show that it is also feasible to use cabin air as the heat sink. Such a system would require only plug-in electrical power, but would be considerably less efficient.

ICE PACK REFREEZER





REQUIREMENTS

- THERMOELECTRIC REFREEZER
  4850 IN3, 21 LBS (W/O ICE PACKS)
- CAPACITY : 4 MODULES
- POWER : 460 WATTS PEAK
- REFREEZE TIME : 4 HOURS
- POWER CONSUMPTION FOR 4 MODULES
  1.25 KWH (CONTROLLER PROVIDES ON-OFF HEAT LOAD CONTROL)
- THERMAL LOAD 4,700 BTU/HR (PEAK)
- LCG LOOP TEMPERATURE 45° TO 50°F
- ICE PACK MODULES (EACH)
  640 IN3, 29.7 LBS

OXYGEN RECHARGE

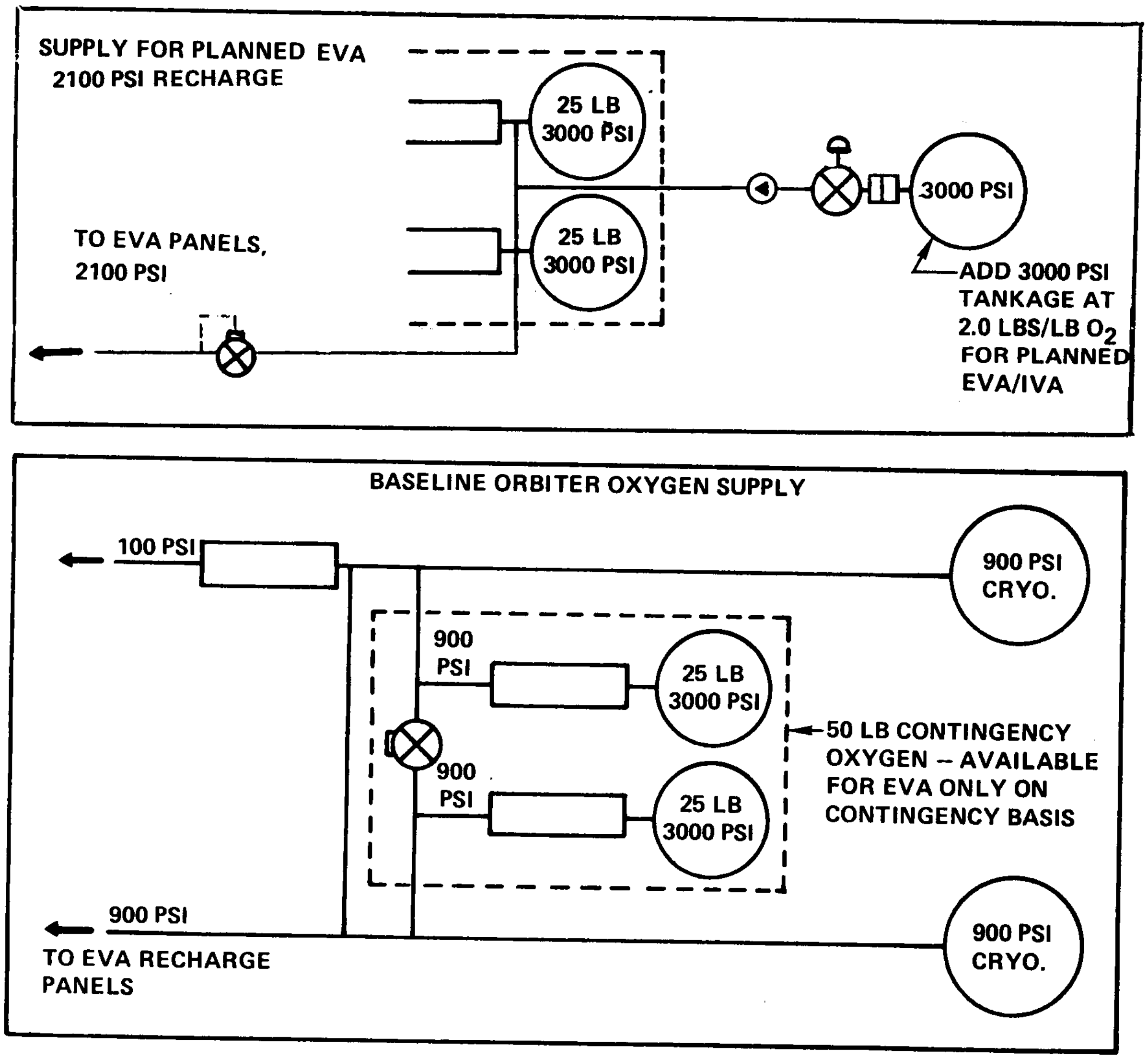
The recommendations for EVA/IVA oxygen recharge are presented on the opposite page. The scar includes all necessary equipment (lines, valves, regulator, etc.). No increase in vehicle tankage for unscheduled EVA's is required (EVLSS's are launched full). For emergency EVA recharge oxygen is withdrawn from the 50 lb contingency oxygen. Carry-on tankage is required only for all planned EVA/IVA.

The oxygen required for a single flight is the sum of the metabolic and leakage, plus the service O_2. Service O_2 includes gas for two suit pressurizations and metabolic plus leakage during ingress and egress.

The recommended EVLSS storage pressure is 2100 psia. This pressure is achieved by integration of the EVA/IVA oxygen storage with the 50 lb contingency reserve. Carry-on tankage for a maximum of 54 man-hours with 7 airlock openings (planned plus unscheduled) was added to the 50 lb contingency O_2. After complete withdrawal of all EVA/IVA O_2 50 lbs of available oxygen remains in the three tanks for contingency use. The final pressure for that condition was calculated to be 2100 psi.

The driver for selecting the high pressure gaseous oxygen system for recharge vs the 900 psi cryogenic supply is the reduced EVA volume (see Section VI). On the other hand, the cryogenic supply has the advantage of a potentially lesser penalty if design margins result in an actual surplus tankage. If this can be counted on for EVA, then the advantage of reduced vehicle penalty could offset the EVA volume advantage. This should be pursued further.

OXYGEN RECHARGE



EQUIPMENT REQUIREMENTS

- Scar : 7.6 lbs
- Carry-on Tankage Penalty : 1.0 lb/lbO_2 (tank only)

OXYGEN REQUIREMENTS PER MAN

- Single EVA/IVA Metabolic & Leakage : 0.1815 lb / Man-Hour
- Multiple EVA/IVA: Metabolic And Leakage : 0.1493 lb / Man-Hour
- Service For Egress/Ingress : 0.224 lb/man / Airlock Opening
- Maximum Consumption Per EVA/IVA (4 hrs) : 0.950 lbs / man

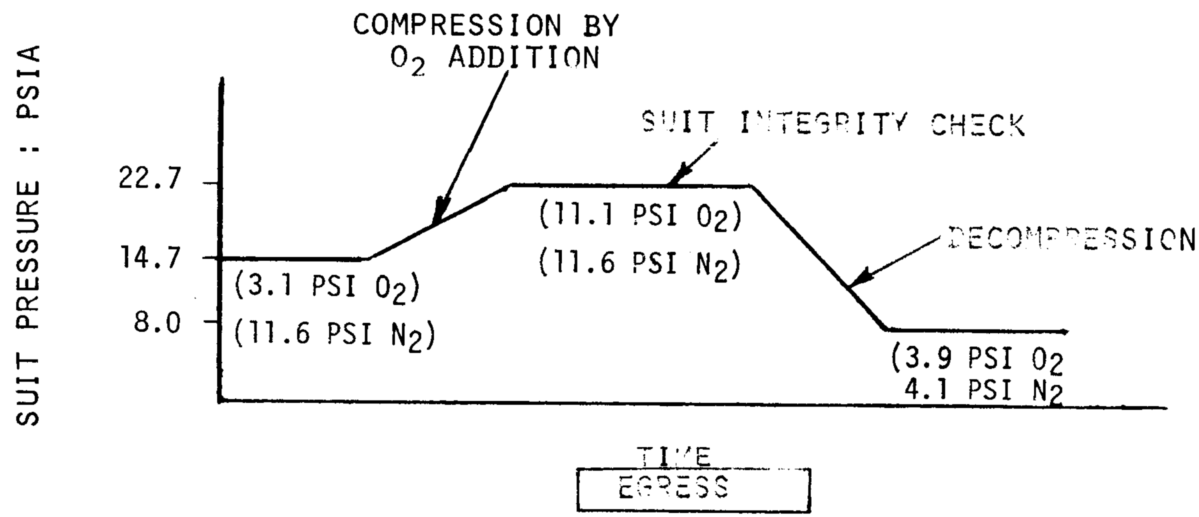
EGRESS/INGRESS PROCEDURES

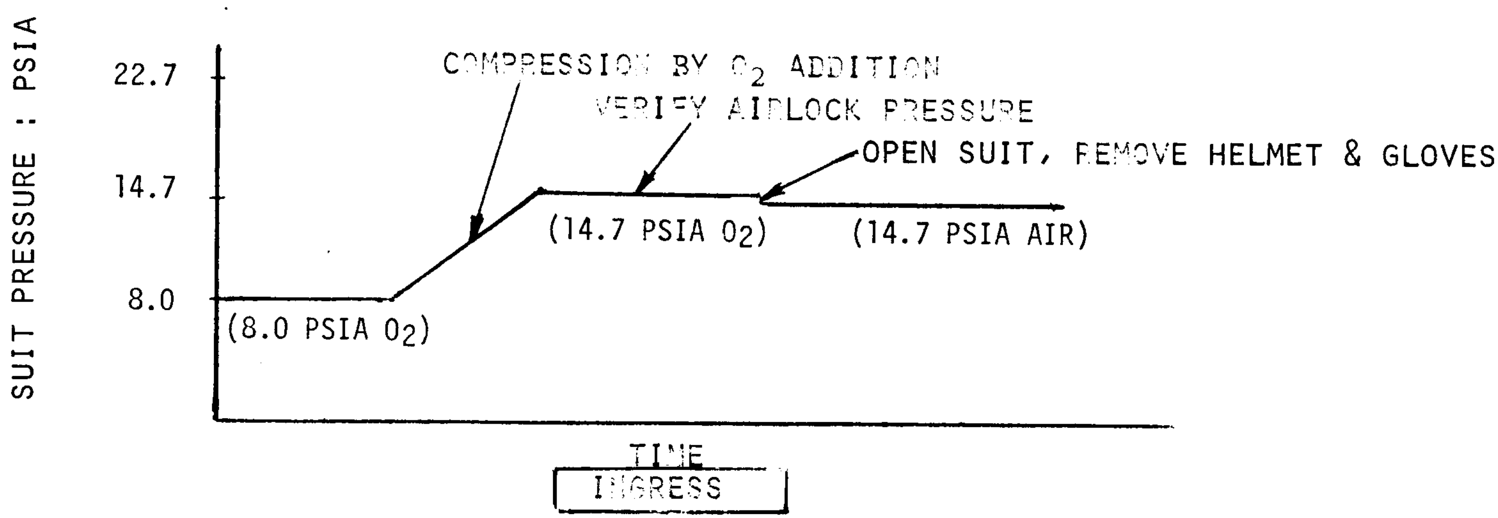
The selected egress/ingress procedures are illustrated on the opposite page. A suit integrity check is required on all EVA/IVA's to verify that all connections have been properly made. O_2 from the EVLSS (service oxygen) is employed for both pressurizations of the suit and provide metabolic and leakage oxygen during the egress and ingress operations.

The egress decompression is achieved by venting the airlock to vacuum. The suit is depressurized to 8.0 psia by venting through the relief valve to the airlock. Aeroembolism (the bends) will not occur since the N_2 partial pressure is equivalent to sea-level conditions. The O_2 partial pressure is also maintained above the minimum requirement.

The ingress compression is accomplished by repressurizing the airlock. The EVLSS will maintain the suit at 8.0 psi above the airlock. When the total suit pressure slightly exceeds 14.7 psia, the EVLSS O_2 supply is manually shut-off while the airlock is repressurizing to 14.7 psia. The suit is then opened, equalizing pressure with the airlock.

EGRESS/INGRESS PROCEDURES



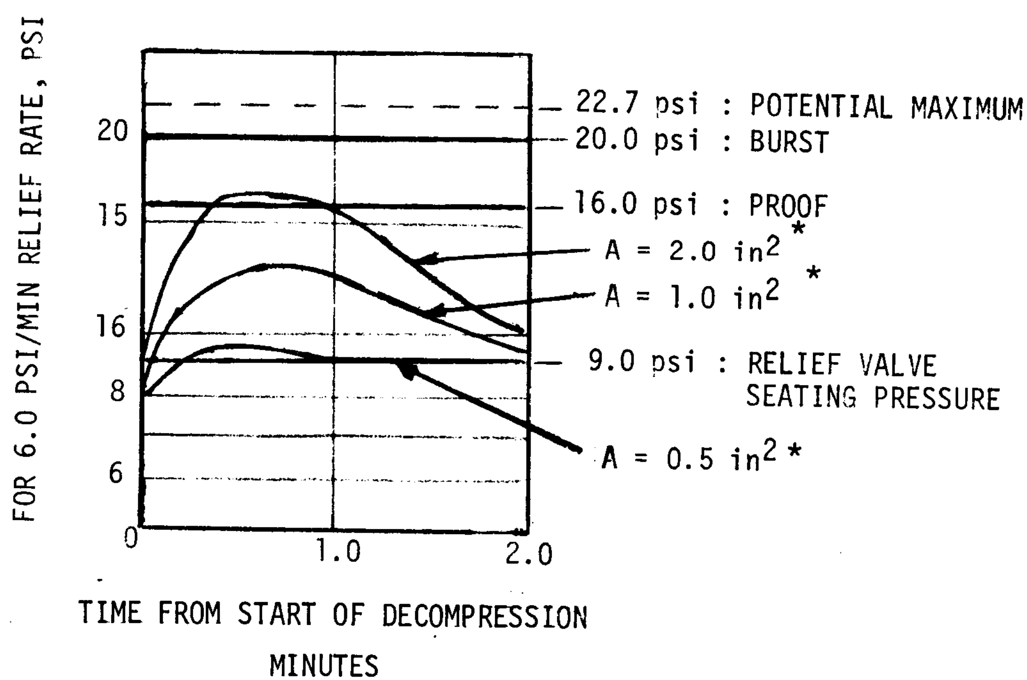


AIRLOCK VENT REQUIREMENTS

Two types of EVA/IVA are required, normal and contingency. Physiological limits for both cases were established*, and are presented on the opposite chart. During a contingency rescue, time is at a premium and the rapid decompression rate must be employed. During rapid decompression high suit pressure differentials can be generated as illustrated by the opposite figure. Since the potential maximum is in excess of the suit burst pressure the suit relief valve characteristics and airlock depressurization system must be designed together.

* Ref. D. Horrigan (NASA-MSC) personnel communication.

AIRLOCK VENT REQUIREMENTS



* Airlock Effective Vent Area

REQUIREMENTS

(1) DUAL RATE AIRLOCK VENT SYSTEM

- NORMAL : 2.5 PSI/MIN
- CONTINGENCY : 6.0 PSI/MIN (FOR MAN)

(2) RELIEF VALVE AND AIRLOCK VENT SYSTEM DESIGNED TOGETHER TO PREVENT OVER PRESSURIZATION OF THE SUIT

AIRLOCK AND DOCKING MODULE DEPRESSURIZATION CONCEPT

The opposite chart presents a schematic to decompress the airlock and/or the docking module (if present). The system employs a compressor to withdraw air from the volume reducing it to a pressure P_c. The remaining air in the decompressed volume is vented to space. The compressed air is stored by overpressurizing the cabin. The maximum pressures obtained are as follows, without relief:

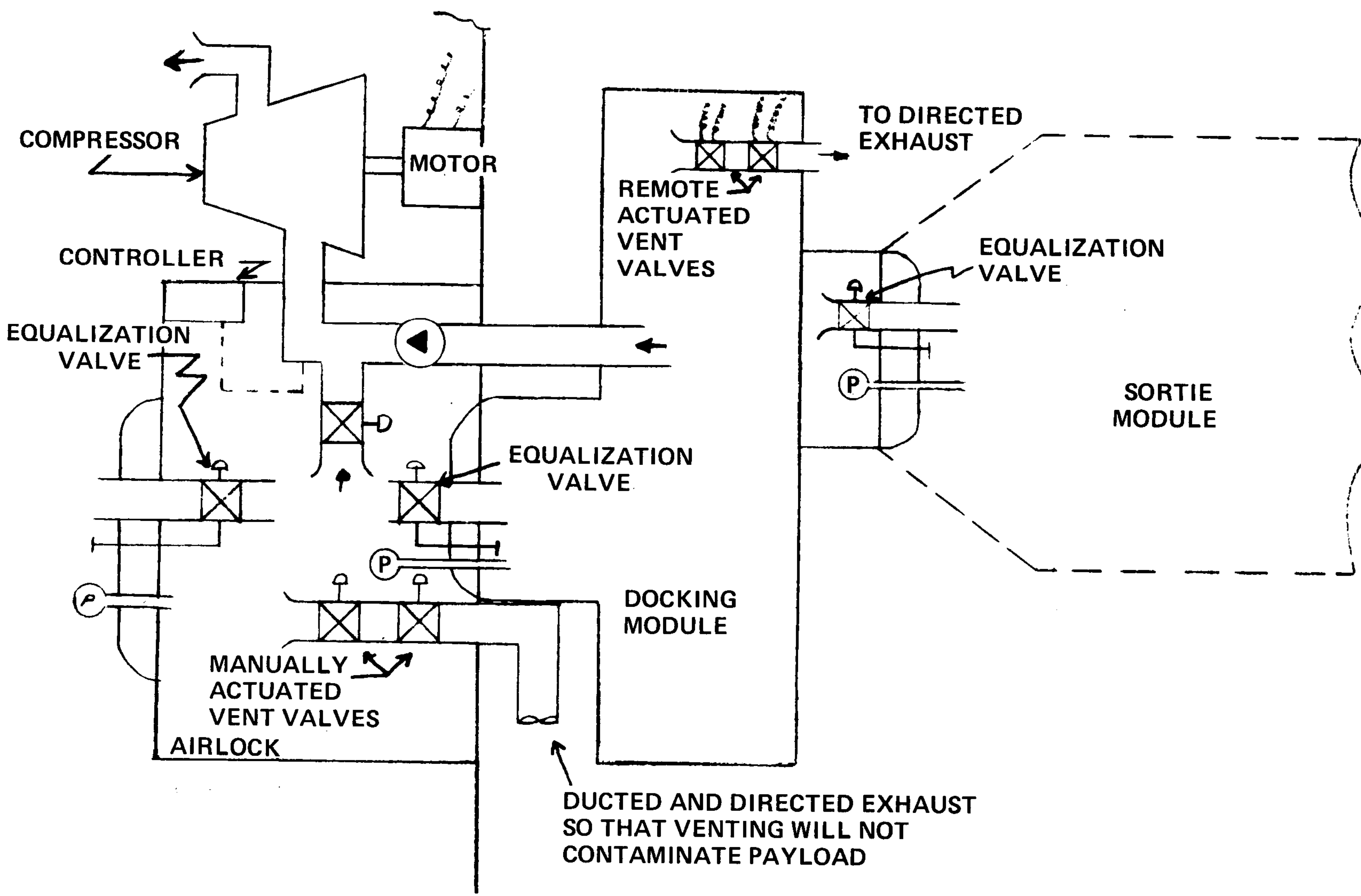
Airlock only	16.2 psia
Docking Module only	17.2 psia
Airlock and Docking Module	18.6 psia

The same system is employed regardless of the vehicle configuration. When both the airlock and docking module are decompressed, the docking module is decompressed first, then the airlock. To minimize potential contamination of experiments, the vented gas is ducted to a remote location and directed away from experiments.

In normal airlock repressurizations the cabin/airlock equalization valve is opened to pressurize the airlock. Cabin gas loss is made up by the normal pressurization system. The correct gas composition is provided without and extra O_2 partial pressure sensor. The tankage penalty is 2.0 lb(total)/Lb(air). It is achieved by N_2 storage as high pressure gas and O_2 in cryogenic stores.

Contingency rate repressurizations also employ cabin gas to provide a high flow rate (450 Lb/Hr) to the airlock. For fail/safe criteria (i.e., failure in equalization valve), flood-flow(manually activated)is also provided in the airlock.

AIR LOCK AND DOCKING DEPRESSURIZATION CONCEPT



COMPARISON OF DEPRESSURIZATION CONCEPTS

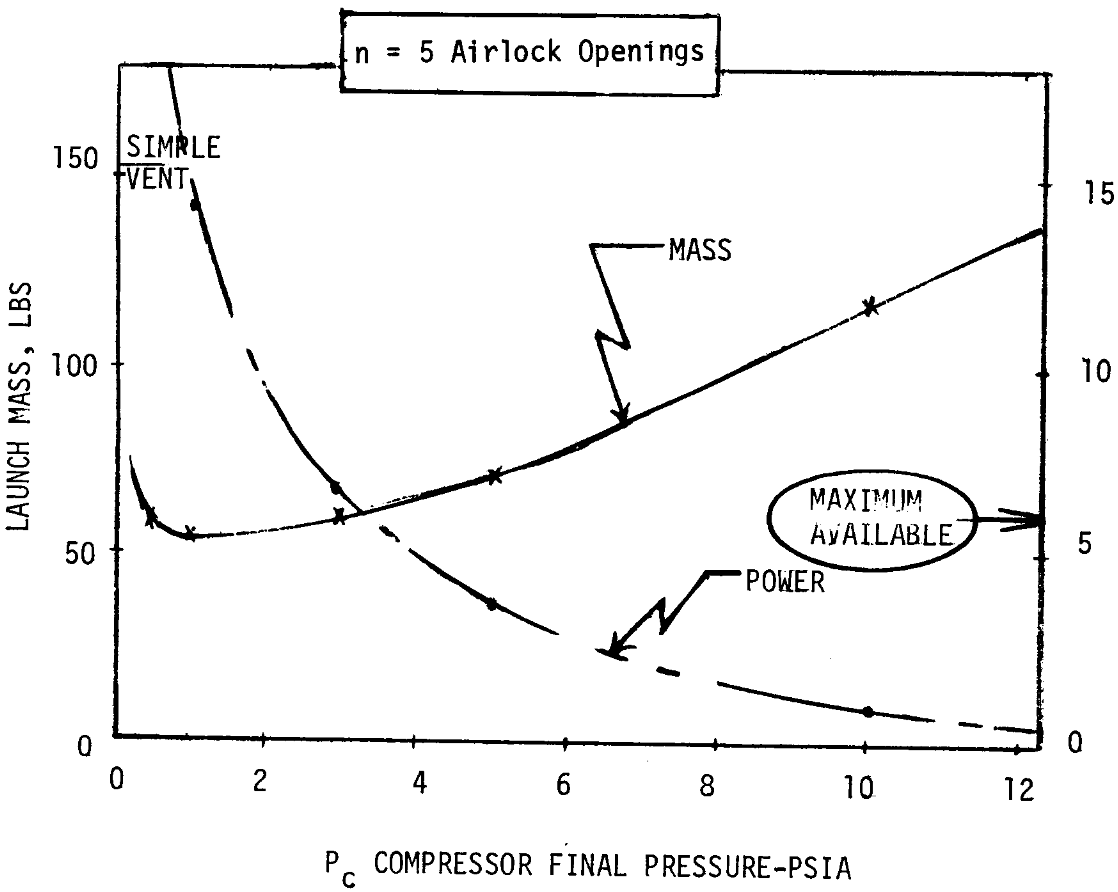
A comparison of simple vent with a compressor plus storage of airlock gas in cabin is presented on the opposite chart. The data are presented for the following conditions:

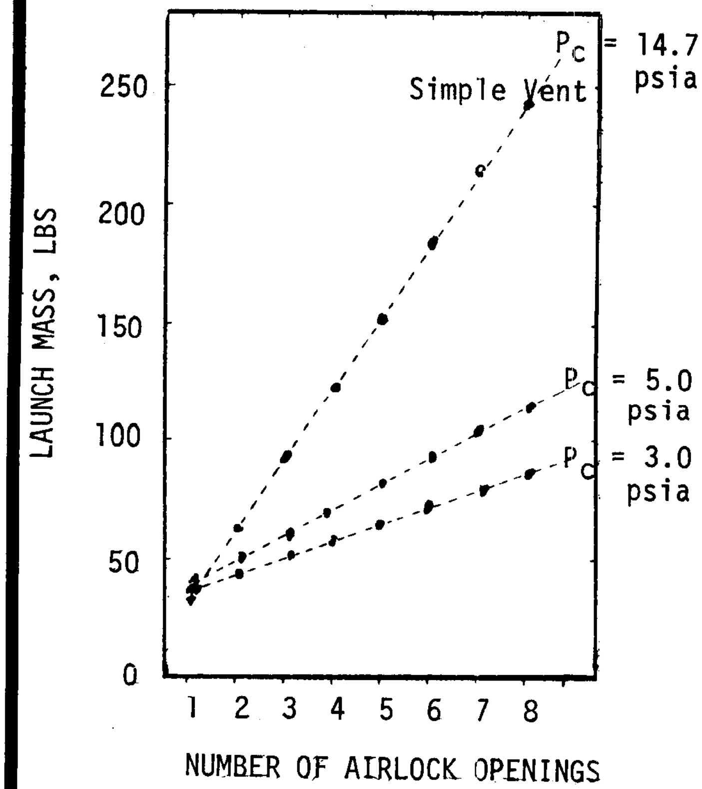
- Gas remaining in airlock below P_c (final compressor pressure) is vented to space
- Compressor and motor overall efficiency = 50%
- Maximum power available with load sharing = 6 KW_e
- Fuel cell power penalty = 1.54 Lb/KWH
- Decompress airlock from 14.7 to 0.0885 psia in 6.0 minutes
- Vented gas penalty of 2.0 Lb (tank + air)/Lb (Air)

The compressor system was found to be power limited; the expected final pressure is between 3 and 5 psia. Potentially the compressor system has an advantage, particularly considering that it has not been optimized. It is recommended that additional study be conducted on the compressor system. However, pending the results of that study simple vent is recommended, since the scar is less. The penalties for simple vent are

Scar	6 lbs
Vented Air (200 Ft^3/Airlock)	15 lbs
Tankage per airlock opening	15 lbs

COMPARISON OF DEPRESSURIZATION CONCEPTS





PENALTIES FOR AIRLOCK DEPRESSURIZATION

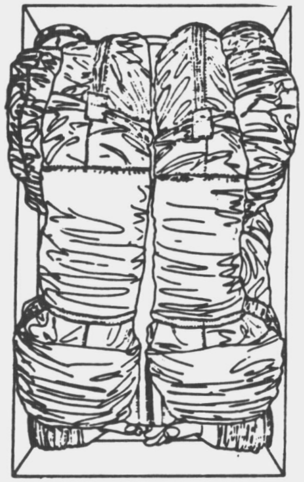
SUIT STOWAGE AND DONNING VOLUMES

Stowage and donning space will be required for the EVA suits in the orbiter vehicle. Two suit volumes are shown on the left to illustrate the maximum and minimum space required for the stowage of one space suit. The A7L-B Apollo and Skylab suit represents a "soft" suit with a minimum stowage volume requirement and the Advanced Extravehicular Suit (AES) represents a "hybrid" suit with a maximum stowage volume requirement.

ILC Industries, Inc. conducted some tests using AES and Intravehicular (IV) suits to determine donning space required for several situations. To don two AES suits plus two Portable Life Support Systems (PLSS) a volume of 50 in x 50 in x 92 in was required with the crewmen assisting each other. To don one AES suit alone, 40 in x 40 in x 92 in was required. To don the IV suit alone 29 in x 29 in x 76 in was required. These volumes are representative of the space which will be required on board the orbiter for donning. NASA-JSC has conducted don/doff/transfer tests with a 22" x 22" x 50" EVA cargo transfer box.

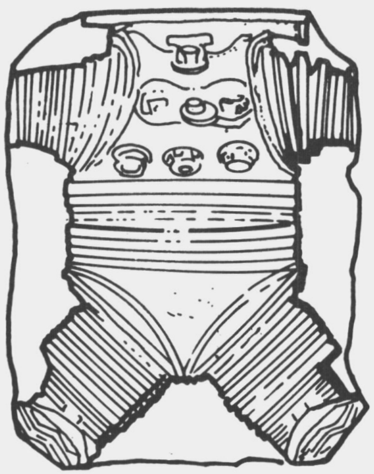
SUIT STOWAGE AND DONNING VOLUMES

STOWAGE



A7L-B

VOL. = 3.3 FT^3
(32" X 20" X 9")

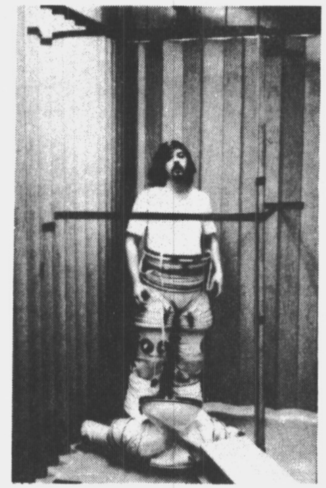


AES

VOL. = 5.7 FT^3
(28½" X 23" X 15")

DONNING

TWO AES SUITS
PLUS BACKPACK



SINGLE AES SUIT

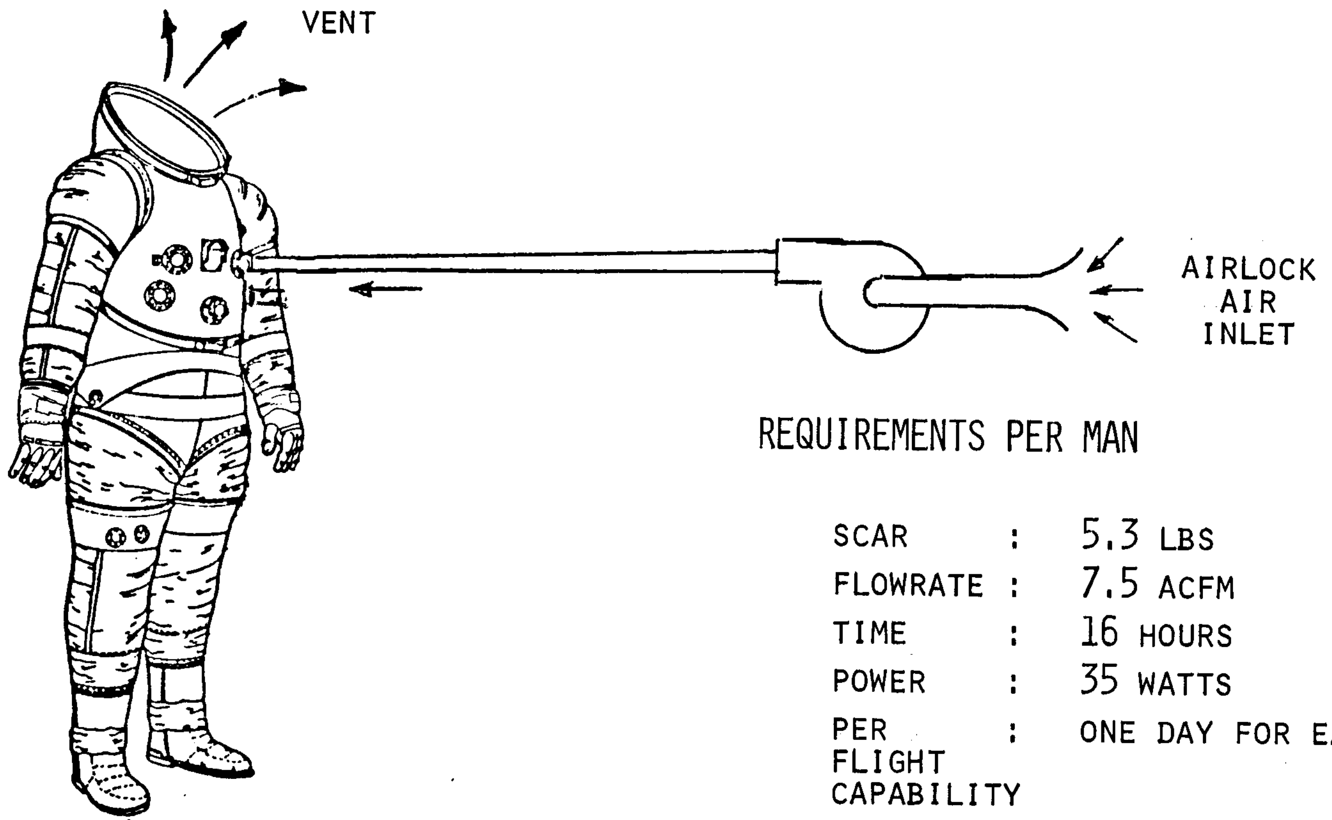
IV SUIT

SUIT DRYING STATION

The suit drying station schematic is shown on the opposite chart. The data are the requirements to evaporate 2 lbs of water from the suit and LCG. The LCG (not shown) is placed inside the suit to dry.

The actual quantity of water which will be retained in the suit with a high effectiveness LCG is uncertain. Tests are recommended to evaluate the quantity of unevaporated sweat retained in the suit following EVA/IVA.

SUIT DRYING STATION



REQUIREMENTS PER MAN

SCAR	:	5.3 LBS
FLOWRATE	:	7.5 ACFM
TIME	:	16 HOURS
POWER	:	35 WATTS
PER FLIGHT CAPABILITY	:	ONE DAY FOR EACH MAN

EVA/IVA EQUIPMENT REQUIREMENTS IN PRESSURIZED AREA FOR ALL FLIGHTS

The opposite chart presents the launch requirements to support one unscheduled and one emergency EVA/IVA with two men each. These items are required on all flights and no distinction is made as to scar. The EVLSS recharge stations and airlock depress systems do form a permanent part of the vehicle. All others can be readily removed.

The stowage location for any item listed is not critical. Any convenient location in the cabin or airlock can be used. For the optional IVA servicing with LCG umbilicals, one of the EVLSS recharge stations should be in the airlock. For the option of conducting one man EVA/IVA's, one of the recharge stations could be in the cabin. To minimize the time required in donning, all equipment should be centralized in a donning area.

EVA/IVA EQUIPMENT
REQUIREMENTS IN PRESSURIZED AREA
FOR ALL FLIGHTS

ITEM	PER MAN		FOR TWO MEN	
	LBS	STOWAGE, IN^3	LBS	STOWAGE, IN^3
(1) EVLSS	91.0	3,640	182.0	7,280
(2) EOP	44.0	1,160	88.0	2,320
(3) EV SUITS, (INCLUDING LCG, UCTA, FCS, CCA, BIO-INST, AND THERMAL/METEROID PROTECTION)	63.5	-	127.0	-
(4) EV SUIT STOWAGE CONTAINER	15.8	11,310	31.6	22,620
(5) TETHER	2.1	170	4.2	340
(6) EVLSS RECHARGE STATION			73.2	4,210
#1 WITH LiOH (1 EACH MAN)	39.5	2,610		
#2 W/O LiOH	33.7	1,600		
(7) AIRLOCK DEPRESS	-	-	6.0	140
TOTAL	N/A	N/A	512.0 LBS	36,910 IN^3

EVA/IVA SUPPORT REQUIREMENTS IN UNPRESSURIZED AREA FOR ALL FLIGHTS

The opposite chart presents the equipment requirements to support an EVA/IVA crewman. These may be stowed in the cargo bay and should be near the airlock egress hatch.

Expendables are simply increases in the capacity of existing systems. No penalty is included for EVLSS recharge and airlock opening for the emergency EVA; the shuttle emergency reserves are sufficient to provide that capability.

Fuel cell reactants have not been determined at this time. The EVA system requires power for lighting and manipulator maneuvering. These two systems have potentially the largest demand for power. However power requirements for these have not been defined for the baseline one unscheduled and one emergency EVA/IVA.

EVA/IVA SUPPORT REQUIREMENTS

IN UNPRESSURIZED AREA

FOR ALL FLIGHTS

ITEM	QUANTITY	PENALTY, LBS
(1) WORK PLATFORM END-EFFECTOR	ONE, STOWED AS 53 X 32 X 14 INCHES	40.0
(2) MOBILITY AID, RAIL IN CARGO BAY	150 FT AROUND CARGO BAY	47.7
(3) LIGHTS	USE CARGO BAY AND MANIPULATOR LIGHTS	TBD
(4) TOOL KIT	USE IV EQUIPMENT	-
(5) EXPENDABLES		-
• HIGH PRESSURE GASEOUS O_2 FOR EVLSS RECHARGE	0.95 LBS/MAN 1.9 LBS/2 MEN	(FROM EMERGENCY RESERVES)
• CRYOGENTIC O_2 FOR AIRLOCK REPRESS (200 FT^3)	3.4 LBS O_2/OPERATION, 6.8 LBS O_2/FLIGHT	4.2 LBS FOR ONE OPERATION (REMAINDER FROM EMERGENCY RESERVES)
• HIGH PRESSURE N_2 FOR AIRLOCK REPRESS (200 FT^3)	12.0 LBS N_2/OPERATION, 24.0 LBS N_2/FLIGHT	25.7 LBS FOR ONE OPERATION (REMAINDER FOR EMERGENCY RESERVES)
• FUEL CELL REACTANTS	TBD	TBD
TOTAL	-	97.6 + LBS

CARRY-ON EVA/IVA SUPPORT REQUIREMENTS IN PRESSURIZED AREA FOR FLIGHTS WITH PLANNED ACTIVITIES

The opposite chart is a summary table of items which will be required on some flights. The requirements for a particular flight will depend upon the nature and number of the planned activities.

CARRY-ON EVA/IVA SUPPORT REQUIREMENTS IN
PRESSURIZED AREA FOR FLIGHTS WITH PLANNED ACTIVITIES

ITEM	MASS STOWAGE	
	LBS	IN^3
(1) EMERGENCY IV SUITS (ONE EACH ADDED CREWMAN OR PASSENGER OVER MINIMUM CREW SIZE OF TWO WHO USE EV SUITS)		
o SUIT	17.0 EACH	-
o SUIT STOWAGE CONTAINER	5.4 EACH	2450 EACH
(2) LiOH FOR EVLSS (PER ONE MAN EVA)	5.8 EACH CANISTER	503 EACH CANISTER
(3) BATTERIES FOR EVLSS (FOR BACK-TO-BACK EVA/IVA)	10.0 EACH	190 EACH
(4) ICE PACK REFREEZER (EMPTY) (FOR NON-VENTING EVA)	21.0	4850
o ICE PACK MODULE	25 EACH	535 EACH
(5) TASK AND EXPERIMENT PECULIAR EQUIPMENT	TBD	TBD

CARRY-ON EVA/IVA SUPPORT REQUIREMENTS IN UNPRESSURIZED AREA FOR UNPLANNED ACTIVITIES

The opposite chart is a summary listing of the support requirements for planned activities. Both the quantity and weight penalty for each item is included. The requirements for a particular flight will depend upon the nature and number of the planned activities.

CARRY-ON EVA/IVA

SUPPORT REQUIREMENTS IN UNPRESSURIZED AREA

FOR PLANNED ACTIVITIES

ITEM	QUANTITY	PENALTY, LBS
(1) HIGH PRESSURE O_2 FOR EVLSS RECHARGE	0.149 LBS O_2/MAN-HR PLUS 0.224 LBS O_2/MAN/EVA	0.298 LBS/MAN-HR PLUS 0.448 LBS/MAN/EVA
(2) CRYOGENTIC O_2 FOR AIRLOCK REPRESS (200 FT^3)	3.4 LBS O_2/OPERATION	4.3 LBS/OPERATION
(3) HIGH PRESSURE N_2 FOR AIRLOCK REPRESS (200 FT^3)	12.0 LBS N_2/OPERATION	25.7 LB
(4) FUEL CELL REACTANTS		
• EVLSS BATTERY RECHARGE	90 WATT-HOURS/MAN-HR/EVA	0.14 LBS/MAN-HR/EVA
• SUIT DRYER POWER	560 WATT-HR/MAN/EVA	0.68 LBS/MAN/EVA
• ICE PACK REFREEZE	0.31 KWH/MAN-HR NON-VENTING	0.48 LBS/MAN-HR NON VENTING
• ICE PACK HEAT LEAK DURING STORAGE	TBD	TBD
• COMM & TELEMETRY	22 WATTS (APPROXIMATELY)	TBD
• MANIPULATOR POWER	TBD	TBD
• LIGHTS	CARGO BAY LIGHTS MANIPULATOR LIGHTS PORTABLE LIGHTS	TBD
(5) TASK AND EXPERIMENT PECULIAR EQUIPMENT	TBD	TBD

TOTAL LAUNCH PENALTIES

The opposite chart presents the launch penalties for the EVA/IVA system for two representative scenarios. One is the minimum launch requirements with provisions for only one unscheduled and one emergency EVA/IVA. The other is for the estimated maximum number of 6 EVA/IVA's.

The minimum launch penalty includes all items previously listed for both pressurized and unpressurized stowage. The EVLSS's, launched fully loaded, are employed for the first EVA/IVA. Sufficient expendables, stowed both in the pressurized and unpressurized areas are carried to conduct a second (emergency) EVA.

The maximum number of EVA/IVA's is 6 (4 planned, 1 unscheduled, and 1 emergency or any combination thereof). The data presented on the opposite chart are for EVA/IVA's conducted with a venting heat sink (i.e., <u>no</u> ice pack refreezer). Expendables for the 4 additional EVLSS recharges are included. Power for lights and manipulator maneuverings are not included, since these quantities have not been determined. The fuel cell reactant quantities therefore will be greater than the quantity stated.

TOTAL LAUNCH PENALTIES

ITEM	MINIMUM LAUNCH PENALTY (CAPABILITY OF EVA/IVA'S NONE PLANNED	LAUNCH PENALTY FOR MAXIMUM NUMBER OF EVA/IVA'S (TOTAL OF 6 WITH TWO MEN EACH)
PRESSURIZED AREA		
• FOR ALL FLIGHTS	512.0 LBS	512.0 LBS
• CARRY-ON		
• LiOH (8 CARTRIDGES)	-	46.4 LBS
• LAUNCH PECULIAR EQUIPMENT	-	TBD
UNPRESSURIZED AREA		
• FOR ALL FLIGHTS	97.6 + LBS	97.6 + LBS
• CARRY-ON		
• HIGH PRESSURE O_2	-	13.1 LBS (6.57 LBS O_2)
• CRYOGENTIC O_2 (200 FT^3 AIRLOCK)	-	17.2 LBS (13.6 LBS O_2)
• HIGH PRESSURE N_2 (200 FT^3 AIRLOCK)	-	102.8 LBS (48.0 LBS O_2)
• FUEL CELL REACTANTS	-	8.9 + LBS (5.8 KWH)
• LAUNCH PECULIAR EQUIPMENT	-	TBD
TOTAL	609.6 + LBS	798.0 + LBS (188.4 LBS MORE THAN MIN.)

IX. EMERGENCIES

EMERGENCY ISSUES

An aim of the present study has been to define an overall emergency concept with maximum flexibility to accommodate an evolving design. The opposing chart illustrates some of the most important issues in arriving at the concept. Other issues, such as use of current technology hardware, are also important.

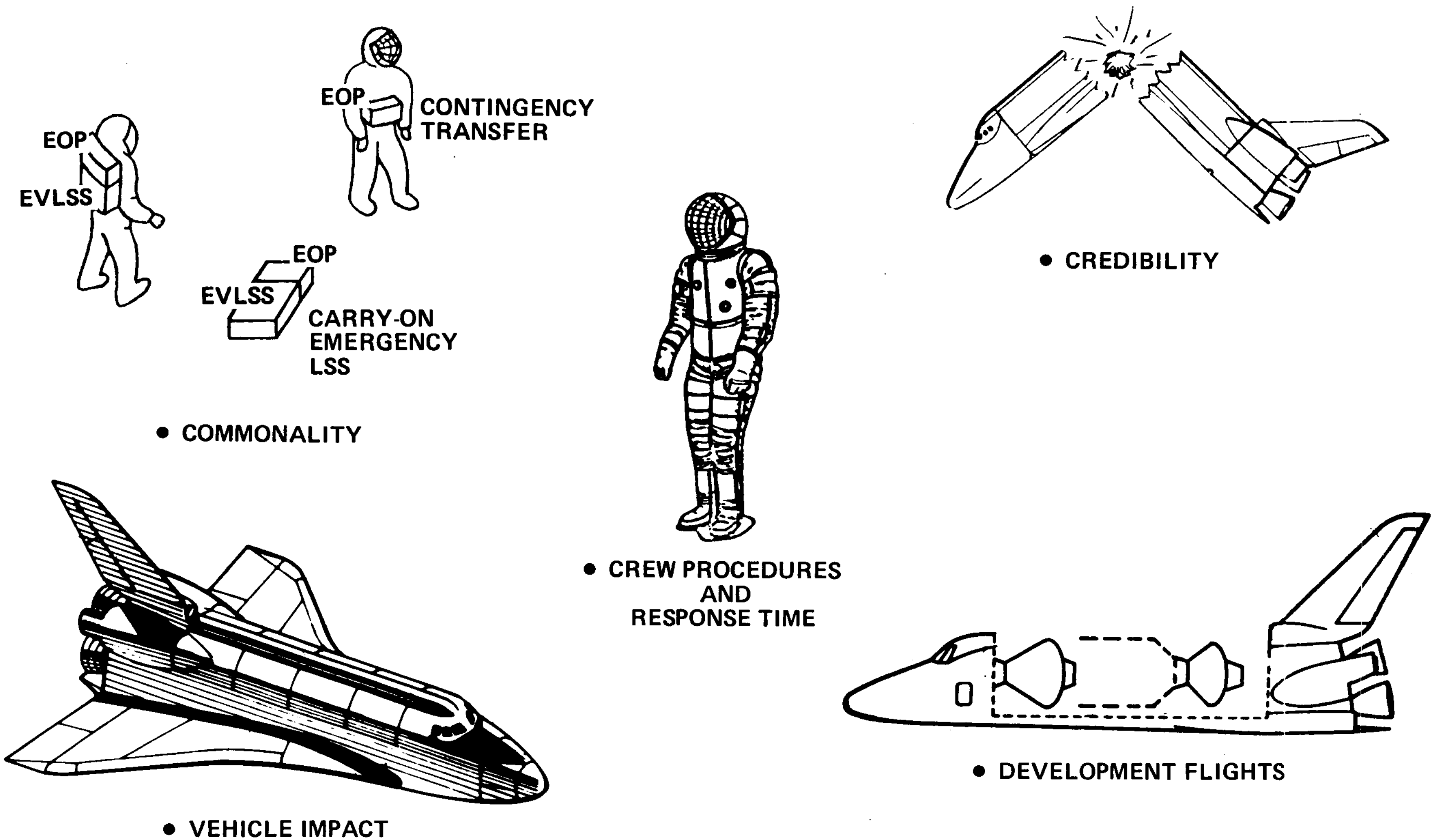
Development flights present some special considerations. During this phase, an orbital rescue capability by a second shuttle will not be available. Also, in general, hazards will be greater. The issue presents itself of whether to accept the higher risks during this period, or to provide additional emergency equipment. The current study has attempted to identify requirements for this special emergency equipment.

Groundrules loosely applied in evaluating emergency situations and concepts included:

- No Dual Contingencies
- No Major Modifications To The Orbiter Configuration (such as refuge chambers)
- Consider All Viable Emergencies
- On-Orbit Rescue Is Feasible During The Operational Phase Of The Orbiter

Supporting detailed studies on Emergencies are contained in Volume V of this report.

EMERGENCY ISSUES



OUTLINE

- BASELINES
- EMERGENCY CLASSES
- SCENARIO ANALYSIS
- VIABLE OPTIONS
- ASSESSMENTS
- PRELIMINARY EMERGENCY SYSTEM
- CONCLUSIONS & RECOMMENDATIONS

BASELINES

- ORBITER BASELINE
- BASELINE SORTIE LAB
- VEHICLE CONFIGURATION

BASELINE ORBITER

The orbiter characteristics listed are basically those of the Preliminary Requirements Review (PRR) configuration, established in October 1972, with changes obtained by personal communications with NASA-JSC and Rockwell International.

The use of aircooled Avionics on the orbiter results in the inability of the orbiter to re-enter unpressurized, the inability to operate the manipulator with a depressurized cabin, and the inability to actively stabilize the orbiter while depressurized. This latter condition could also prevent on-orbit rescue, although the expected tumbling rate resulting from a depressurization (with no large force applications) would be fairly low, and probably would not preclude the rescue. Although the baseline orbiter cannot re-enter depressurized, the case of including this capability was also investigated in the present study to determine the impact on emergency system requirements.

ORBITER BASELINE

150K ORBITER

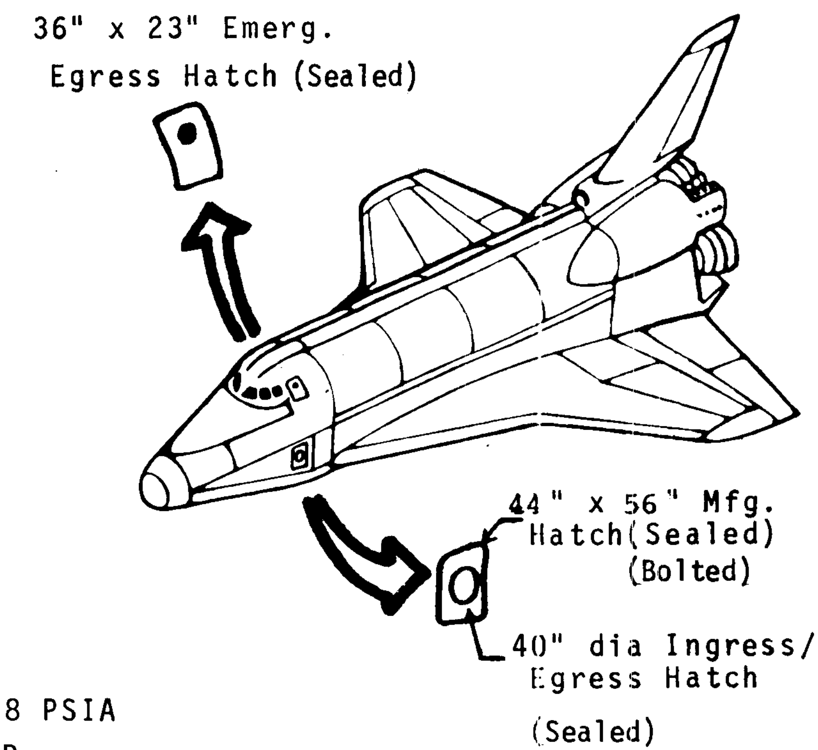
- 20" SHORTENED CABIN (2000 ft^3)
- 63" dia x 82" AIRLOCK (144 ft^3)
- DOCKING MODULE CARRY-ON

EMERGENCY RE-ENTRY

- 95 MIN PANIC MODE (WORLDWIDE AIRFIELDS)
- 165 MIN QUICK RETURN (8 US BASES)
- 285 MIN QUICK SAFE RET. (5 US BASES)
- 810 MIN PLANNED RETURN (3 US BASES)

DEPRESSURIZED CABIN

- CANNOT REENTER UNPRESSURIZED
- MANIPULATOR CANNOT FUNCTION UNPRESSURIZED
- CANNOT STABILIZE ON-ORBIT UNPRESSURIZED
- EMERGENCY AVIONICS OPERABLE TO APPROXIMATELY 8 PSIA
- STRUCTURAL CABIN ΔP MAX. OF 0.5-1.5 PSI INWARD



NOTE: HATCHES MUST BE SEALED PRIOR TO RE-ENTRY

BASELINE ORBITER EMERGENCY SYSTEMS

FLOOD FLOW

- UP TO 150 pph CABIN PRESSURE MAKEUP FOR ONE HOUR, AUTOMATIC ON LOW CABIN PRESSURE (APPROX. 14 PSIA)
    - — 100 lb EMERGENCY 3000 psi N_2
    - — 50 lb EMERGENCY 3000 psi O_2
    - — 15 pph CRYOGENIC O_2
- ATTEMPTS TO MAINTAIN 14.7 ± 2 PSIA CABIN, 3.1 ± .1 PSIA OXYGEN PARTIAL (N_2 MAKEUP SHUTS OFF WHEN P_{O_2} FALLS TO 3.0, STAYS OFF UNTIL P_{O_2} REACHES 3.2)
- 150 pph PURGE FLOW POSSIBLE BY MANUAL ACTUATION OF RELIEF VALVE

AIRLOCK

- CARRY-ON 15 SECOND EMERGENCY AIRLOCK REPRESSURIZATION TO 3.25 PSIA
- AIRLOCK PURGE CAPABILITY (MANUAL ACTUATION DEPRESS/REPRESS VALVES)

C & W

- FIRE, CABIN TOTAL PRESSURE, O_2 AND CO_2 PARTIAL PRESSURE, CABIN FLUID LOOP TEMPERATURE, HIGH O_2 AND N_2 FLOW

OXYGEN MASKS

- 4 FACE MASKS - 10 MINUTE 900 PSIG PORTABLE O_2 - PLUG-IN TO VEHICLE OPERATION OR RECHARGE

FIRE CONTROL

- 4 PORTABLE FOAM FIRE EXTINGUISHERS
- CONTINUOUS 1 lb/DAY OVERBOARD PURGE OF AVIONICS BAY; BAY MAINTAINED 0.4 PSI BELOW CABIN BY SUPPLY VIA RELIEF VALVE
- AUTOMATIC 6% FREON 13B1 FLOOD IN AVIONICS BAYS

SORTIE LAB

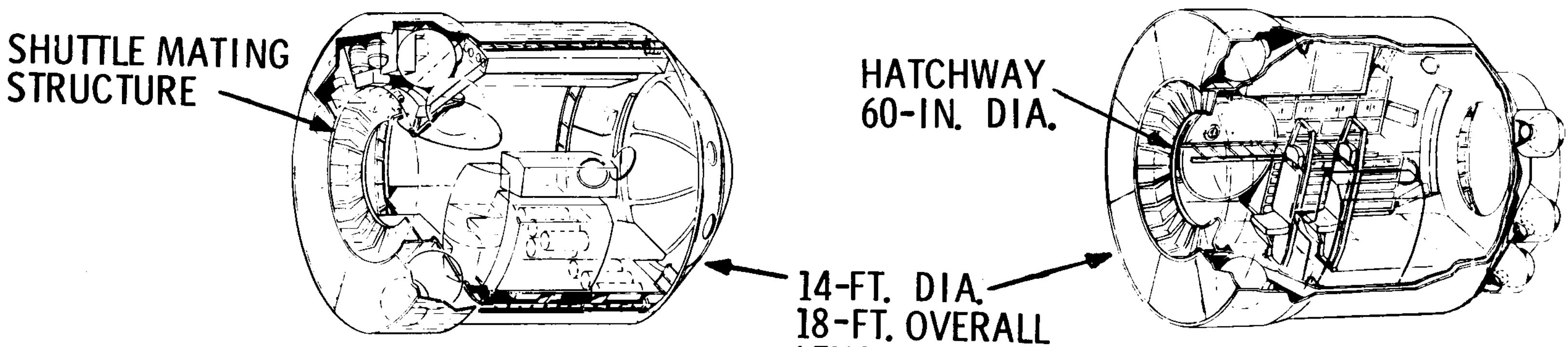
Baseline information on the Sortie Lab were obtained from the Phase B Research and Applications Module (RAM) study documentation and consultation with General Dynamics. This was supplemented by subsequent NASA study results on the Sortie Can* and Sortie Lab **. These latter studies are basically a departure from the RAM design to consider evolving payload and mission requirements, and are directed primarily toward early and austere applications. The basic module configuration and major subsystems are similar, although currently less uniquely defined for the Sortie Lab.

Some of the emergency/safety related aspects of the RAM design are two IV suits, two 10-ft umbilicals, two 30-ft umbilicals, two oxygen masks with 45-minute portable oxygen supplies, one fire extinguisher, and one portable light located in the basic Sortie RAM. The EC/LSS provides purge oxygen flow for an open suit flow loop. In addition an emergency intercom and caution and warning displays and tone are provided. Common to both the RAM and Sortie Lab designs is only a single-egress capability (i.e., only one exit hatch/path for emergency egress). An exception to this is the case of an experiment airlock in the aft end of the module. The RAM system also includes the capability to stack modules; a Ram Support Module (RSM) can be added between the Sortie RAM payload module and the orbiter cabin. In addition, a 32 ft. payload module is available in the system. The RAM safety studies recommend that all RAM internal hatches be positioned open during manned occupancy. The orbiter cabin-to-airlock hatch would be closed.

* "Sortie Can Conceptual Design", NASA-MSFC Program Development Advanced Studies Report No. ASR-PD-DO-72-2, March 1, 1972.

** "Sortie Lab Program Review", First Phase B Review, NASA-MSFC, November 16, 1972.

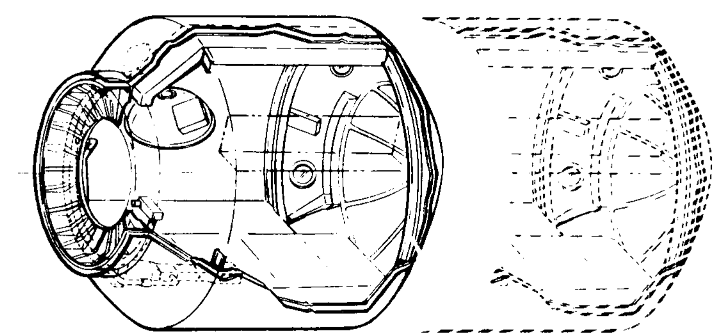
BASELINE SORTIE LAB (RAM)



SORTIE RAM   RAM SUPPORT MODULE

PHYSICAL

- RAM REPRESENTATIVE OF SORTIE LAB
- SORTIE LAB LENGTH 25-1/2 FT.
- 18 & 32 FT RAM'S CAN BE COMBINED
- RAM TOTAL PRESSURIZED VOLUMES OF 1900 AND 3900 FT^3
- SINGLE EGRESS PATH THROUGH FWD HATCH



RAM PAYLOAD MODULE
(18-FT. & 32-FT.)

BASELINE SORTIE LAB EMERGENCY SYSTEMS (RAM)

REPRESSURIZATION

- VALVES AND CONSUMABLES FOR ONE DEPRESS/REPRESS

SUITS

- 8 PSI SUITS AND PURGE O_2/N_2 SUIT LOOP (6 HOURS)
- 10 FT AND 30 FT UMBILICALS

FACE MASKS

- 45 MINUTE PORTABLE O_2
- PLUG-IN O_2/N_2 FROM ECLSS

C & W

- FIRE; RAPID PRESSURE DECAY; CONTAMINATION; O_2, N_2, AND CO_2 PARTIAL PRESSURES; FREON LOOP TEMPERATURE, ETC.

FIRE CONTROL

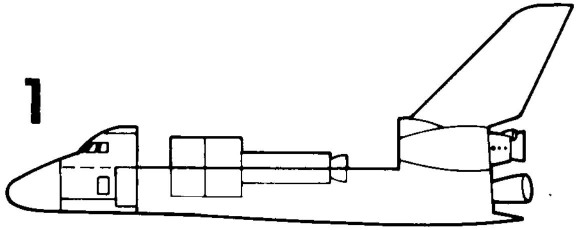
- PORTABLE FOAM FIRE EXTINGUISHER
- PORTABLE LIGHT

VEHICLE CONFIGURATIONS

The opposing chart illustrates the discrete functional configurations associated with the Rockwell PRR baseline. The distinguishing factors are manned access routes from the orbiter cabin and docked manned payloads. It should be noted that the old flex-tunnel module deployment is included in Configuration No. 3. While the sketches are specific to the PRR baseline, it is believed that the results of the emergency analysis will apply to any foreseeable modifications to these configurations.

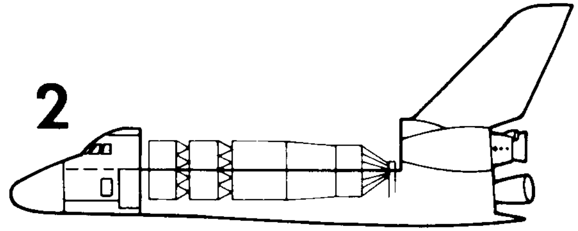
VEHICLE CONFIGURATIONS

1



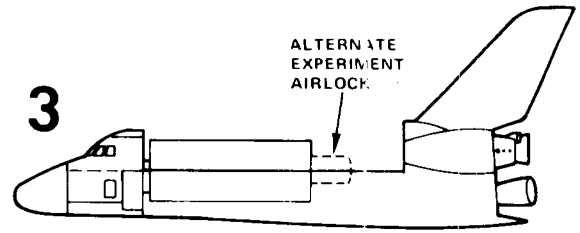
- NO DOCKING MODULE
- UNBLOCKED ACCESS TO AIRLOCK
- NO SORTIE MODULE

2



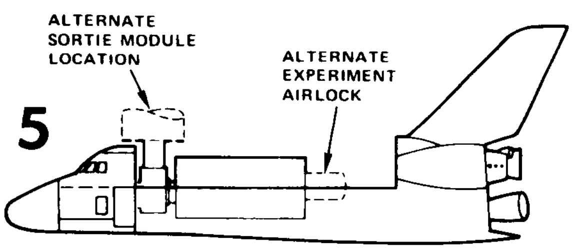
- NO DOCKING MODULE
- EVA ACCESS TO AIRLOCK BLOCKED
- NO SORTIE MODULE

3



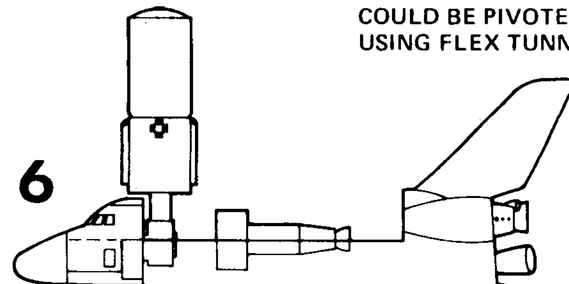
- NO DOCKING MODULE
- EVA ACCESS TO AIRLOCK BLOCKED
- SORTIE MODULE IN PLACE (EQUIVALENTLY COULD BE PIVOTED FROM PAYLOAD BAY USING FLEX TUNNEL)

5



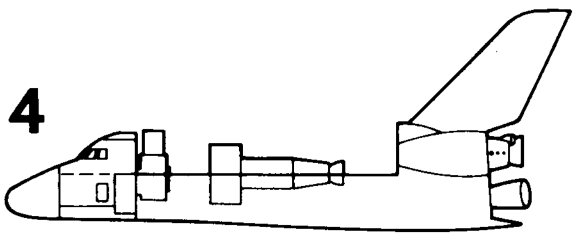
- DOCKING MODULE IN PLACE
- EVA ACCESS TO AIRLOCK THROUGH DOCKING MODULE
- SORTIE MODULE IN PLACE (EQUIVALENTLY COULD BE DOCKED TO TOP OF DOCKING MODULE)

6



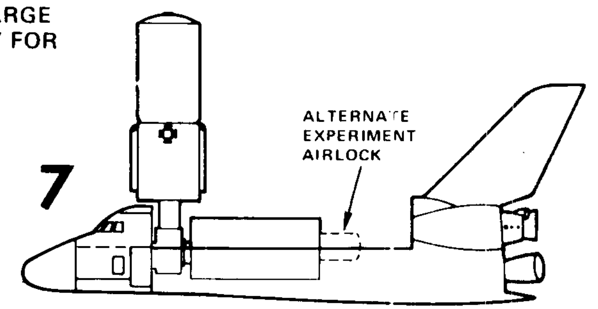
- DOCKING MODULE IN PLACE
- EVA ACCESS TO AIRLOCK THROUGH DOCKING MODULE
- NO SORTIE MODULE
- DOCKED TO LARGE OBSERVATORY FOR SERVICING

4



- DOCKING MODULE IN PLACE
- EVA ACCESS TO AIRLOCK THROUGH DOCKING MODULE
- NO SORTIE MODULE

7



- DOCKING MODULE IN PLACE
- EVA ACCESS TO AIRLOCK BLOCKED
- SORTIE MODULE IN PLACE
- DOCKED TO LARGE OBSERVATORY FOR SERVICING

EMERGENCY CLASSES

- CREDIBLE EMERGENCIES
- EXAMPLES
- SUMMARY OF EMERGENCY EFFECTS

CREDIBLE EMERGENCIES

Eight classes of credible emergencies with a potential requirement for EVA/IVA equipment or action were identified during the Tasks, Guidelines and Constraints phase of this study. Major sources of information were the Aerospace, Rockwell, and RAM safety studies, as well as identification of potential contingency situations by VSD. The degree of credibility of each emergency is, of course, highly dependent on vehicle design, and the option often exists for designing to an acceptable risk level. It is expected that as the basic orbiter and Sortie Lab FMEA and safety studies progress, the credibility of some of the contingencies will be modified.

The opposing chart lists the eight classifications. The classes do not indicate a sequence of estimated importance or credibility. Additional detail on the listed emergencies will be given on the following charts.

After the credible emergency classes were established, they were condensed into four categories. These are summarized in a chart following the discussion of the eight classes. Next, viable options for each of these four categories will be described.

SUMMARY OF CREDIBLE EMERGENCIES

CLASS I	FIRE OR RELEASE OF TOXIC SUBSTANCES
CLASS II	EXPLOSION
CLASS III	DECOMPRESSION OF PRESSURIZED COMPARTMENT
CLASS IV	INTERNAL HATCH FAILURE OR BLOCKED ACCESS PATH
CLASS V	FAILURE TO DOCK/UNDOCK
CLASS VI	FAILURE OF AIRLOCK OR OTHER EXTERNAL HATCH
CLASS VII	INSPECT/REPAIR SHUTTLE EXTERNAL DAMAGE
CLASS VIII	RESCUE DISABLED EVA/IVA CREWMAN

CLASS I - FIRE OR RELEASE OF TOXIC SUBSTANCES

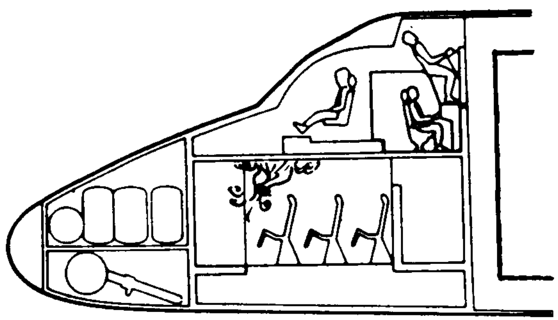
A fire or release of toxic substances could occur in the orbiter cabin, a manned experiment module, the unpressurized cargo bay, or a docked freeflyer. Fires could be caused by a variety of sources such as electrical discharge, short circuits, chemical reactions, or open flames. Most fires would produce toxic byproducts but other sources of toxic material include cryogen spills, propellant leakage, and experimental chemicals*. The cases chosen for illustration are a fire in the cabin or in a manned experiment module.

Contingency scenarios were defined, detailed timelines established, and emergency equipment requirements determined for the following five emergencies chosen as representative.

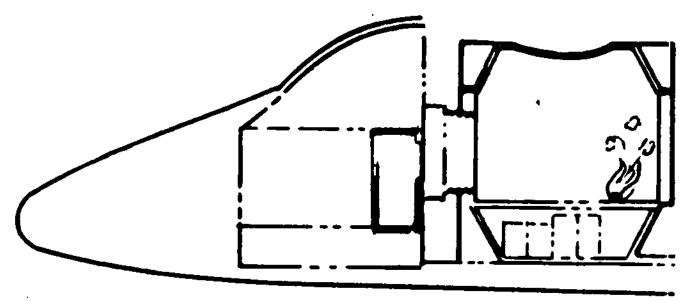
I-a	Fire contaminates cabin
I-a-A	• Re-enter with contamination
I-a-B	• Depressurize and repressurize first
I-b	Fire in unpressurized cargo bay
I-c	Fire in manned sortie module
I-c-A	• Cabin affected
I-c-B	• Cabin not affected

* It is estimated that about 37% of the flights in the October 1972 NASA-JSC Traffice Model would involve potentially hazardous sortie and servicing activities which could release toxic materials. A secondary effect of the release of toxic materials is the obstruction of vision by smoke/fumes.

EXAMPLE CLASS I EMERGENCY
FIRE OR RELEASE OF TOXIC SUBSTANCES



ORBITER CABIN



MANNED EXPERIMENT MODULE

CLASS II - EXPLOSION

An explosion could occur in many locations in the shuttle orbiter. However, the most likely locations are in the cargo bay, a docked free-flyer, or in an attached experiment module. The case of an explosion in the shuttle pressure cabin is probably unlikely, but it is included, since if it did occur, it would require immediate emergency action to save the crew. An explosion could be followed by almost any other type of emergency situation, although some combinations are less credible than others.

Contingency scenarios were defined, detailed timelines established, and emergency equipment requirements determined for the following four emergencies chosen as representative:

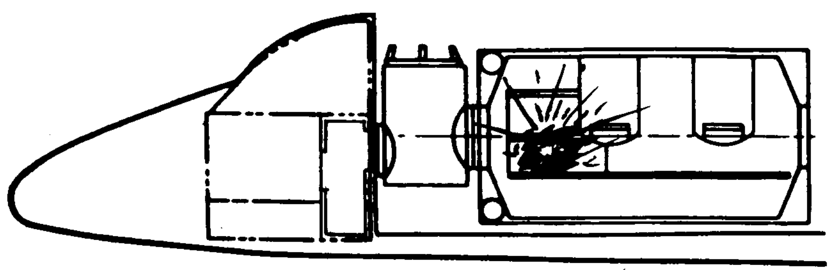
II-a Explosion in cabin; shuttle cannot re-enter

II-a-A • Depressurize and repressurize cabin; await rescue
II-a-B • Await rescue with contaminated cabin

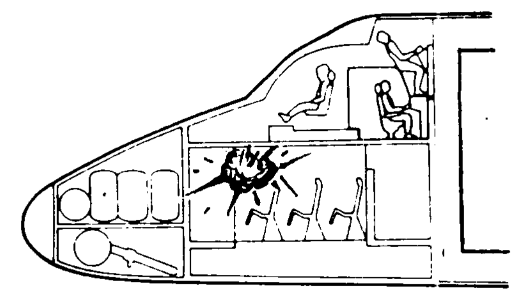
II-b Explosion in sortie module; blocked access to cabin
II-c Explosion in sortie module, with decompression (no blocked access)

EXAMPLE CLASS II EMERGENCY

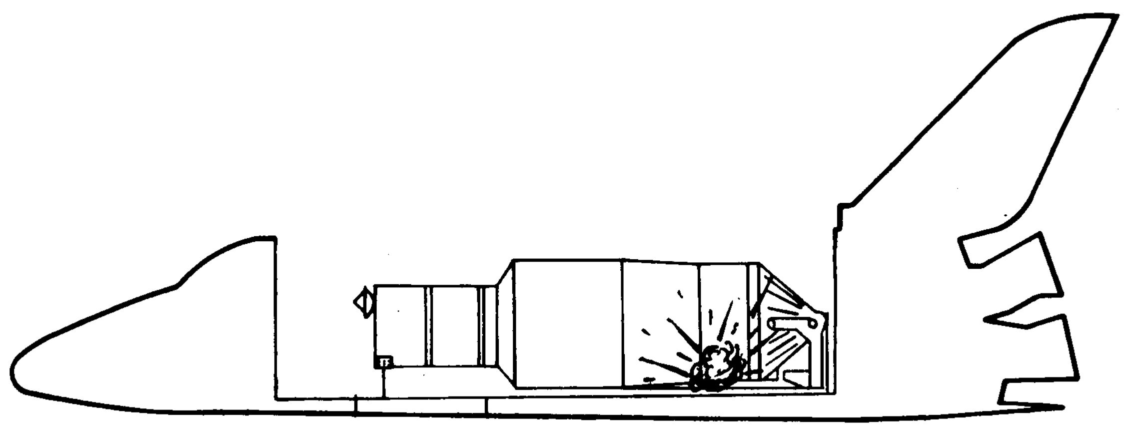
EXPLOSION



SORTIE MODULE



ORBITER CABIN



UNPRESSURIZED CARGO BAY

CLASS III - DECOMPRESSION

The scenario chosen for illustration here is the case of slow decompression of the orbiter cabin. The leakage rate is slow enough that there is time for the crewmen to don their suits, if this mode of safing were chosen. Other places a decompression could occur are the airlock, a manned sortie module, a space station module, or a pressurized docked free-flyer during servicing.

Such an occurrence could result from a seal failure (window, airlock hatches, pressure bulkhead feedthroughs, etc.), micrometeoroid impact, structural flow, overboard vent failure, secondary effects from a fire or explosion, or collision damage. The credibility of an accidental decompression is established by considering a recent tabulation of USAF accidental decompressions*, listing 417 occurrences, and a rate of 1335 per 100,000 hours flying above 50,000 ft. In addition, experience with the X-15 has resulted in 24 accidental decompressions out of 199 flights. For a "work horse" vehicle such as the space shuttle, which is designed for use on a variety of missions over a period of years, the finite probability of a decompression requires protective measures.

In the current study it was mutually agreed with the Technical Monitor that an explosive decompression would not be considered credible, as such an occurrence would likely be a disaster anyway. Rapid decompressions were included, however.

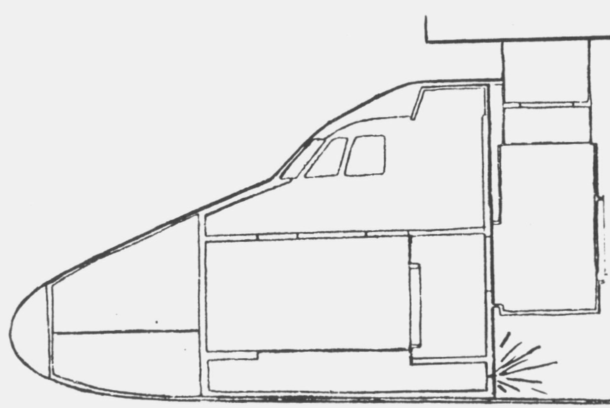
Also by mutual agreement with the Technical Monitor, three basic orbiter capabilities were considered in the decompression analysis: (1) the orbiter can re-enter unpressurized and crew provisions must support 3 hours of depressurized operation prior to re-entry, (2) same, but 10 hours prior to re-entry, and (3) the orbiter <u>cannot</u> re-enter depressurized, and crew provisions must support 96 hours of depressurized operation prior to on-orbit rescue.

The following five representative contingency scenarios were defined, detailed timelines established, and emergency equipment requirements determined:

III-a	Repairable leak in cabin
III-a-A	• Shuttle <u>cannot</u> re-enter depressurized
III-a-B	• Shuttle <u>can</u> re-enter depressurized
III-b	Unrepairable leak in cabin
III-b-A	• Shuttle <u>cannot</u> re-enter
III-b-B	• Shuttle <u>can</u> re-enter depressurized
III-c	Leak in sortie module

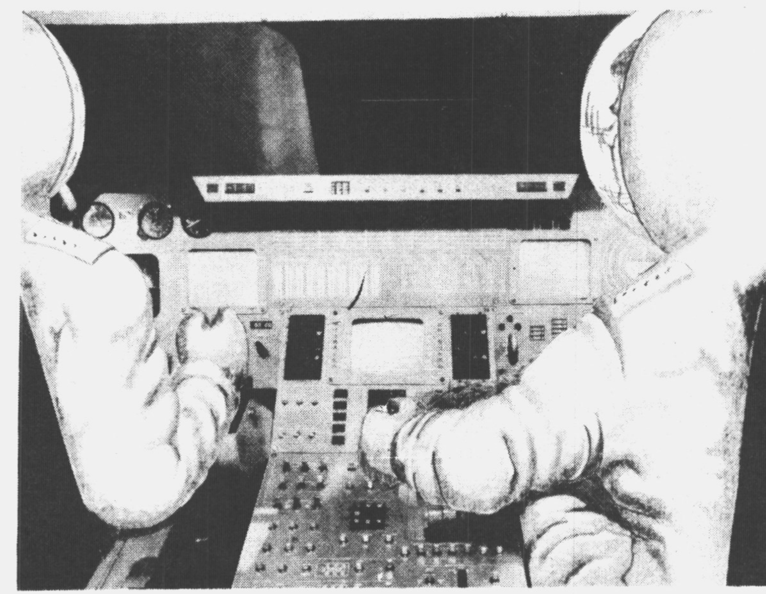
* From: Wilson, C. L., "Re-evaluation of Emergency Pressurization Requirements for Brief Flights Above 50,000 Feet", Aerospace Medicine; February 1971, pp 183-185.

EXAMPLE CLASS III EMERGENCY
DECOMPRESSION



ORBITER CABIN

UNPRESSURIZED
MISSION ABORT



CLASS IV - INTERNAL HATCH FAILURE OR BLOCKED ACCESS

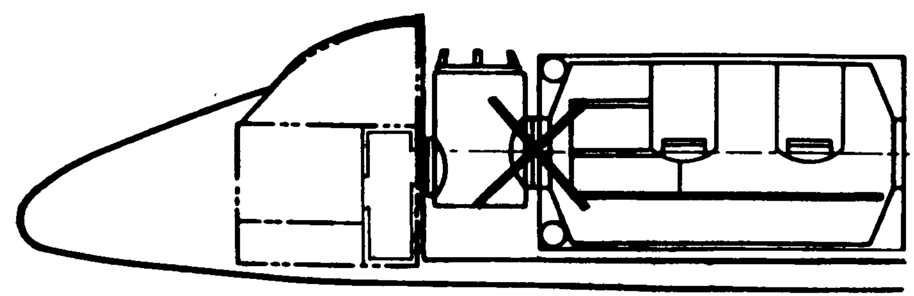
This class of emergencies considers cases by which internal access to the orbiter cabin is blocked, via a hatch failure or some other reason. It is important whenever a crewman is in some other manned pressurized compartment, such as a sortie module or docked free-flyer. The hatch failure can be either one of opening or closing, in such a way that shirtsleeve access to the orbiter cabin is not possible. Current designs of the shuttle and manned modules baseline that the crewmen must ingress the cabin prior to re-entry. The example chosen for illustration is the case of blocked access between the orbiter and a sortie module, with the docking module in place.

A distinguishing geometric factor is whether or not the docking module is present. Three representative contingency scenarios were defined, detailed timelines established, and equipment requirements determined:

IV-a	Docking module not available
IV-a-A	• Manipulator not functional
IV-a-B	• Manipulator as translator
IV-b	Docking module available

EXAMPLE CLASS IV EMERGENCY

INTERNAL HATCH FAILURE OR BLOCKED ACCESS PATH



BLOCKED RETURN FROM SORTIE MODULE

CLASS V - FAILURE TO DOCK/UNDOCK

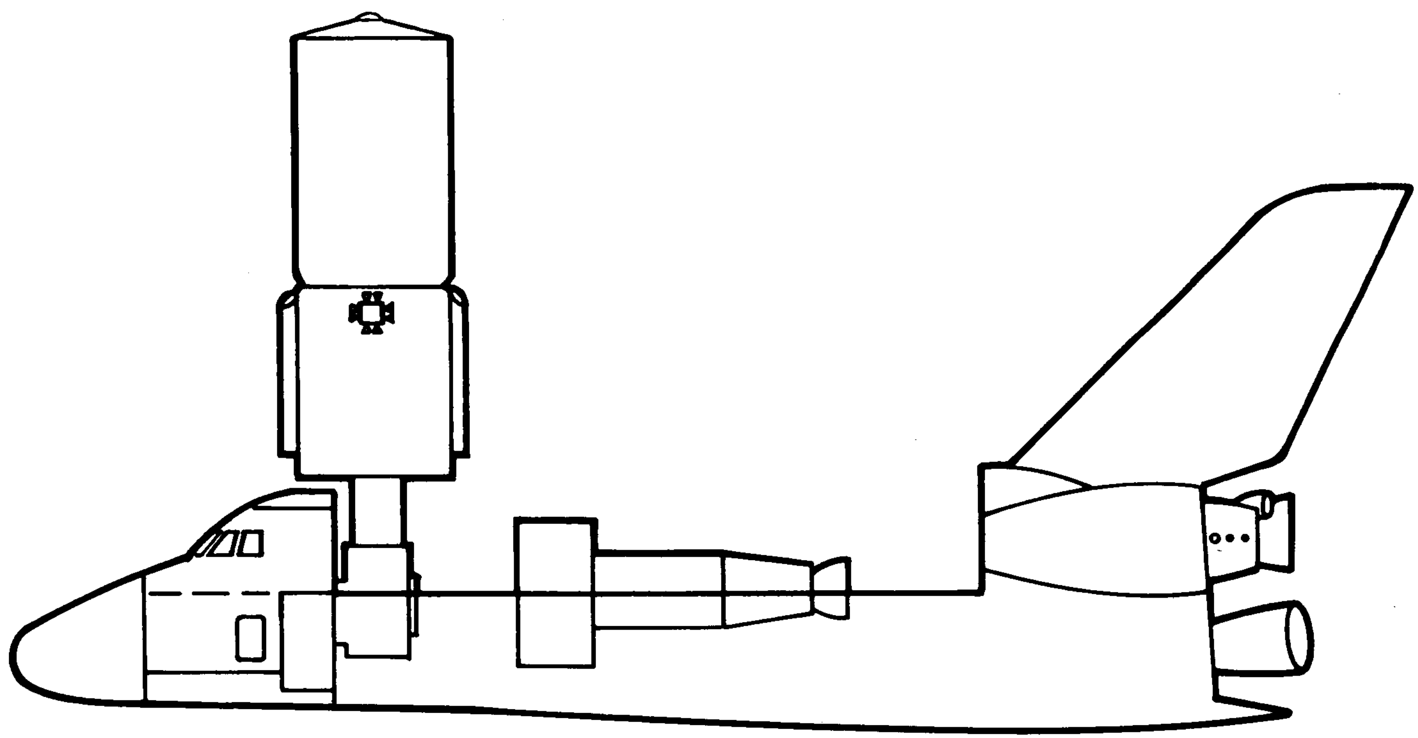
The primary qualifying factors that determine the separate scenarios in this case are whether the failure prevents docking from occurring or whether the failure prevents safe release following docking. In the case of failure to "hard" dock, the case of on-orbit rescue by a second shuttle is of primary interest, although in other missions, such as modular space station personnel rotation, this could also be considered a contingency. Failure of the rescue shuttle to dock with a depressurized orbiter is a particularly viable contingency, as the PRR baseline orbiter design would not have the ability to stabilize in orbit following pressure loss and avionics failure. The illustrated case of failure to undock is also important, as it could prohibit re-entry.

Two representative scenarios were defined, detailed timelines established, and equipment requirements determined:

V-a	Failure of rescue shuttle to dock
V-b	Failure to undock

EXAMPLE CLASS V EMERGENCY

FAILURE TO DOCK/UNDOCK



ORBITER DOCKED TO LARGE OBSERVATORY

CLASS VI - FAILURE OF AIRLOCK OR OTHER EXTERNAL HATCH

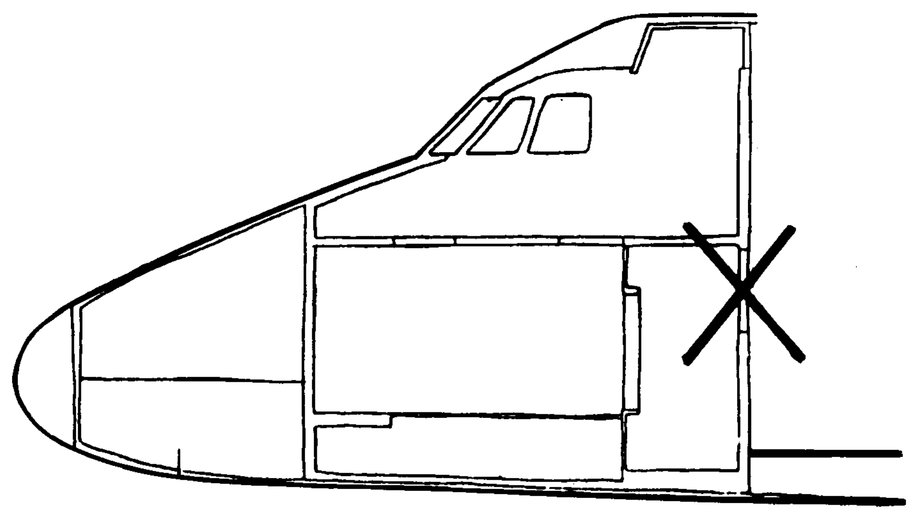
This class of contingency is concerned with failure of an external hatch to open when required or to close and seal. The scenario illustrated is the case of an outer hatch failing to seal when closed following an EVA/IVA.

Other specific examples falling in this class are cabin hatch fail to open, equalization valve failure, EVA hatch fail to open, airlock failure to pressurize, cabin side leak, and EVA hatch failure to close.

Two representative scenarios were defined, detailed timelines established, and equipment requirements determined:

VI-a	EVA hatch fail to seal
VI-b	Hatch to cabin fail to open

EXAMPLE CLASS VI EMERGENCY
FAILURE OF AIRLOCK OR OTHER EXTERNAL HATCH



AIRLOCK HATCH
SEAL FAILURE

CLASS VII - INSPECT/REPAIR SHUTTLE EXTERNAL DAMAGE

This class includes a wide variety of contingencies which can result from a number of causes during ascent or orbital operations. Among the most credible causes are: (1) collision during booster or drop tank separation, docking, cargo manipulation, or with meteoroids or other debris, (2) solid rocket motor case burn-through, (3) secondary damage from explosions in or near the cargo bay, and (4) malfunction of automated systems during payload deployment or retrieval. Rockwell has suggested this latter to be particularly significant, even though the capability to jettison is a design goal. Because of the many in-line operations during such an operation, an EVA level of redundancy is highly desirable.

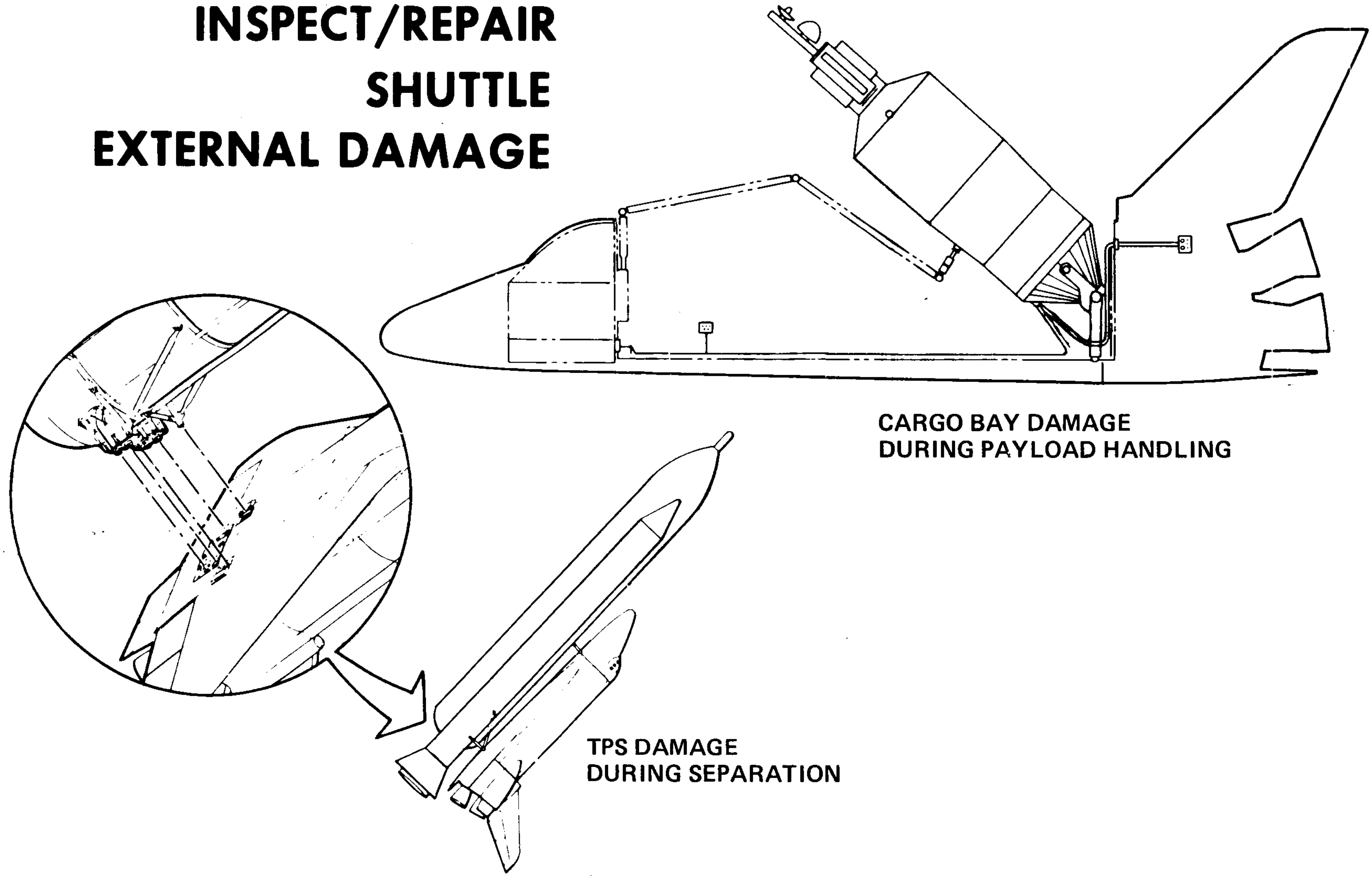
Thermal Protection System (TPS) damage inspection was chosen for definition as a representative scenario, a detailed timeline was established, and equipment requirements were determined:

VII-a TPS inspection

The representative Class II scenario of explosion in the cargo bay also serves as representative of tasks to be accomplished inspecting/repairing cargo bay damage listed here.

EXAMPLE CLASS VII EMERGENCY

INSPECT/REPAIR SHUTTLE EXTERNAL DAMAGE



CLASS VIII - DISABLED EVA/IVA CREWMAN

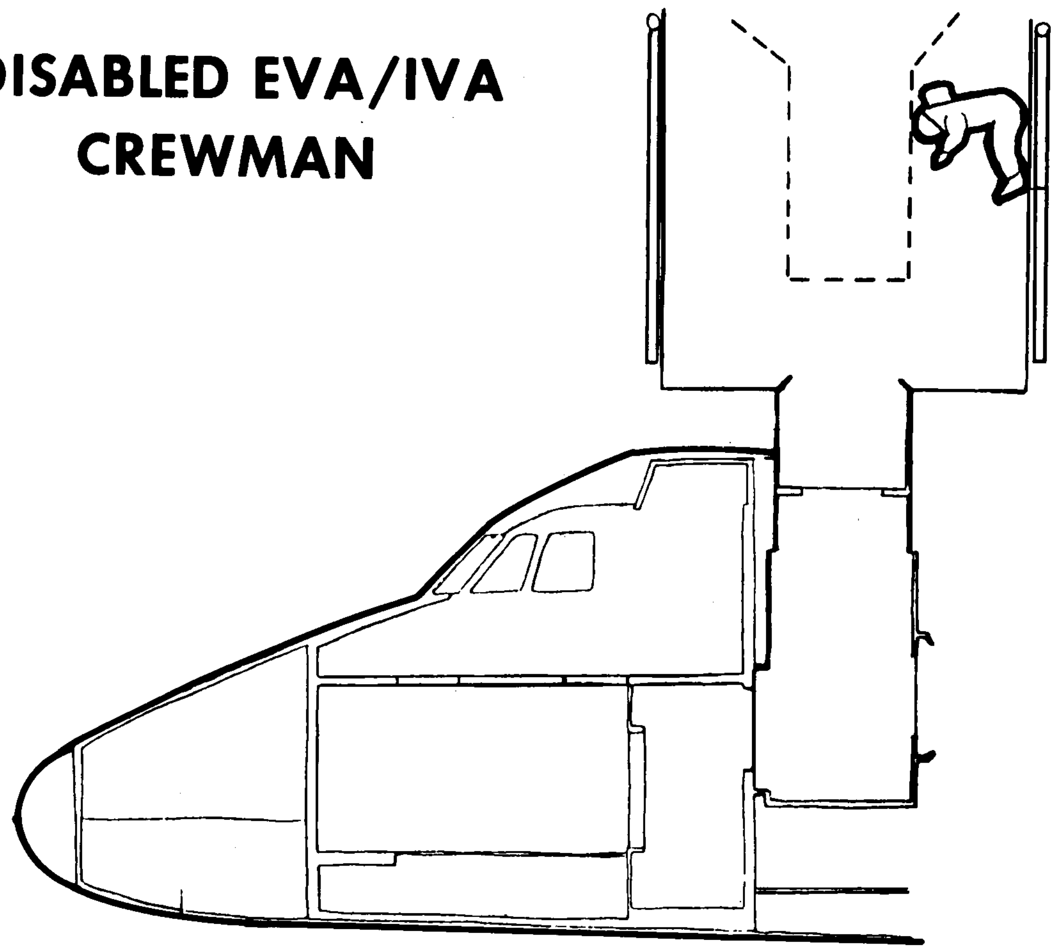
The primary distinguishing factors that define the scenarios in this case are whether or not the disabled crewman is conducting EVA or IVA, whether or not 2 men are involved in the EVA/IVA, and, in the case of EVA, whether or not he is in physical contact with the orbiter. The illustrated scenario is the case of a disabled or unconscious IVA crewman servicing a docked large observatory.

Some causes of crewman disability could be illness, extravehicular life support system failure, suit leak, or manipulator failure. Six scenarios selected as representative for detailed analysis, timelines, and equipment requirements determination are:

VIII-a	Disabled, drifted EVA crewman
VIII-a-A	• Two man EVA
VIII-a-B	• One man EVA
VIII-b	Manipulator malfunction/disabled crewman
VIII-b-A	• Two man EVA
VIII-b-B	• One man EVA
VIII-c	Disabled IVA crewman
VIII-c-A	• Two man IVA
VIII-c-B	• One man IVA

EXAMPLE CLASS VIII EMERGENCY

DISABLED EVA/IVA CREWMAN



UNPRESSURIZED
IVA SERVICING
MISSION

SUMMARY OF EMERGENCY EFFECTS

Evaluation of the preceding classes of emergencies lead to the recognition of a degree of commonality of effects. Consideration of these effects will lead to a definition of viable options on overall approaches to achieve safety. Coupled with the timeline analysis of representative scenarios, equipment requirements and procedures for a workable approach will be identified.

SUMMARY OF EMERGENCY EFFECTS

- CONTAMINATED ATMOSPHERE
- ACCIDENTAL DECOMPRESSION
- INABILITY TO RE-ENTER
- CREWMAN STRANDED

SCENARIO ANALYSIS

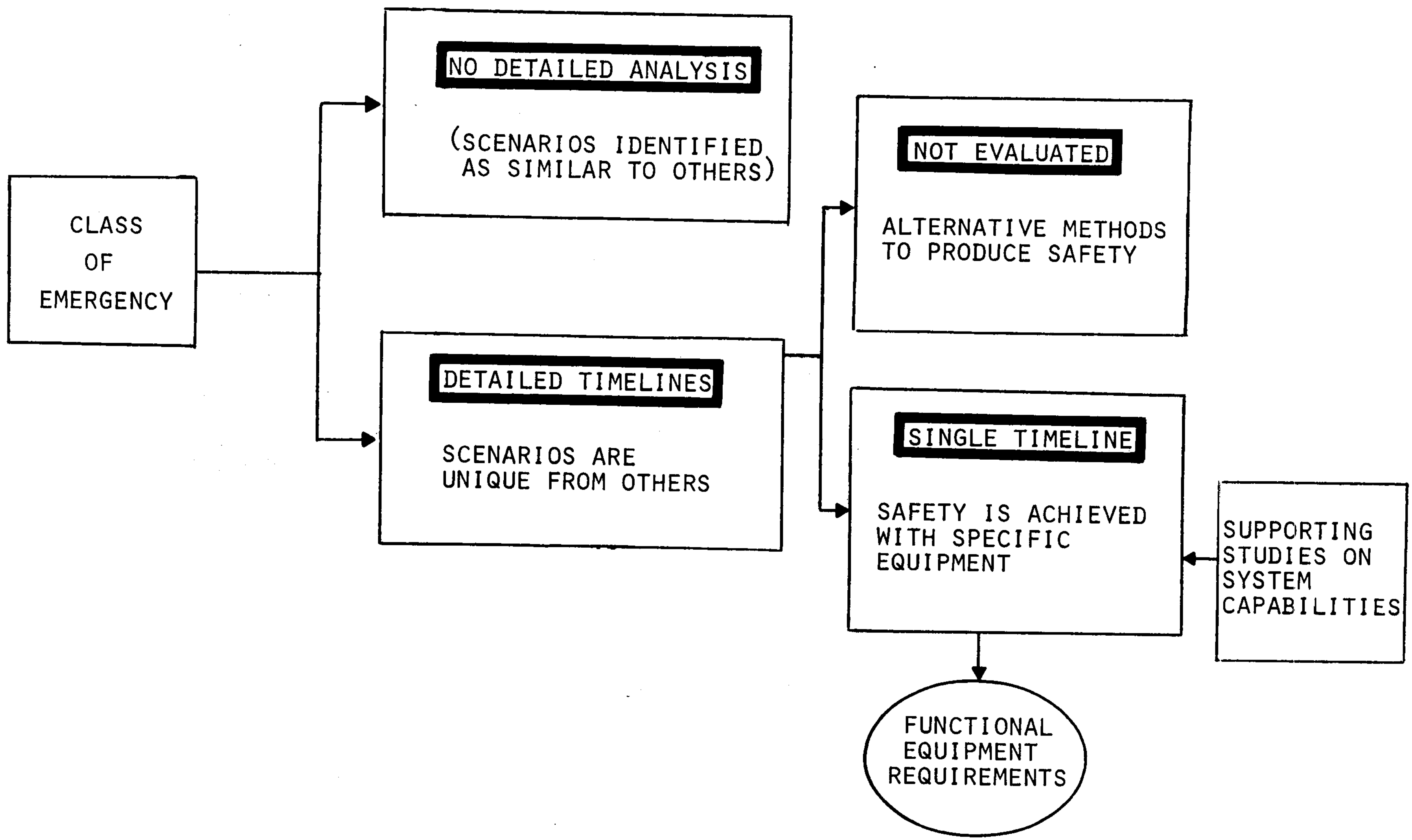
- APPROACH
- REPRESENTATIVE FUNCTIONAL FLOW ANALYSES
- CRITICAL TIMELINES

APPROACH FOR TIME CRITICAL EMERGENCY ANALYSIS

The opposing chart illustrates how functional equipment requirements were determined. The 8 classes of emergencies were subdivided into 28 representative scenarios which were unique from others. A timeline was prepared on each to identify equipment requirements and time critical operations. An emergency concept was established from these scenario analyses and supporting studies on system capabilities. While the concept was not optimized, it was at least determined to be feasible. Limited trade studies, notably in the contingency LSS area, were performed in order to make a preliminary emergency system recommendation.

Two representative scenario functional flow diagrams are given on the following pages. Others are presented in Volume V.

APPROACH FOR TIME CRITICAL EMERGENCY ANALYSIS



REPRESENTATIVE SCENARIO I-a

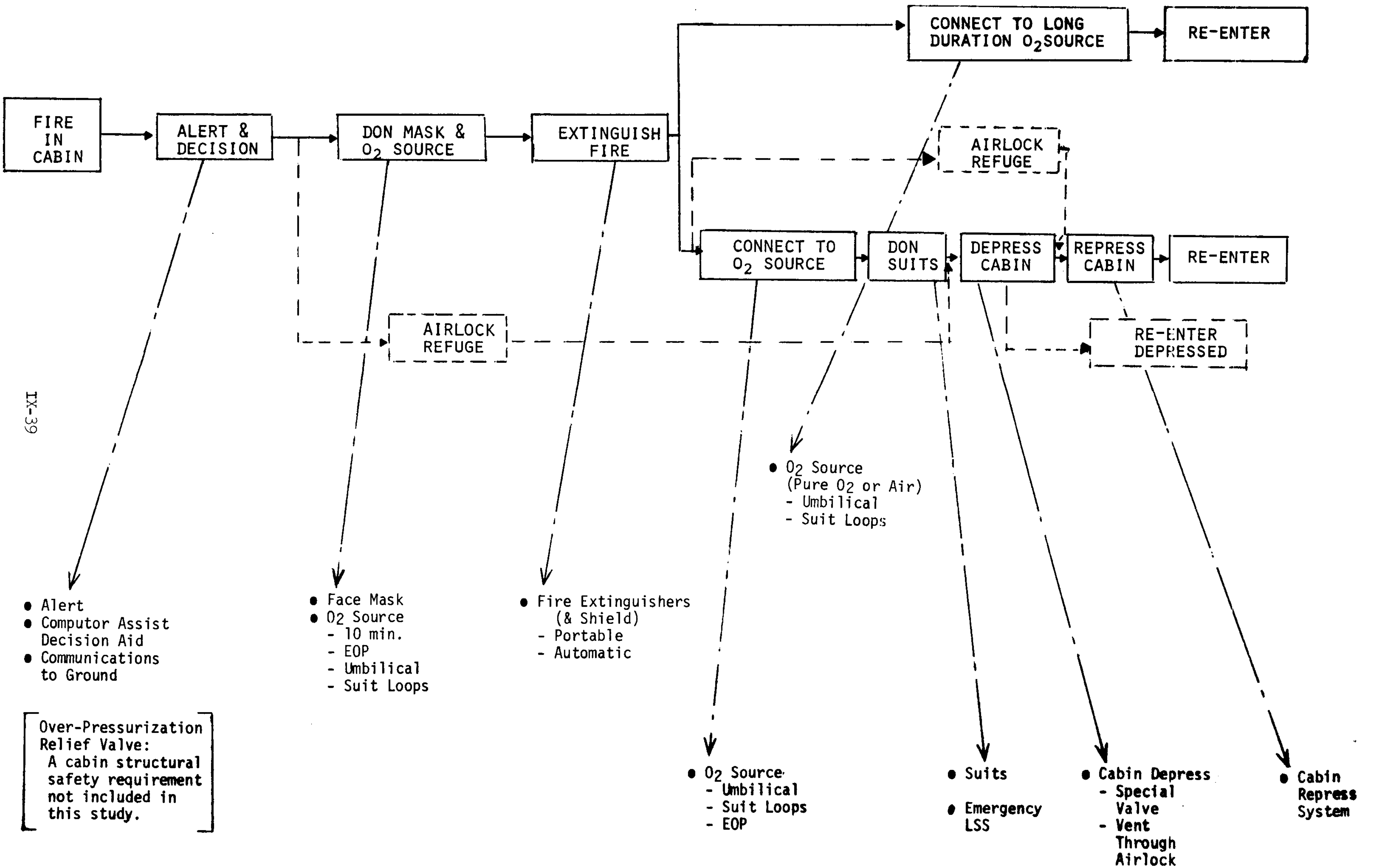
FIRE CONTAMINANTS CABIN

Two alternate paths to safety were considered. The scenario is representative of a general contaminated cabin emergency (e.g., release of toxic substances from an experiment or decomposition of insulations on over-heated electronics, etc.). Cabin purge was not included in the analysis of this scenario because of the very large purge quantities expected to be required to reduce an unknown contaminant and its concentration to an assured acceptable concentration level. (See purge requirements curve under Assessments)

The time required to initiate face mask operation is 3 to 5 minutes, including alert and decision. The contaminant sources are not known and, consequently, the concentration levels are also unknown. However, since the time required is short, essentially all contaminant exposures should be survivable with little or no permanent damage to the crewman.

Long term use of face masks does impose a risk of O_2 toxicity. Data from NASA CR-1205 (III) indicates O_2 toxicity symptoms can occur after 4 hours with pure O_2 at 14.7 psia; the nominal time for occurrence is 10 hours and as high as 15 hours has been observed before symptoms appear. Based on the same data, the Apollo astronauts were exposed to pure O_2 in excess of the nominal time. Obviously the data are conservative. For an emergency 10 hours of exposure to 14.7 psia, O_2 should be acceptable.

REPRESENTATIVE SCENARIO I-A
FIRE CONTAMINATES CABIN



REPRESENTATIVE SCENARIO III-b

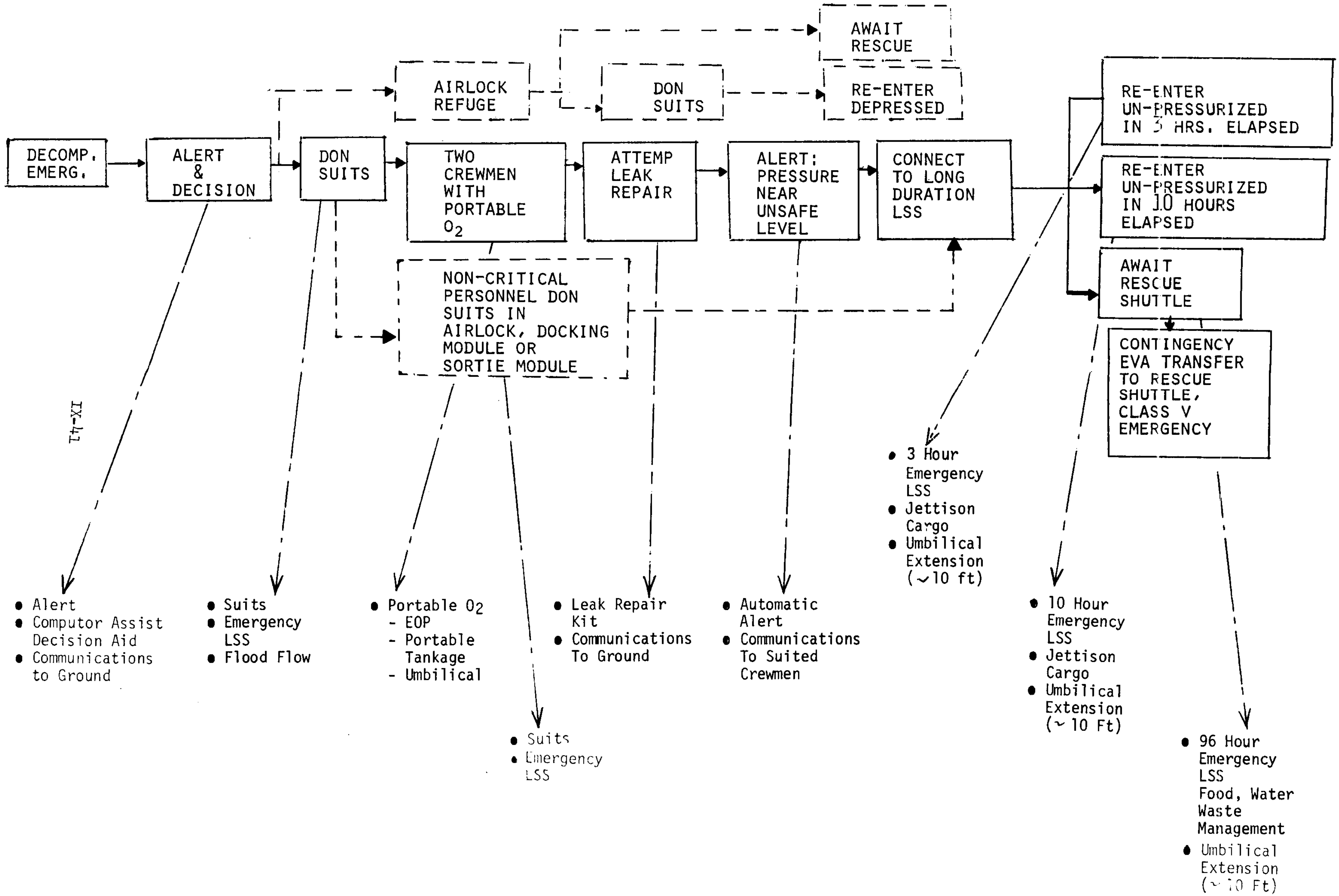
UNREPAIRABLE LEAK IN CABIN

A number of conditions and options are possible for a cabin decompression. The opposite chart presents a scenario where there is a limited time available for repair activities; but due to the location and size of the hole there is inadequate time to complete repairs. The worst case decompression rate and available options are discussed elsewhere.

The airlock as a refuge is an optional item for either long term or temporary use. In addition, it might be employed as a convenience area for food, water, and waste management during on-orbit stay for 96 hours. In that case the crew would alternate on approximately 12 hours shifts, depressurizing the airlock each time. However, the quantity of expendable gas is large (approximately 65 lbs of gas, 130 lb penalty, for 8 airlock operations at 8.0 psia). In addition the crew must interchange gas connectors while depressurized. Consequently that approach is not recommended.

Conducting a repair of a leak once the cabin had been depressurized requires both flood flow and a second emergency gas storage for repressurization. The latter would require 150 lbs of air (for 14.7 psia), 300 lbs penalty. Since the leakage may be located behind a permanently installed part, repair can not be assured. Therefore the capability of repressurization of the cabin after a repair of a leak is not recommended (high penalties, no assurance of success).

REPRESENTATIVE SCENARIO III-B
UNREPAIRABLE LEAK IN CABIN



CONTINGENCY EGRESS BEST TIMELINES

The opposing chart takes the ideal best suit donning times and adds other necessary steps to obtain contingency egress times. As a subsequent chart on Depressurization Emergency Safing will illustrate, various levels of safety are obtained at various points in the sequence. The communications check is not required for safety during the IV donning sequence. Neither is the depressurization time necessarily applicable as chargeable against "getting safe" in the IV emergency case, and is not included in this "best" egress time summation. Corrective action may take place at other than the indicated point in the sequence.

EVA rescue egress times are shown for completeness, although not supported by detailed timelines in this briefing.

Details on development of these timelines are given in Volume V.

CONTINGENCY EGRESS BEST TIMELINES

ACTION	TIME (MIN: SEC) IV EMERGENCY STANDBY	IV EMERGENCY SHORT STAY	IV EMERGENCY LONG STAY	EVA RESCUE STANDBY	EVA RESCUE UNSUITED
ALERT & DECISION	2:00	2:00	2:00	2:00	2:00
DONNINGS					
SUIT	0:35	4:56	7:06	0:50	10:13
EVLSS/EOP DON & CHECKOUT	-	-	-	-	8:16
UMBILICAL DON	0:45	0:45	0:45	-	-
ACTIVATE	0:05	0:05	0:05	0:05	0:55
COMM. CHECK	-	-	-	-	0:35
SUBTOTAL	1:25	5:46	7:56	0:55	19:59
CHECKOUT & DEPRESSURIZE					
PRESSURIZE (6 PSI/MIN)	1:20	1:20	1:20	1:20	1:20
INTEGRITY CHECK	0:15	0:15	0:15	0:15	0:15
DEPRESSURIZE (6PSI/MIN)	-	-	-	2:27	2:27
CORRECTIVE ACTION	0:45	0:45	0:45	0:45	0:45
SUBTOTAL	2:20	2:20	2:20	4:47	4:47
GRAND TOTAL	5:45	10:06	12:16	7:42	26:46

CRITICAL RESPONSE TIME SUMMARY

The opposite page summarizes "best" and "recommended" times required to accomplish specific tasks for emergencies. The best donning times are taken directly from the previous chart on Contingency Egress Best Timelines. The recommended values includes a safety factor multiplier of two on all donning times (rounded to next higher minute). The resulting times are consistent with Apollo simulations for lunar surface EVA's and experienced values for transearth EVA's. (No data are available for experienced values on lunar surface EVA's.)

The Alert and Decision "recommended time" allows a 2-minute time period to evaluate alternate courses of action. The depress and repress "best" times correspond to the physiological limit (6 psi/min) for a total pressure change of 14.7 psi. The "recommended" times are actually "nominal" times, and are included for reference. The airlock rate is for the nominal physiological limit of 2.5 psi/min. The cabin and sortie module nominal rate is for depressurizing a 2000 ft^2 volume through the airlock vent valve.

Egress to airlock includes 2 minutes for alert and decision (the appropriate value here), 30 seconds to egress to the airlock, 15 seconds to open the hatch, 1 minute for all the crew to enter the airlock, and 15 seconds to close the hatch.

The contingency transfer time is the time required for two men to conduct a contingency EVA transfer from a failed shuttle to a rescue shuttle, and includes the time for transfer by a manipulator arm and the time required to repressurize the airlock in the rescue shuttle. The same time is required for EVA transfer of two men from a sortie module into the cabin through a side hatch.

EVA emergency return is the time required to return to the airlock, close the hatch, and repressurize. The best time is for a translation velocity of 2.5 ft/sec and the recommended is for 0.5 ft/sec. EVA rescue from stand-by is the time necessary for a crewman in an unpressurized suit, with EVLSS checked out but helmet and gloves off, to return a disabled crewman conducting a one-man EVA to a safe environment. The time includes 10 minutes for the rescue crewman to become aware of the problem. He then completes donning at either best or recommended rate. The times to reach the disabled crewman for best and recommended rates are also presented.

CRITICAL RESPONSE TIME SUMMARY

ACTION	TIME (MIN:SEC) BEST TIME	RECOMMENDED
ALERT AND DECISION	2:00	4:00
EMERGENCY SUIT CHECKOUT & PRESSURIZE	2:20	2:20
DON BREATHING MASK	0:30	1:00
DON FIRE PROTECTIVE GARMENT	0:30	1:00
DON IV SUIT (STANDBY)	1:25	3:00
DON IV SUIT	5:46 (7:56)*	12:00 (16:00)*
DON IV SUIT WITH LCG	6:46 (8:56)*	14:00 (18:00)*
DON EVA SUIT, EVLSS, AND EOP	19:59	40:00
DEPRESS AND REPRESS TIMES-CABIN & SORTIE MOD.	2:30	60:00***
-AIRLOCK	2:30	6:00***
EGRESS TO AIRLOCK	-	4:00
CONTINGENCY TRANSFER	-	20:00
EVA EMERGENCY RETURN	10:00	24:00
EVA RESCUE (FROM STANDBY)**-REACH CREWMAN	20:00	21:00
-COMPLETE	37:00	38:00

* (LONG TERM)

** INCLUDES 10 MINUTE RECOGNITION TIME

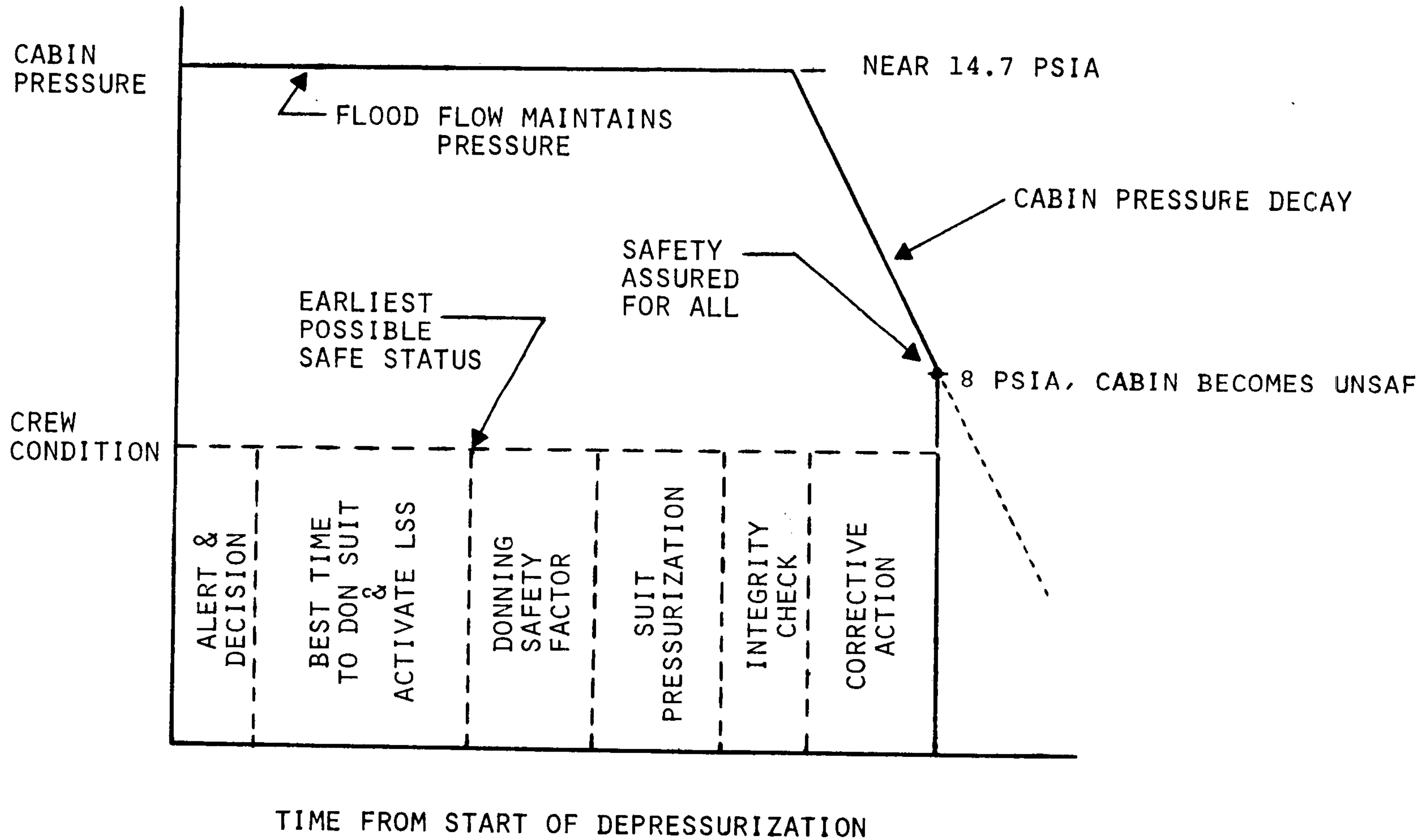
*** NOMINAL TIMES

DEPRESSURIZATION EMERGENCY SAFING CONSIDERATIONS

The opposite chart illustrates the time critical factors in assuring crew safety following a decompression emergency,where it is assumed the emergency scenario taken is to immediately don pressure suits. The upper curve indicates that the orbiter flood flow system, if capable of a high enough flowrate, will maintain cabin pressure near 14.7 psia until the emergency tankage is exhausted. Once the flood flow oxygen/nitrogen is expended the cabin pressure will decay; after the pressure falls below approximately 8 psia the crew will be in danger of experiencing the bends, and the cabin will become unsafe. For example, at the PRR baseline flood flow capability of 150 pph for one hour (3/8" effective hole diameter), the total safe time is about 1 hour and 45 minutes.

The dotted-in lower boxes indicate the sequence of action taken by the crewmen. First, they must be alerted by a warning tone, determine what the nature of the emergency is, and reach a decision to don suits. Next, they must don their suits and activate the suit emergency life support system. At this point, a crewman who can follow the "best" suit donning timeline and who neither makes mistakes nor has any malfunction is safe - his LSS is hooked-up and operating and he would be ok if the cabin pressure had fallen to 8 psia. To allow for less proficient crewmen,a donning safety factor must be added, however. At the end of this delta-time increment everyone will have his suit on and LSS activated. Gross mistakes and/or equipment malfunctions will be immediately apparent and corrective action will be taken; thus a time allotment should be reserved for this function. Less gross problems will be revealed by the suit pressurization/integrity check and corrective action taken at that time. While subsequent checks and corrective actions could possibly be required, these fall in the category of double failures. One allocation for each box shown should assure safety for essentially all cases, and is recommended. The sum of the time allotments given to the boxes, then, is the time for which a safe cabin (or refuge) pressure level must be assured for credible leak rates.

DEPRESSURIZATION EMERGENCY SAFING CONSIDERATIONS



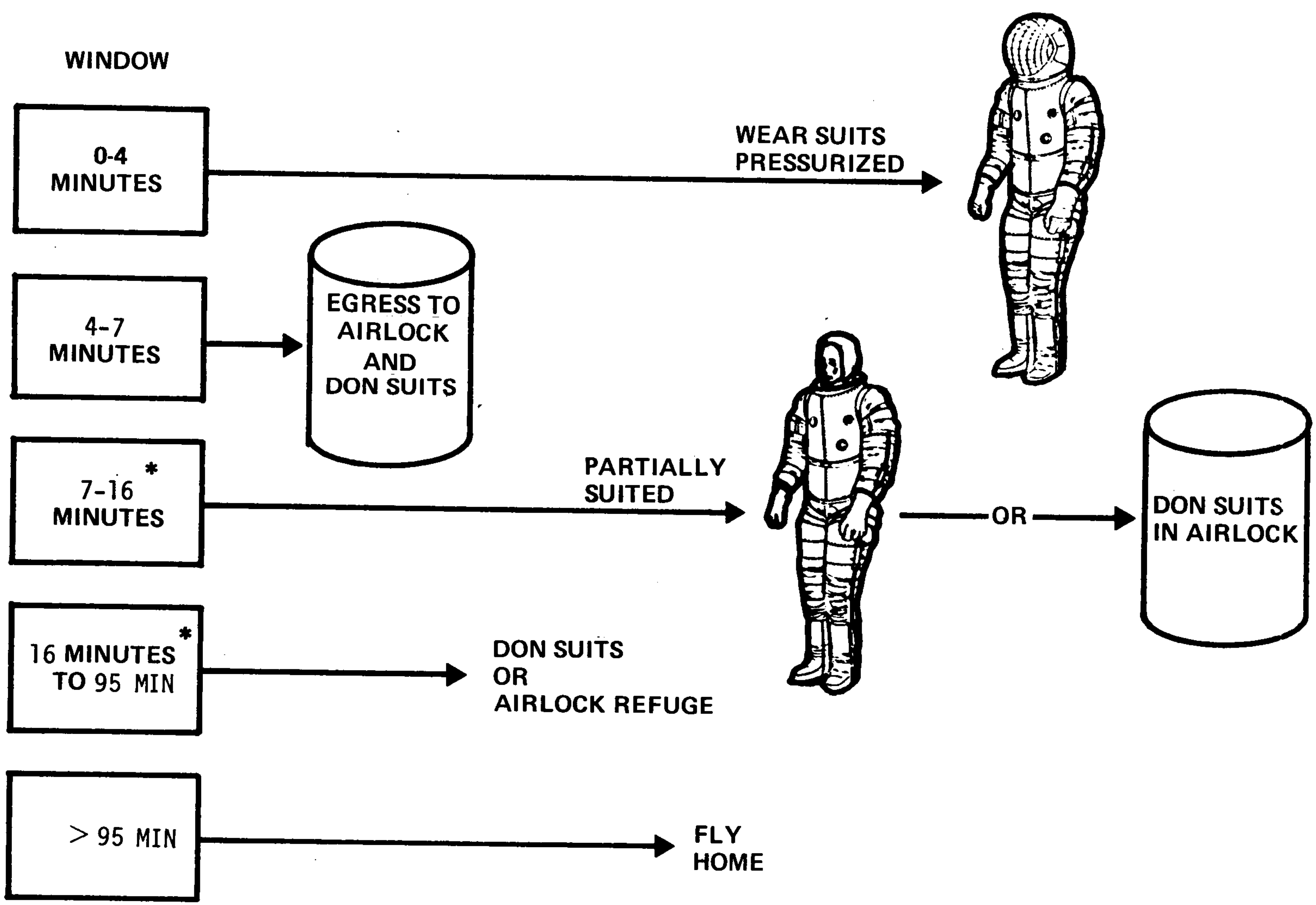
DECOMPRESSION RATE CONSIDERATIONS

Based on the recommended values of the critical response times, the various options open for survival of decompressions were established and are illustrated on the opposing chart. While a highly capable crewman can better the recommended times, and thus other "last ditch" options are open to him, the shuttle emergency IV concept should not be designed to require these more proficient crew performances. Indeed, in a contingency situation the crewman should be careful, deliberate, and perform all necessary safety checks.

The IV equipment requirements for these options were evaluated in order to arrive at the recommended emergency concept/procedures. It should be noted that the rapid decompression rates indicated are credible in this study, but are not considered in the PRR baseline. Additional study is currently underway at Rockwell relative to the decompression problem

The 95-minute fly-home breakpoint corresponds to the "Panic Mode" return mode, where landing includes worldwide airfields.

DECOMPRESSION RATE CONSIDERATIONS

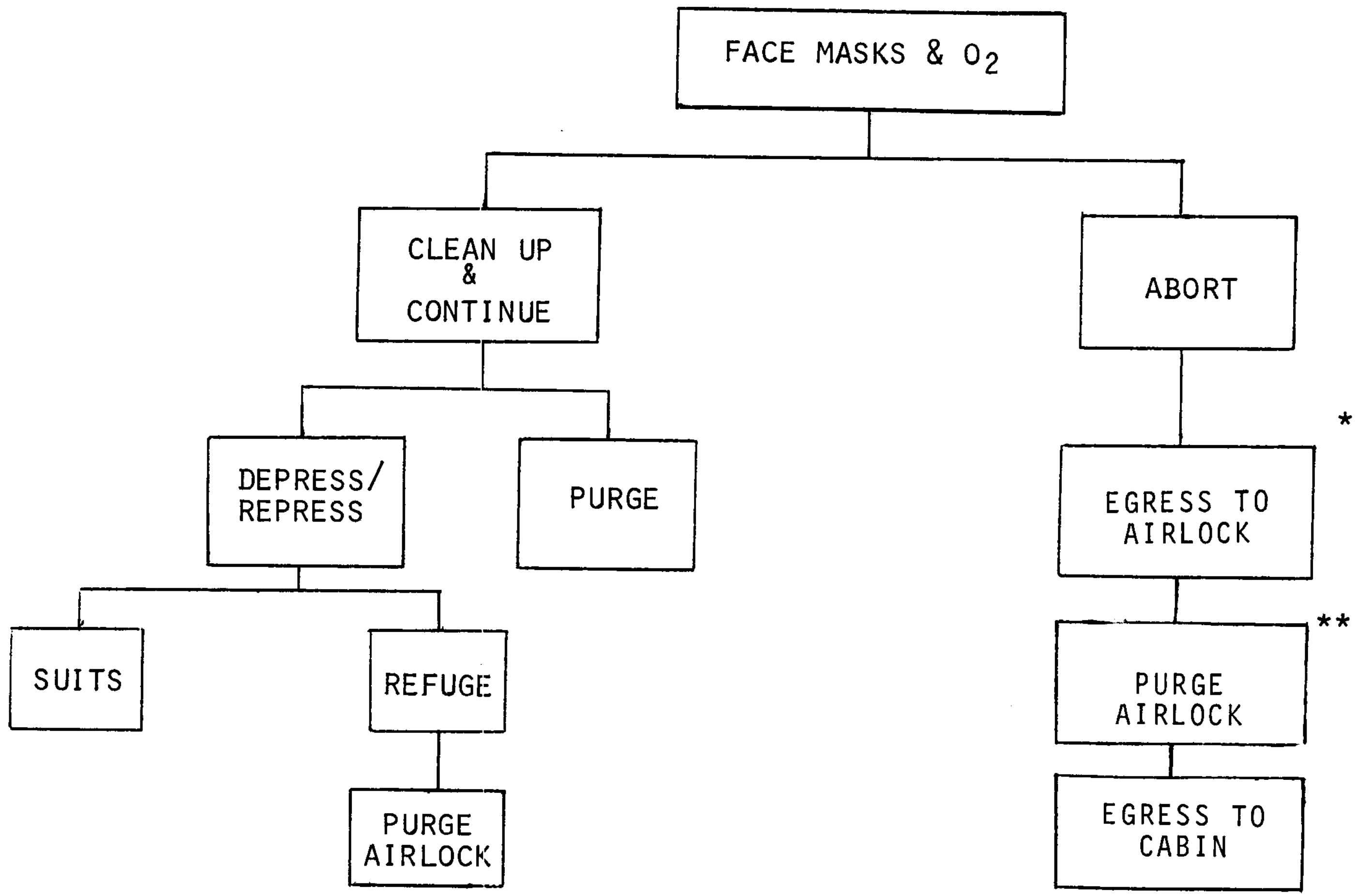


*16 MINUTES FOR SHORT DURATION SUIT CONFIGURATION, 20 MINUTES FOR LONG DURATION CONFIGURATION

VIABLE OPTIONS

- CONTAMINATED ATMOSPHERE
- DECOMPRESSION
- INABILITY TO RE-ENTER
- STRANDED CREWMAN
- SUMMARY

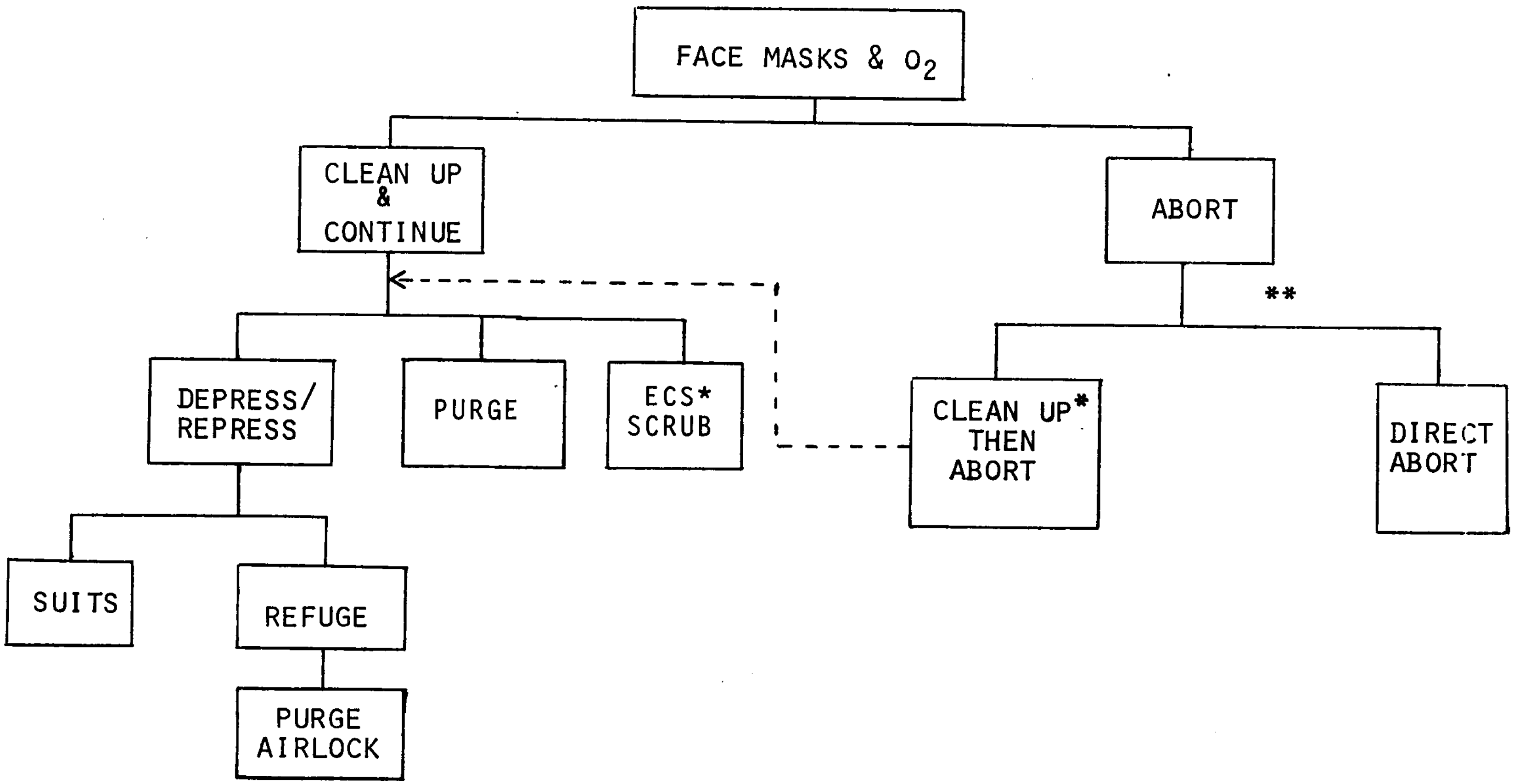
VIABLE CONTAMINATED SORTIE LAB OPTIONS



* NOT CONSIDERED VIABLE TO EGRESS DIRECTLY TO CABIN BECAUSE OF CONTAMINATION POTENTIAL

** NOT CONSIDERED VIABLE TO DEPRESS/REPRESS AIRLOCK WHILE OCCUPIED

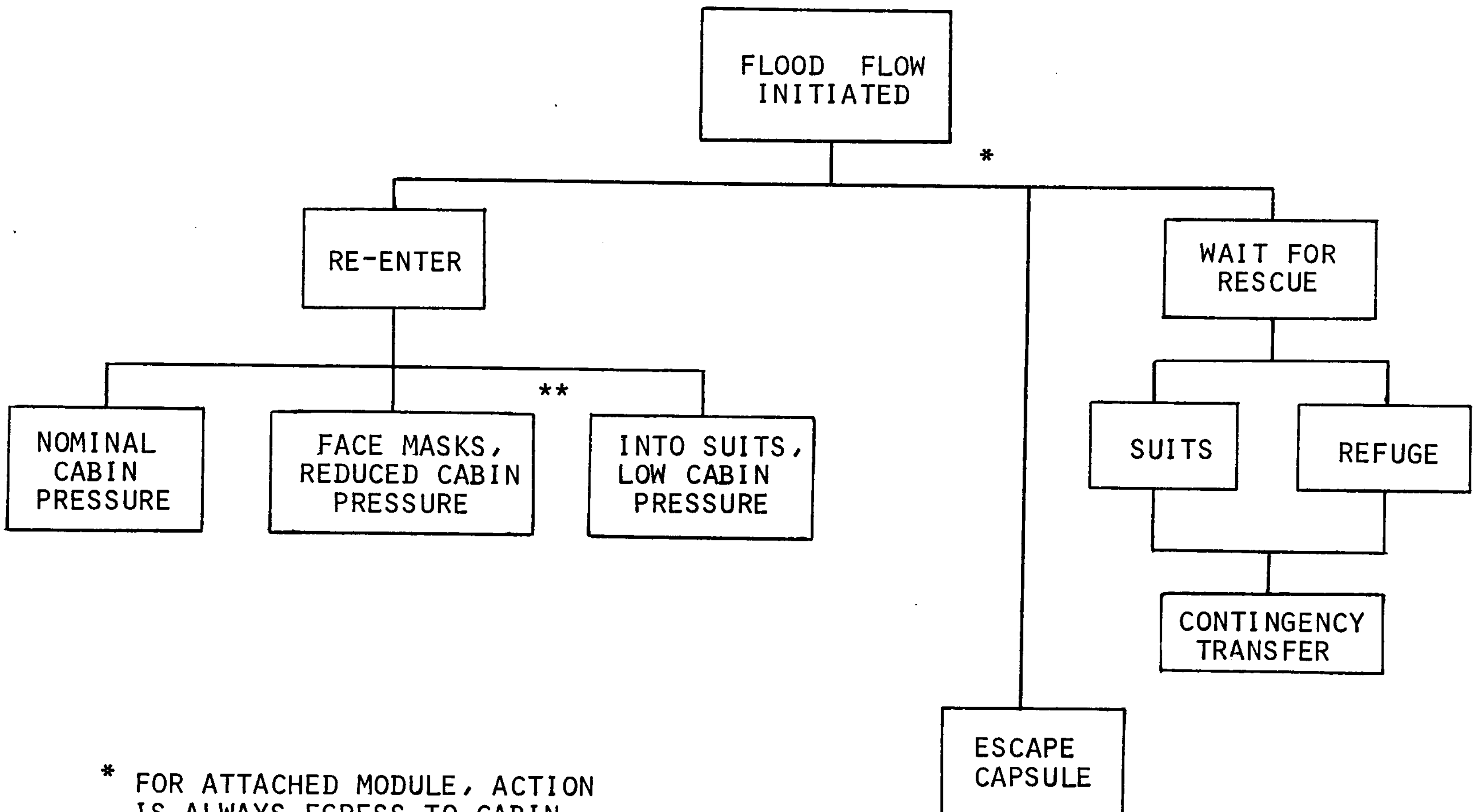
VIABLE CONTAMINATED CABIN OPTIONS



* MAY BE REQUIRED FOR VISIBILITY; ECS SCRUB VIABLE OPTION TO CLEAR SMOKE

** REFUGE AND WAIT FOR ON-ORBIT RESCUE
NOT CONSIDERED VIABLE OPTION FOR CONTAMINATED ATMOSPHERE

VIABLE DEPRESSURIZATION OPTIONS

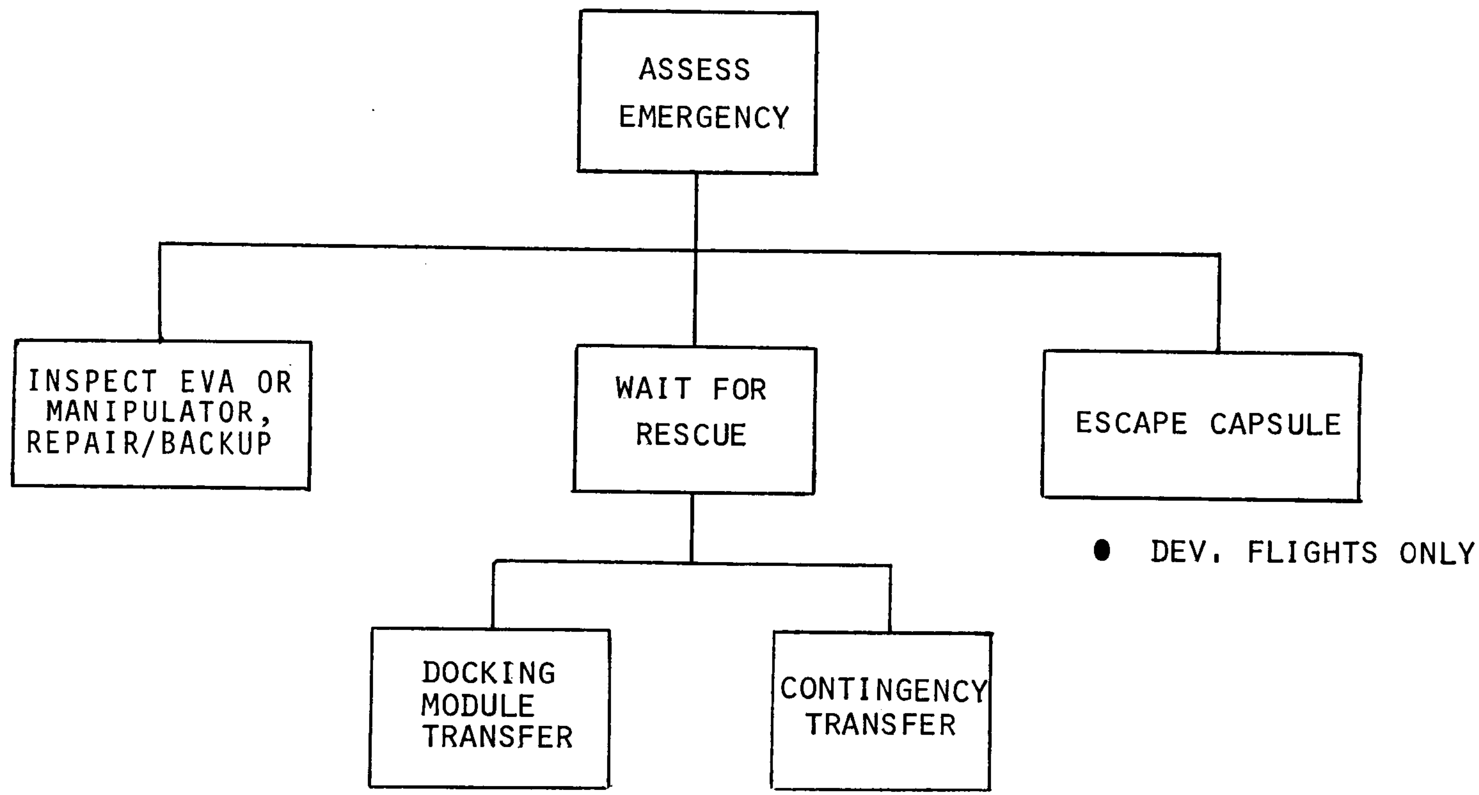


* FOR ATTACHED MODULE, ACTION IS ALWAYS EGRESS TO CABIN

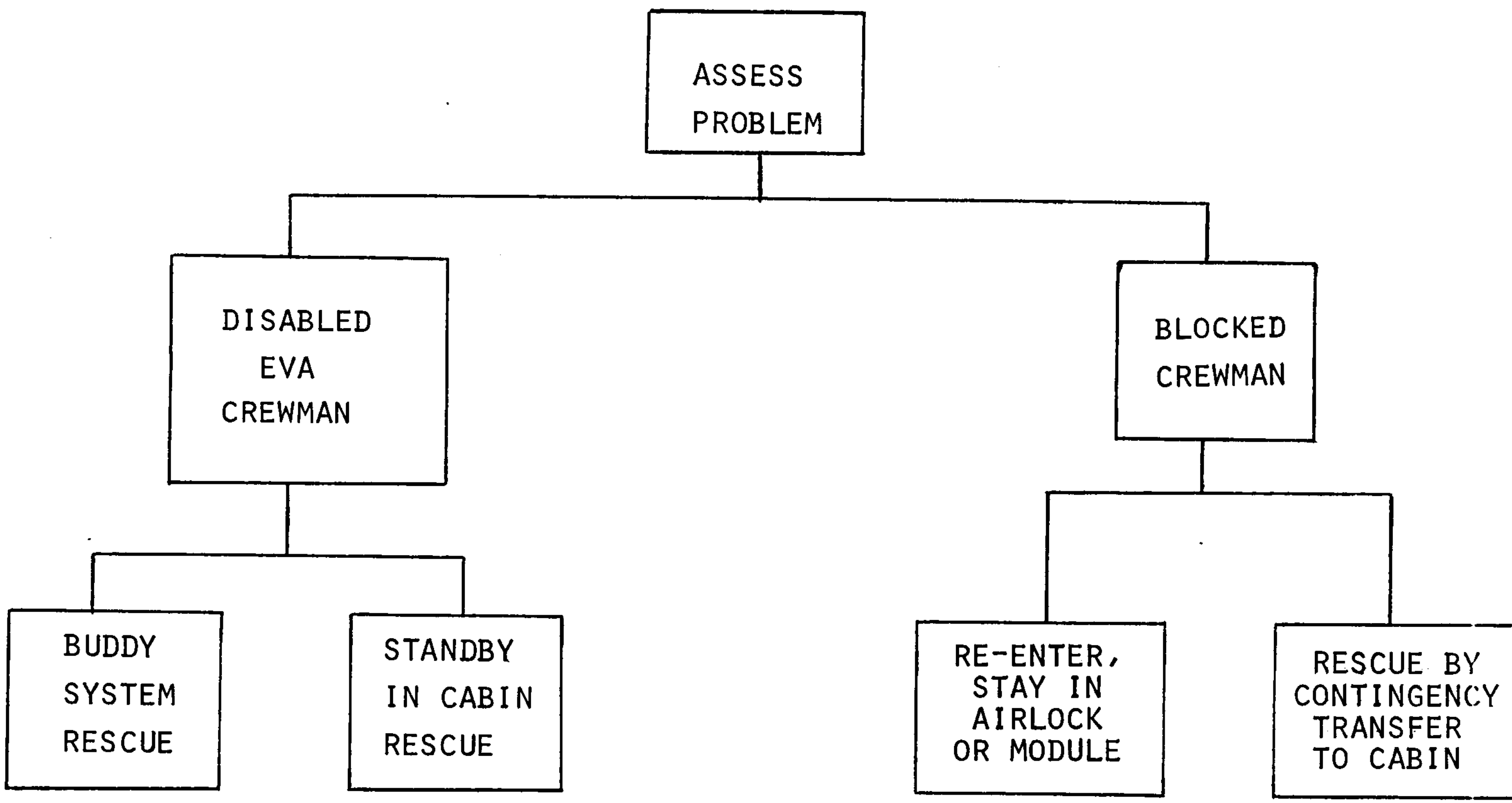
** REQUIREMENT FOR FACE MASKS DEPENDS ON REDUCED PRESSURE LEVEL MAINTAINED

● DEV. FLTS. ONLY

INABILITY TO RE-ENTER OPTIONS



VIABLE STRANDED CREWMAN OPTIONS



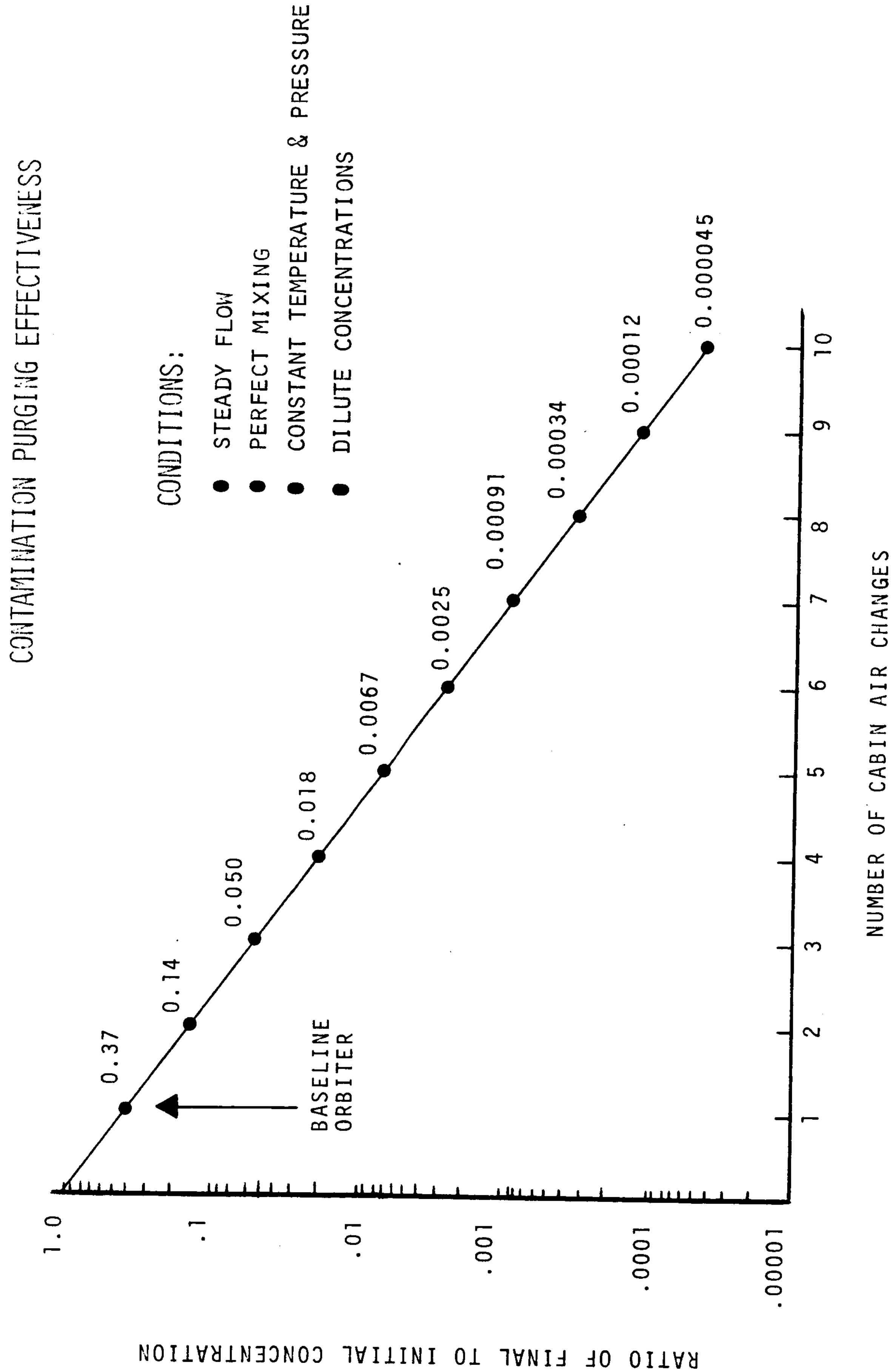
SUMMARY OF OPTIONS

EMERGENCY	FUNCTIONAL OPTIONS	FACE MASKS	PURGE	ECS SCRUB	DEPRESS/REPRESS	REFUGE	PURGE AIRLOCK	SUITS	EGRESS TO CABIN	MAINTAIN NOMINAL CABIN PRESSURE	MAINTAIN REDUCED CABIN PRESSURE	LOW CABIN PRESSURE	EVA	ON-ORBIT RESCUE	CONT'G, X-FER TO RESCUE VEHICLE	ESCAPE CAPSULE (DEV. FLTS. ONLY)	CONT'G, X-FER TO CABIN	BUDDY SYSTEM	STANDBY IN CABIN	REENTER IN AIRLOCK OR MODULE
CONTAMINATED ATMOSPHERE	DECONTAMINATE (CABIN OR MODULE)	✓	✓																	
		✓		✓																
		✓			✓			✓												
		✓				✓	✓													
	ABORT MISSION (CABIN)	✓																		
	ABORT MODULE	✓				✓	✓		✓											
DECOMPRESSION	RE-ENTER (CABIN)									✓										
		✓									✓									
								✓				✓								
	WAIT FOR RESCUE (CABIN)	✓						✓						✓	✓					
						✓		✓						✓	✓					
	ESCAPE (CABIN)															✓				
	ABORT MODULE								✓											
INABILITY TO RE-ENTER	REPAIR/CORRECT							✓					✓							
	WAIT FOR RESCUE													✓						
								✓						✓	✓					
	ESCAPE															✓				
STRANDED CREWMAN	RESCUE DISABLED EVA CREWMAN							✓					✓					✓		
								✓					✓						✓	
	RESCUE BLOCKED CREWMAN							✓									✓			
	RE-ENTER (BLOCKED CREWMAN)																			✓

ASSESSMENTS

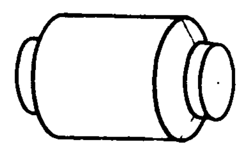
FLOOD FLOW CONCLUSIONS - PURGE CONTAMINATION

- BASELINE ORBITER PURGE QUANTITY INSUFFICIENT TO CLEAR CABIN (63% REDUCTION; MUST INCREASE TO 700 LB GAS FOR REDUCTION TO 1% INITIAL CONCENTRATION)
- SIMILARLY IMPRACTICAL TO CLEAR SORTIE MODULE BY PURGE
- REDUCED PRESSURE PURGE IS POSSIBLE, BUT STILL CARRIES HIGH PENALTY (AT 8 PSIA LEVEL, APPROX. 350 LB PURGE GAS IS NEEDED FOR CABIN REDUCTION TO 1% INITIAL CONCENTRATION)
- BASELINE ORBITER PURGE QUANTITY SUFFICIENT TO CLEAR AIRLOCK

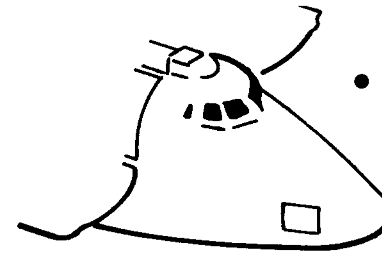


CONTAMINATION PURGING EFFECTIVENESS
CONDITIONS:
STEADY FLOW
PERFECT MIXING
CONSTANT TEMPERATURE & PRESSURE
DILUTE CONCENTRATIONS
BASELINE ORBITER
0.37
0.14
0.050
0.018
0.0067
0.0025
0.00091
0.00034
0.00012
0.000045
1.0
.1
.01
.001
.0001
.00001
1
2
3
4
5
6
7
8
9
10
NUMBER OF CABIN AIR CHANGES
RATIO OF FINAL TO INITIAL CONCENTRATION

DEPRESS/REPRESS CONSIDERATIONS



SORTIE LAB



CABIN

PURPOSE

- CLEAR CONTAMINATED CABIN IF CANNOT RE-ENTER WITHIN SHORT DURATION
- CLEAR CONTAMINATED ATTACHED MODULE

IMPACTS

- TEMPORARY OPERATION DEPRESSURIZED
- ADD VALVING TO DUMP PRESSURES;*COULD DUMP CABIN THROUGH AIRLOCK IF WEAR SUITS (ABOUT 1 HR DUMP TIME)
- EXISTING CABIN FLOOD FLOW PROVISIONS ADEQUATE TO REPRESS IN 1 HOUR
- SUITS OR REFUGE LIFE SUPPORT REQUIRED FOR 2 HOURS

CONCLUSION

- DEPRESS/REPRESS IS PRACTICAL WAY TO CLEAR CONTAMINATION

ALTERNATES

- LONG TERM FACE MASK USE (DISCOMFORT, OXYGEN TOXICITY, ADDITIONAL CONSUMABLE O_2)
- INCREASE PURGE CAPABILITY (HIGH PENALTY)
- SCRUB SMOKE WITH ECS

*OR MANUALLY OPEN RELIEF VALVE

ASSESSMENT OF DECOMPRESSIONS

- DECOMPRESSIONS ASSOCIATED WITH VEHICLE FAILURES ARE LIKELY TO BE LESS THAN 1/2" EFFECTIVE DIAMETER (REDUNDANT SEALS PRECLUDE PROBABILITY OF LARGE LEAK)
- DEBRIS COLLISION PROBABILITY CAN BE GREATLY REDUCED BY INCREASED TRACKING - ESPECIALLY LARGE OBJECTS
- ANY IMPACT CAUSING PENETRATION WILL LIKELY DAMAGE TPS SUCH THAT CANNOT RE-ENTER (DEBRIS, METEOROID, DEPLOYMENT/DOCKING)
- CERTAIN HAZARDOUS SITUATIONS CAN BE ANTICIPATED (DEPLOYMENT/DOCKING)
- ABOVE CONSIDERATIONS DIVIDE PROTECTION REQUIREMENTS:
  - CAPABILITY TO RE-ENTER NEEDED WITH HOLES LESS THAN 1/2" DIA
  - REPAIR OR RESCUE/ESCAPE CAPABILITY NEEDED FOR CASE OF IMPACT DAMAGE
  - PROTECTIVE MEASURES DURING KNOWN HAZARDS

CABIN PRESSURE MAINTENANCE OPTIONS

MAINTAIN NEAR-NOMINAL CABIN PRESSURE

- CURRENTLY 14.7 PSIA, 10 PSIA ALTERNATE UNDER EVALUATION
- SIMPLEST SYSTEM

MAINTAIN REDUCED CABIN PRESSURE (INITIAL 14.7 $\pm$ .2)

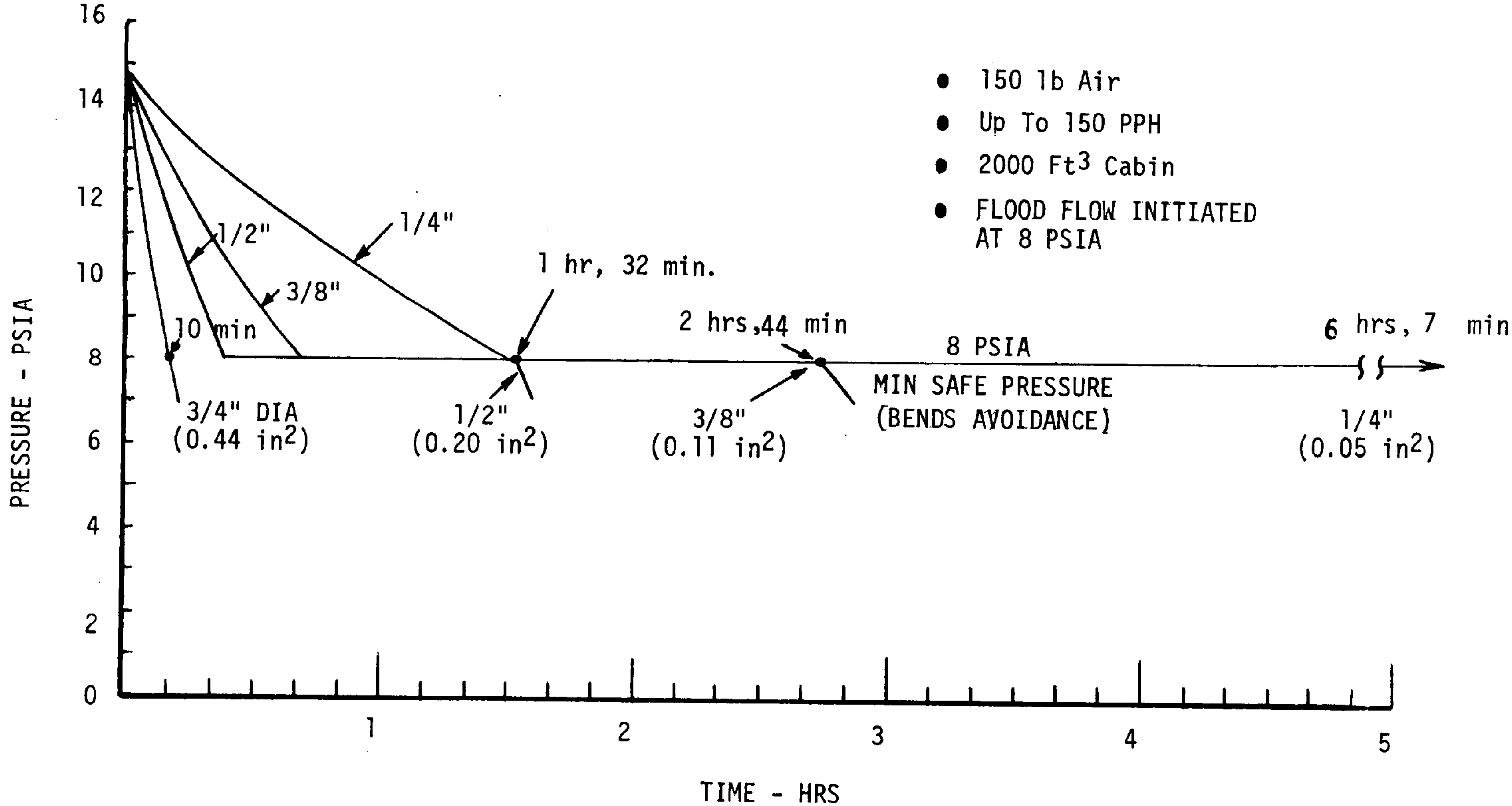
- INCREASED DURATION
- STRUCTURAL/VENT IMPACTS
- 10 PSIA : MINIMUM TEMPORARY WITHOUT OXYGEN MASKS*
  (USAF EMERGENCY ALVEOLAR ppO_2 = 50 mm Hg, IMPAIRED PERFORMANCE)
- 8 PSIA : MINIMUM WITHOUT DECOMPRESSION SICKNESS OR MAJOR AVIONICS IMPACTS, OXYGEN MASKS REQUIRED*

MAINTAIN LOW CABIN PRESSURE

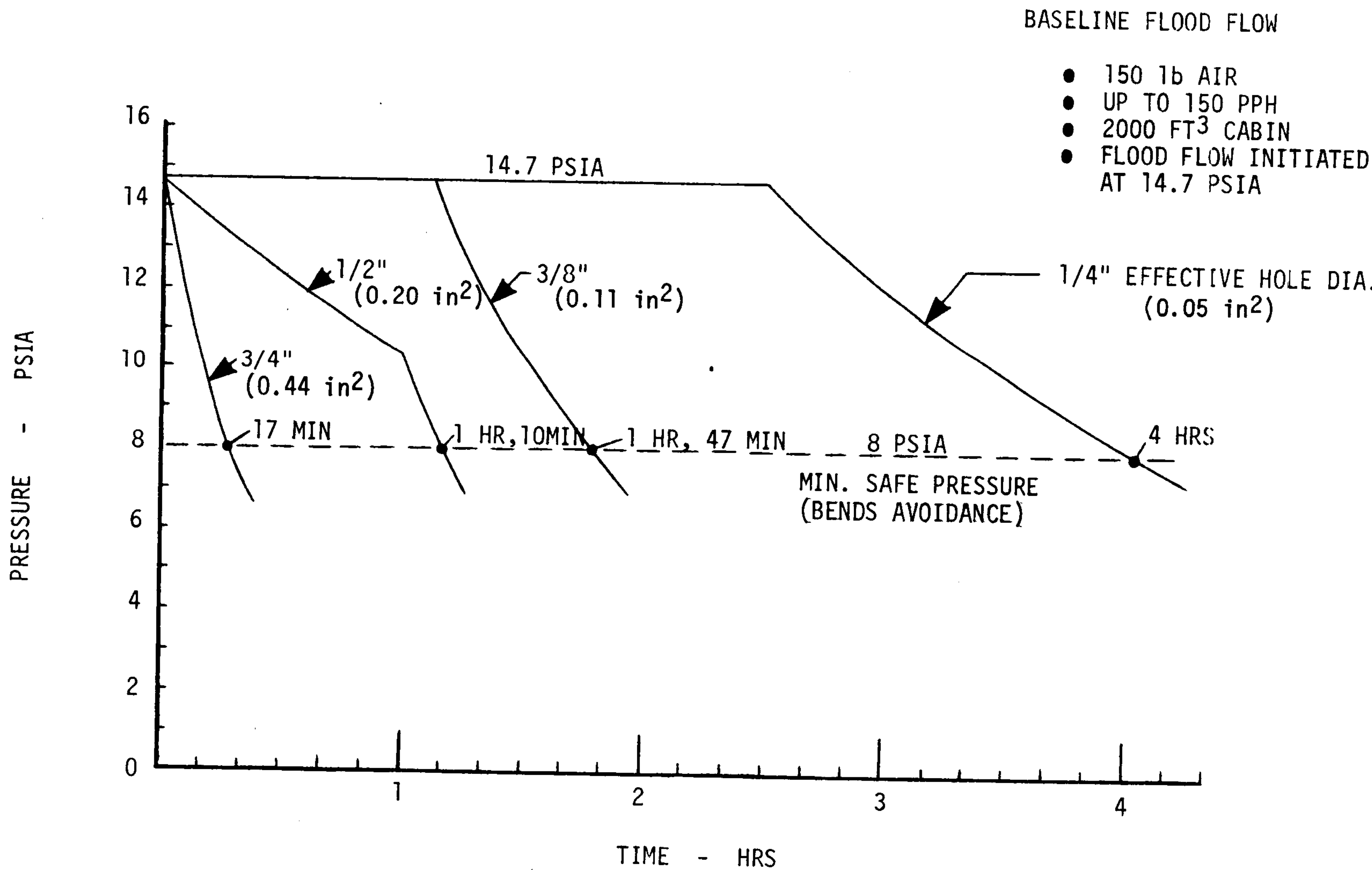
- FURTHER INCREASED DURATION
- STRUCTURAL/VENT IMPACTS
- ADDITIONAL AVIONICS COOLING REQUIRED (SIGNIFICANT IMPACT)
- APPROX. 2 PSIA : AVIONICS MINIMUM PRESSURE CAPABILITY
- PRESSURE SUITS REQUIRED

* FOR WORST CASE OXYGEN TRANSIENT CONCENTRATION GRADIENTS

DEPRESSURIZATION RATE AT 8 PSIA HOLD



CABIN DEPRESSURIZATION RATE



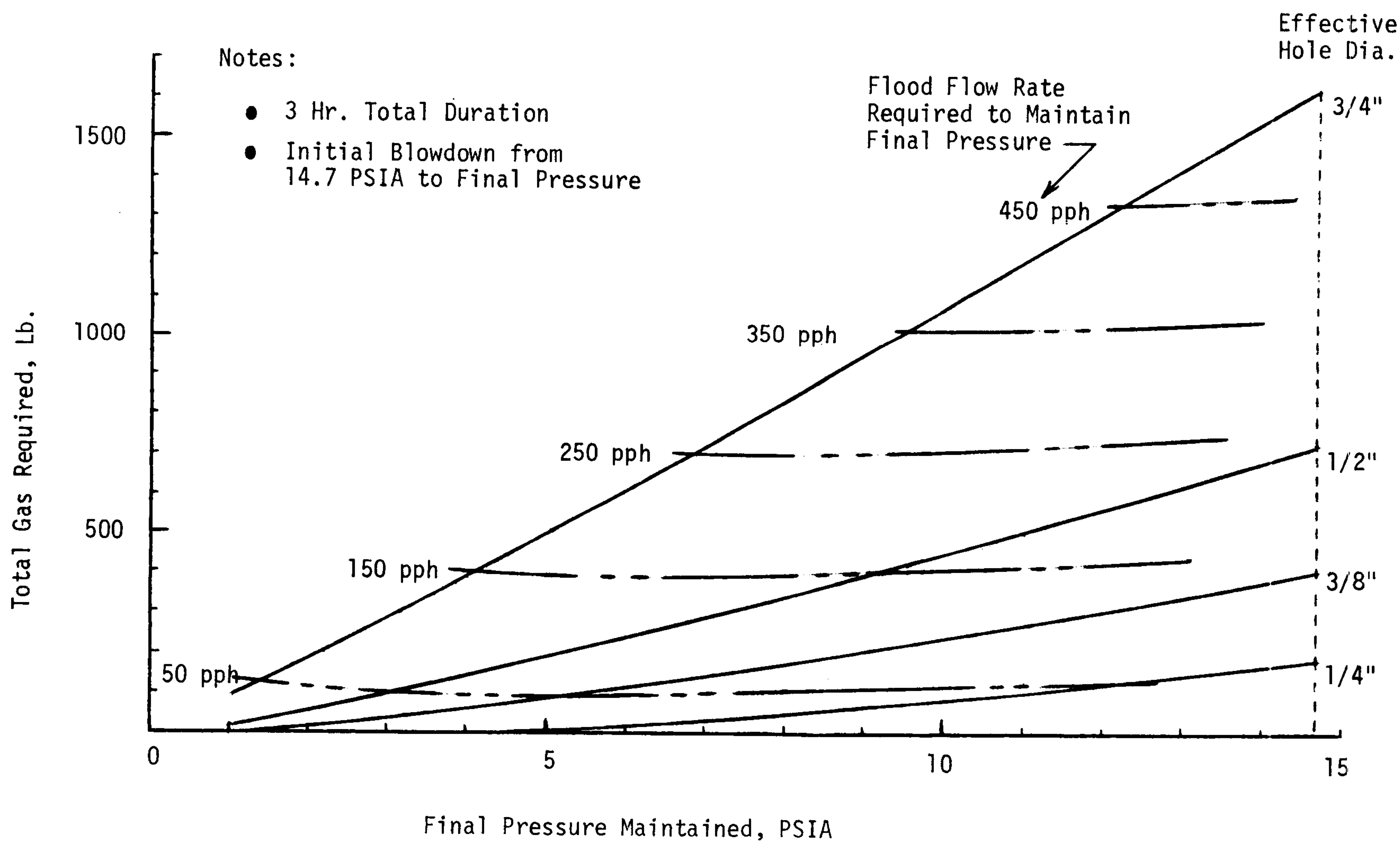
FLOOD FLOW GAS REQUIREMENTS SUMMARY

EFFECTIVE HOLE DIA. (INCH)	FLOOD FLOW RATE (PPH) FOR PRESSURE MAINTAINED (PSIA)				TOTAL GAS (LB) FOR PRESSURE MAINTAINED (PSIA)			
	2	8	10	14.7	2	8	10	14.7
1/4	8	33	40	60	0	49	80	180
3/8	19	74	92	135	15	171	236	405
1/2	34	132	164	240	58	345	454	720
3/4	74	295	367	540	180	836	1064	1620

NOTES:

1. 3 HR TOTAL DURATION, 165 MIN QUICK RETURN + 15 MIN CONTINGENCY
2. INITIAL BLOWDOWN FROM 14.7 TO MAINTAINED PRESSURE; HELD THERE UNTIL END OF 3 HRS

FLOOD FLOW GAS REQUIREMENTS



EVALUATION OF CABIN PRESSURE LEVELS MAINTAINED

	FINAL CABIN PRESSURE, PSIA		
	14.7	10	8
3 Hour Return - Max. Hole Dia (1)	7/32"	5/16"	3/8"
95 Min. Return - Max. Hole Dia (1)	9/32"	7/16"	1/2"
1/2" Dia. Hole Gas Reqt's. (1) - 95 Min. Return	240 pph, 380 lb (2)	165 pph, 220 lb (2)	132 pph, 155 lb
Emergency Gas Utilization	Depletes N_2 at 60% O_2 Depletion, Continues Makeup with O_2	Depletes N_2 & O_2 At Same Time	Depletes O_2 at 70% (3) N_2 Depletion, Then Baseline Shuts Off N_2
Alveolar Oxygen: (4) Nominal Range	105 100 - 110 mm Hg	101 47 - 106 mm Hg	98 26 - 102 mm Hg
Oxygen Masks (4)	Not Required	Marginal	Required
Flammability	22 - 24% O_2; 100% after N_2 Depletion	32 - 36% O_2	39 - 44% O_2 Until O_2 Depletion
Structural/Relief Valve Modifications	None	Required	Required

NOTES:
(1) Calculated for blowdown from 14.7 to final pressure prior to initiation of flood flow-does not consider unequal N_2/O_2 depletion.
(2) Extra tankage and increased flow capacity required
(3) Regulator change required to avoid N_2 regulator lock-out when O_2 is depleted
(4) 90 mm Hg is min. alveolar O_2 for unimpaired performance; 50 mm Hg is USAF emerg. level and gives performance impairment. Alveolar range is due to potential concentration gradient and control tolerance bands
(5) Evaluation is for baseline system, assuming only those changes required to operate at given pressure levels

FLOOD FLOW PRESSURE MAINTENANCE SUMMARY

- 14.7 PSIA PRESSURE MAINTENANCE
  - Baseline orbiter not safe for re-entry (95 min.) with effective hole diameter larger than about 1/4"
  - Excessive makeup gas system mods. to hold 1/2 inch hole for 95 min. (230 lb. extra gas; 60% increased flowrate; tankage ratio mods. to deplete O_2/N_2 at same time)
- 10 PSIA PRESSURE MAINTENANCE
  - Modest makeup gas system mods. to hold 1/2" hole for 95 min. (70 lb. extra gas; 10% increased flowrate; regulator change)
  - Safe without oxygen masks, including transient concentration gradients
  - Increases fire hazard a modest amount (10-12% greater oxygen concentration than 14.7 psia baseline)
  - Minimal structural/vent/avionics impacts (undefined)
- 8 PSIA PRESSURE MAINTENANCE
  - Minimal makeup gas system mods. to hold 1/2" hole for 95 min. (no extra gas or flowrate; tankage ratio mods. to deplete O_2/N_2 at same time; regulator change)
  - Oxygen masks required because of potential transient concentration gradients
  - Increases fire hazard somewhat more (17-20% greater oxygen concentration than 14.7 psia baseline)
  - Minimal structural/vent/avionics impacts (undefined)
- 2 PSIA PRESSURE MAINTENANCE
  - Least makeup gas system mods. to hold 1/2" hole for 95 min. (regulator change only)
  - Requires pressure suits with oxygen mask use during donning
  - 100% cabin oxygen concentration at 2 psia (baseline makeup system)
  - Excessive structural/vent/avionics impacts (undefined)

FLOOD FLOW CONCLUSIONS - MAINTENANCE OF PRESSURE

- FOR HOLES UP TO 1/2" EFFECTIVE DIA., 8-10 PSIA PRESSURE MAINTENANCE FOR 95 MIN. RETURN IS PRACTICAL, DOES NOT INVOLVE EXCESSIVE PENALTIES, AND PERMITS SHIRTSLEEVE RE-ENTRY. FURTHER STUDY REQUIRED TO SELECT 8 OR 10.
- FOR HOLES LARGER THAN 1/2" EFFECTIVE DIA., MAINTENANCE OF PRESSURE ABOVE 8 PSIA FOR 95 MIN. RETURN IS NOT PRACTICAL, AND PRESSURE SUIT OPERATION IS REQUIRED.
- GAS REQUIREMENTS FOR 3 HR. SHIRTSLEEVE RETURN ARE IMPRACTICAL FOR HOLE SIZES OF 1/2" EFFECTIVE DIA. (345 LB @ 8 PSIA, 454 LB @ 10 PSIA)
- FOR HOLES UP TO ABOUT 3/4" EFFECTIVE DIA., THE BASELINE FLOOD FLOW CAPABILITY OF 150 pph HOLDS PRESSURE ABOVE 8 PSIA LONG ENOUGH TO DON PRESSURE SUITS. FLOW MUST BE INITIATED AT NEAR 14.7 PSIA AND OXYGEN MASK MAY BE REQUIRED. SUBSEQUENT REDUCED PRESSURE RE-ENTRY (2 PSIA OR LESS), ON-ORBIT RESCUE, OR USE OF ESCAPE MODULE IS REQUIRED.
- FOR HOLES GREATER THAN 3/4" EFFECTIVE DIA., CONSTANT WEAR SUITS ARE ONLY SAFE ALTERNATIVE. SUBSEQUENT DEPRESSURIZED RE-ENTRY, ON-ORBIT RESCUE, OR USE OF ESCAPE MODULE IS REQUIRED.

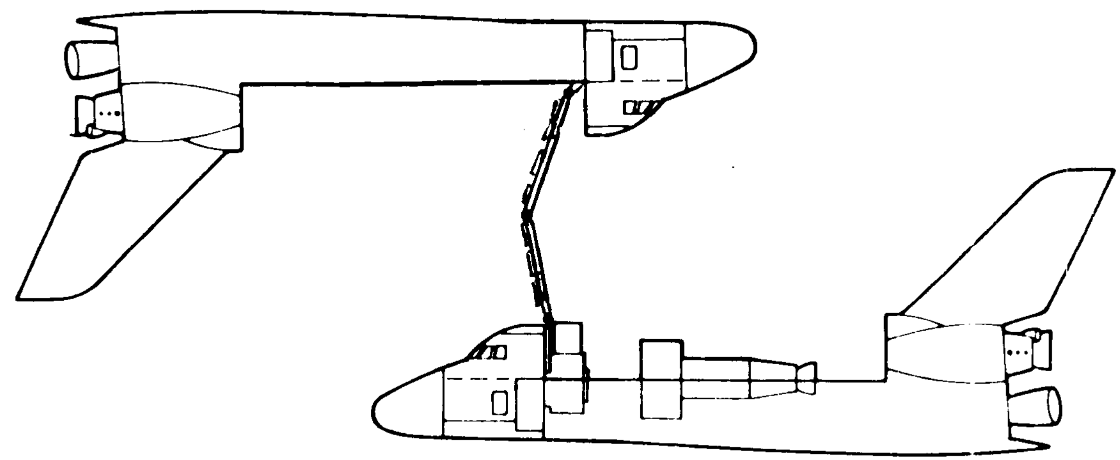
RESCUE ORBITER CONTINGENCY TRANSFER

For any contingency prohibiting re-entry, the preferred mode of survival for the operational phase of the shuttle program is on-orbit rescue. Normally this will be accomplished by direct docking, perhaps with the rescue shuttle bringing up a docking module and adapter. However, if a hard dock is not possible due to lack of stabilization of the disabled vehicle (perhaps because of a cabin depressurization and resultant loss of avionics), or some damage or failure to jettison in the docking area, a contingency EVA transfer will be necessary.

Drift rates due to avionics loss are expected to be small, thus in most instances it is likely that a synchronization maneuver can be accomplished. Then the manipulator arm would be an effective translation aid. Necessary EVA equipment, such as thermal protection for the IV suits, tethers, and EOP's could be brought up by the rescue orbiter.

RESCUE ORBITER CONTINGENCY TRANSFER

DRIVER:
RESCUE ORBITER CANNOT DOCK



REQUIREMENTS:

- MOBILITY AIDS ON RESCUE MANIPULATOR
- SUITS WITH CONTINGENCY TRANSFER LSS AND THERMAL PROTECTION
- TETHERS
- RESCUE CREWMAN

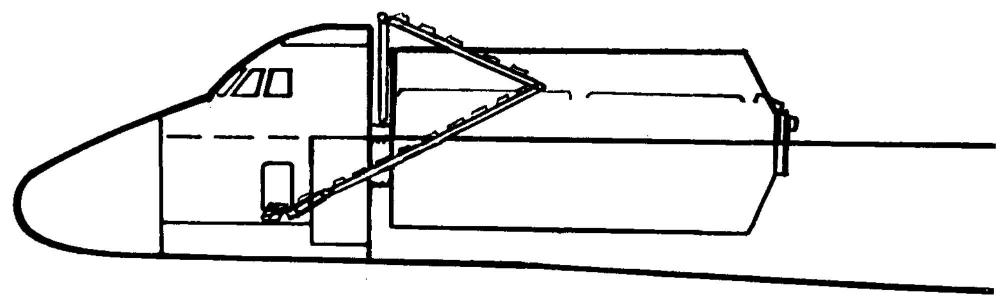
* RESCUE ORBITER MUST SYNCHRONIZE WITH DISABLED SHUTTLE DRIFT

CONTINGENCY TRANSFER FROM SORTIE MODULE

As illustrated on the opposing page, the impact of blocked IV access from the sortie module to the cabin is great. The credibility of this contingency and the possibility of designing to acceptable risk levels should be studied in more detail. Based on consultation with General Dynamics, it is probable that experiments can be designed/arranged in the sortie module such that blocked access due to an experiment failure would not occur. Then, if all hatches connecting the sortie module and cabin are left open, with only the cabin/airlock hatch closed, it is expected that the risk of blocked access can be made acceptably low by appropriate hatch design. (The cabin/airlock hatch is kept closed to avoid contaminating the cabin.) This precludes EVA during pressurized manned sortie module operation, even if a docking module is present, as safe EVA operation requires an open external hatch.

In addition to the blocked access impacts listed, the cabin must also be depressurized/repressurized, and an umbilical in the cabin from the cabin suit loop must be available to permit assistance to the sortie module crewman performing the contingency transfer.

CONTINGENCY TRANSFER FROM SORTIE MODULE



DRIVER:
BLOCKED
IV ACCESS

MAJOR IMPACT:
- CONTINGENCY TRANSFER SUITS, LSS, THERMAL PROTECTION, AND TETHER IN SORTIE MODULE
- REMOTE SECOND HATCH ON SORTIE MODULE
- CONTINGENCY LSS IN SORTIE MODULE
- MOBILITY AIDS AND SIDE HATCH USE
- RESEAL SIDE HATCH BEFORE RE-ENTER

RECOMMEND:
- DESIGN TO ACCEPTABLE RISK OF NO BLOCKED ACCESS
- OPERATE SORTIE MODULE AND AIRLOCK/SORTIE MODULE HATCHES OPEN
- OPERATE CABIN/AIRLOCK HATCH CLOSED

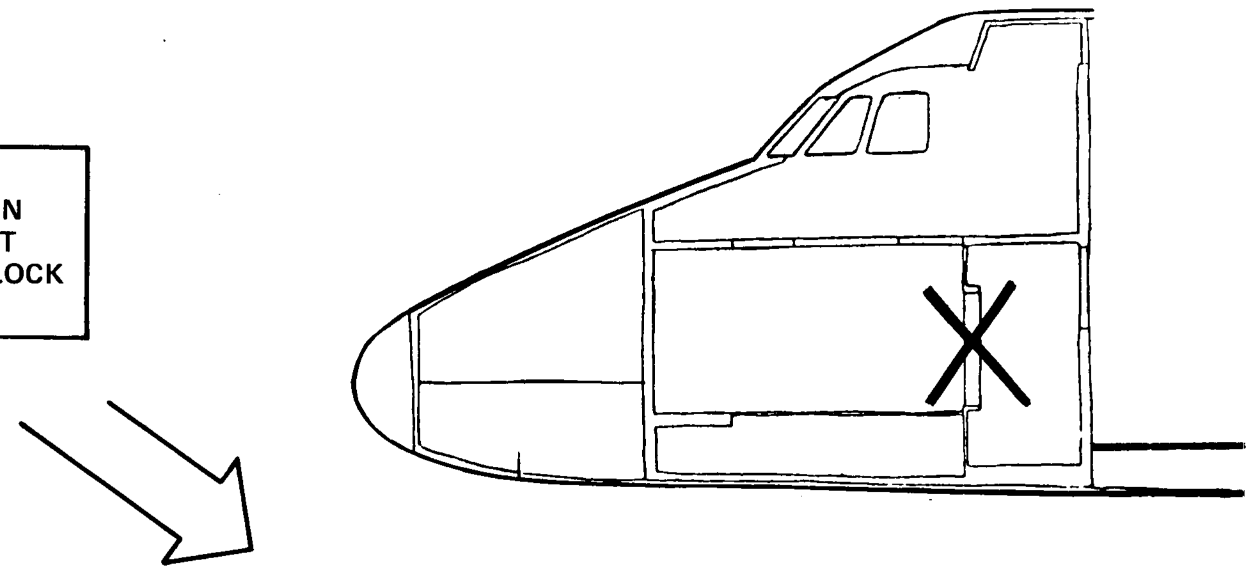
BLOCKED ACCESS IN AIRLOCK

This contingency includes various ways of blocking EVA return as described previously under Class VI. The illustrated case is for a cabin hatch failure to open.

Similar to the case of blocked access from the sortie module, it is expected that this contingency can be reduced to an acceptable risk level by appropriate design. EVA would always be conducted with external hatches open, thus precluding simultaneous manned sortie module operation (unless by IVA).

BLOCKED ACCESS IN AIRLOCK

DRIVER:
EVA RETURN
BLOCKED AT
CABIN/AIRLOCK
HATCH



IMPACT:
- CONTINGENCY LSS IN AIRLOCK
- MOBILITY AIDS AND SIDE HATCH USE

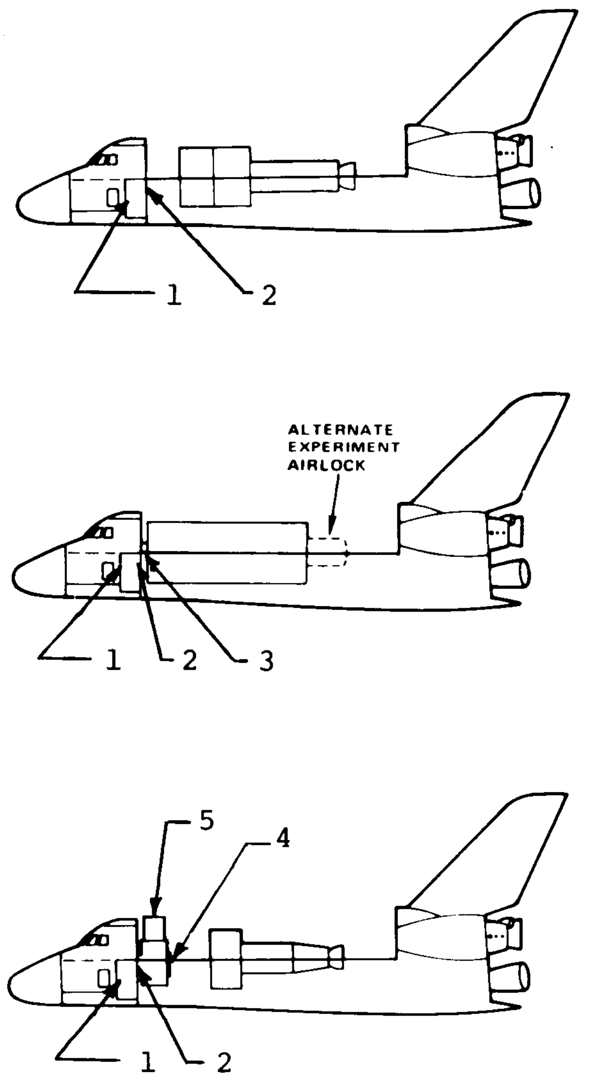
RECOMMEND:
- DESIGN FOR ACCEPTABLE RISK OF NO BLOCKAGE

RECOMMENDED HATCH POSITIONS

HATCH	CONDITIONS	POSITION
CABIN-TO-AIRLOCK	ALL	CLOSED
AIRLOCK-TO-		
● VACUUM	NO EVA	CLOSED
	ONE MAN EVA	CLOSED
	TWO MAN EVA	OPEN
● SORTIE MODULE OR DM*	MANNED	OPEN
	UNMANNED	CLOSED
SORTIE MODULE-TO-DM	MANNED SORTIE MODULE	OPEN
	UNMANNED	CLOSED
DM-TO-		
● VACUUM	SAME AS AIRLOCK-TO-VACUUM	
● DOCKED VEHICLE	SAME AS SORTIE MODULE-TO-DM	

*DM - DOCKING MODULE

EVALUATION OF HATCH OPENING DIRECTION



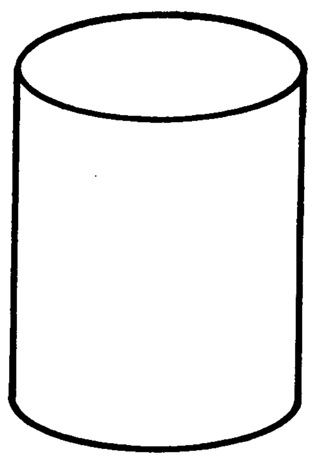
HATCH	NO.	OPENS IN	OPENS OUT
CABIN-TO-AIRLOCK	1	P	N
AIRLOCK-TO- ● VACUUM ● SORTIE MODULE ● DOCKING MODULE	2	P	A
SORTIE MODULE-TO- ● AIRLOCK ● DOCKING MODULE	3	P	A
DOCKING MODULE-TO- ● VACUUM ● SORTIE MODULE	4	P	A
DOCKING MODULE-TO- ● VACUUM ● DOCKED VEHICLE	5	P	A

P – PREFERRED

A – ACCEPTABLE

N – NOT ACCEPTABLE

SPECIAL AIRLOCK CONSIDERATIONS FOR STRANDED CREWMAN



- FOR ONE-MAN EVA, STANDBY PARTIALLY SUITED CREWMAN IS LOCATED IN CABIN
- CONTINGENCY REPRESS AIRLOCK AT 6.0 PSI/MIN USING CABIN AIR
- DESIGN RELIEF VALVE AND AIRLOCK DEPRESS SYSTEM TOGETHER.
- NO REQUIREMENT IDENTIFIED FOR 0→3.25 PSIA REPRESS IN 15 SECONDS

EVALUATION OF AIRLOCK REFUGE

PHYSICAL

- LARGE ENOUGH FOR 2-MAN SUIT DONNING, 4 MEN SHIRTSLEEVES
- ENLARGE OR ADD DOCKING MODULE FOR LARGER CREW

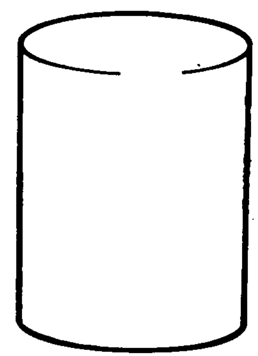
ECS

- 144 FT^3 AIRLOCK WILL SUSTAIN 2 SHIRTSLEEVES MEN 41 MINUTES, 4 MEN 34 MINUTES - 300 BTU THERMAL STORAGE IS LIMITING
- OCCUPANCY DURING AIRLOCK PURGE WOULD REQUIRE NO ADDITIONAL ECS
- SUIT ECS LOOPS AND UMBILICALS REQUIRED IF USE FOR SUIT DONNING
- SIMPLE AIRLOCK ECS REQUIRED IF USE AS REFUGE DURING CABIN OR SORTIE LAB DEPRESS/REPRESS OR FOR TEMPORARY FOOD/WASTE MANAGEMENT
- MAJOR ECLSS MODIFICATIONS, SUITS, AND CONTINGENCY TRANSFER LSS REQUIRED FOR LONG TERM REFUGE

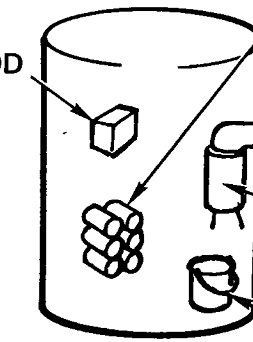
CONCLUSIONS

- NO IMPACT AS TEMPORARY REFUGE FOR PURGE DURING EGRESS FROM CONTAMINATED SORTIE LAB
- CONDUCT SORTIE LAB DEPRESS/REPRESS FROM CABIN
- NOT PRACTICAL AS LONG TERM REFUGE
- REMAINING USES SHOULD BE TRADED AGAINST OTHER ALTERNATIVES

AIRLOCK AS REFUGE



TEMPORARY REFUGE



AS LONG TERM REFUGE

POTENTIAL USES

- TEMPORARY FOR SUIT DONNING IN EVENT OF DECOMPRESSION - PROVIDES QUICKEST ROUTE TO SAFETY (16-20 MINUTE OCCUPANCY NEEDED FOR SUIT DONNING)
- TEMPORARY WHILE DEPRESS/REPRESS CABIN OR SORTIE LAB - MUST SIMULTANEOUSLY PURGE AIRLOCK (2 HOUR OCCUPANCY)
- TEMPORARY DURING PURGE WHILE EGRESS FROM CONTAMINATED SORTIE LAB TO CABIN (30 MINUTES TO 1 HOUR OCCUPANCY)
- LONG TERM WHILE WAIT FOR ON-ORBIT RESCUE (96 HOURS)
- TEMPORARY FOR FOOD AND WASTE MANAGEMENT DURING SUITED LONG TERM WAIT

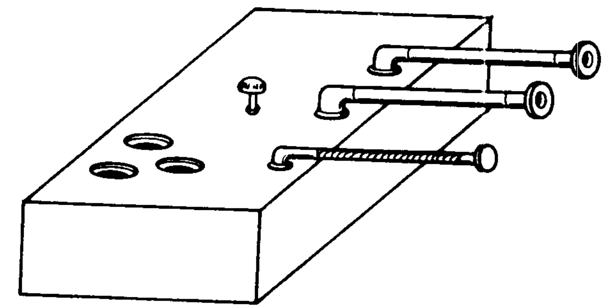
EVALUATION OF IV SUITS

- ONLY PRACTICAL MEANS FOR SURVIVAL IN DEPRESSURIZED CABIN WHILE WAITING FOR ON-ORBIT RESCUE
- ONLY WAY TO PROTECT AGAINST LARGE LEAKS (CONSTANT WEAR)
- CAN WEAR INTERMITTENTLY TO PROTECT DURING HAZARDOUS OPERATIONS
- PERMITS RE-ENTRY AT LOW CABIN PRESSURES (AVIONICS AND OTHER ORBITER MODS. REQ'D., POTENTIAL SAVINGS ON FLOOD FLOW)
- PERMITS SUITED DEPRESS/REPRESS OF CONTAMINATED CABIN (SAVES AIRLOCK PURGE)
- PERMITS CONTINGENCY TRANSFER/RESCUE THROUGH CABIN SIDE HATCH

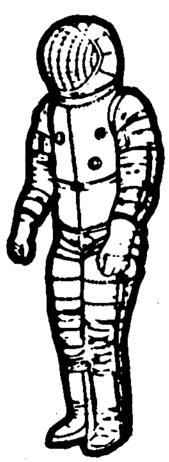
IV SUITS AND CONTINGENCY LSS

POTENTIAL USES

- DEPRESSURIZED OR LOW PRESSURE OPERATIONS/REENTRY
- LONG TERM DEPRESSURIZED WAIT FOR ON-ORBIT RESCUE
- CONTINGENCY TRANSFER TO RESCUE SHUTTLE
- CONTINGENCY TRANSFER OF BLOCKED CREWMAN INTO CABIN SIDE HATCH
- CABIN DEPRESS/REPRESS TO CLEAR CONTAMINATION

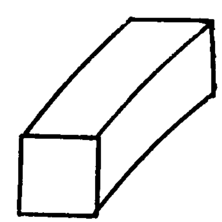


CONTINGENCY IV LSS



8 PSIA SUITS

- PROTOTYPE UNDER DEVELOPMENT
- REQUIREMENTS DETERMINED FOR MINIMUM ORBITER IMPACT

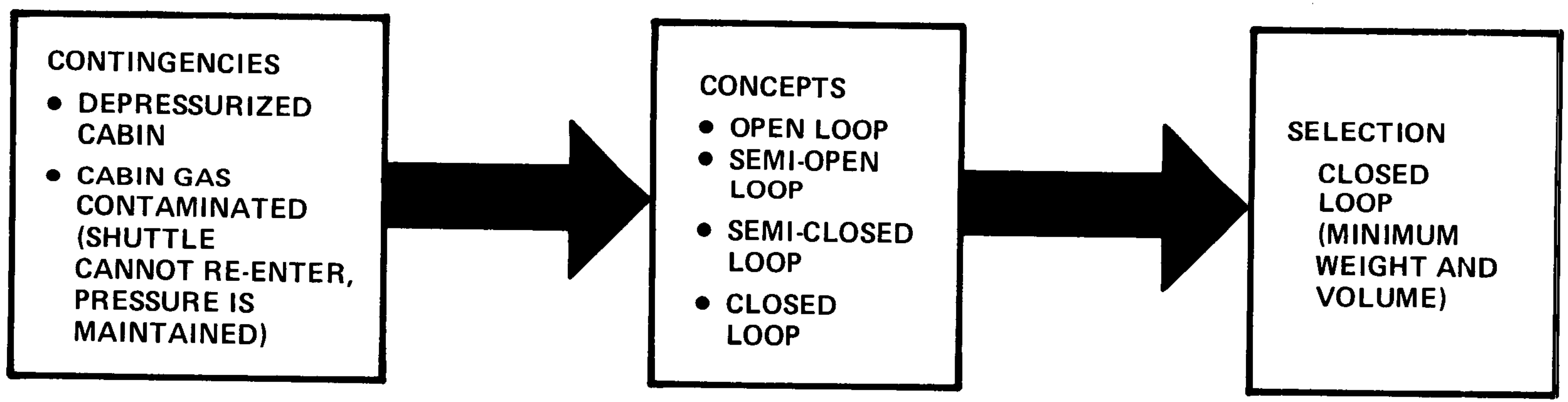


PORTABLE CONTINGENCY TRANSFER LSS

CONTINGENCY IV LSS

A significant amount of effort was devoted to trades to select and identify requirements for the emergency IV life support system. The opposing page illustrates the preliminary screening process and concepts considered in selecting the basic approach of a closed loop system. Following charts present detailed trade results on the closed loop system alternates.

CONTINGENCY IV LSS



CONTINGENCY IV LSS CONCEPTS

Four systems were analyzed as candidates for the closed loop contingency IV LSS, ranging from an almost completely carry-on system to a completely integral system.

The EVLSS is almost completely a carry-on system, and takes advantage of commonality with EVA equipment, two sets of which are already required for other contingency reasons. The vehicle interface is for stowage (perhaps under the seat) and for a cooling water outlet and umbilical. An umbilical water loop is already recommended for the airlock, and the scar penalty to run additional flow and plumbing is small. One major disadvantage is that the IV suits must have liquid cooling garments (LCG's).

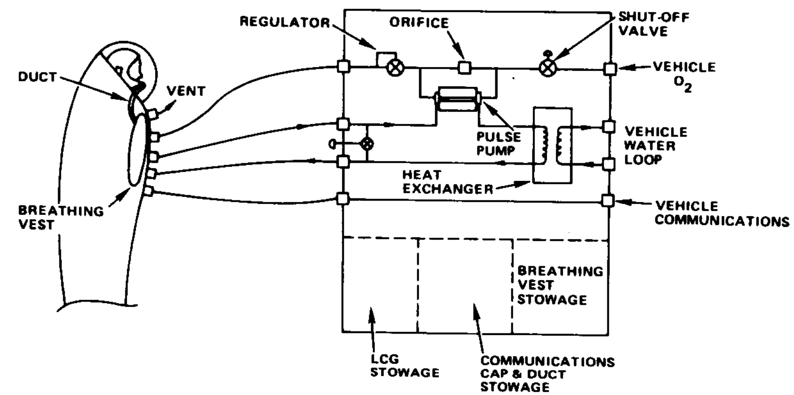
The breathing vest concept is derived from the Litton Contingency Transfer System (CTS), and is carry-on except that now both vehicle water loops and oxygen are required. It is semi-closed loop. Disadvantages are extra suit complications for both the breathing vest system and the LCG, as well as lack of any experience with the concept past the prototype stage.

The carry-on closed vent system uses both vehicle water and oxygen, and interfaces for condensate storage and power. It uses a high recirculating vent flow (13 ACFM) for cooling, thus simplifying the suit.

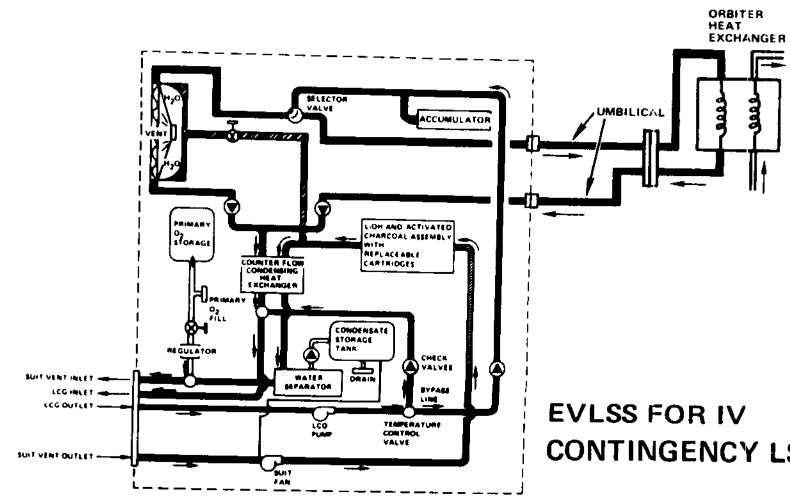
The next logical step is the integral suit loop, requiring greatest vehicle scar, but making most complete use of existing vehicle capabilities and thus minimizing duplication of LSS equipment and expendables. It again cools by a high recirculating vent flow.

Redundancy provisions were not included in the concepts and trades at this stage, and should be included in future, more detailed studies.

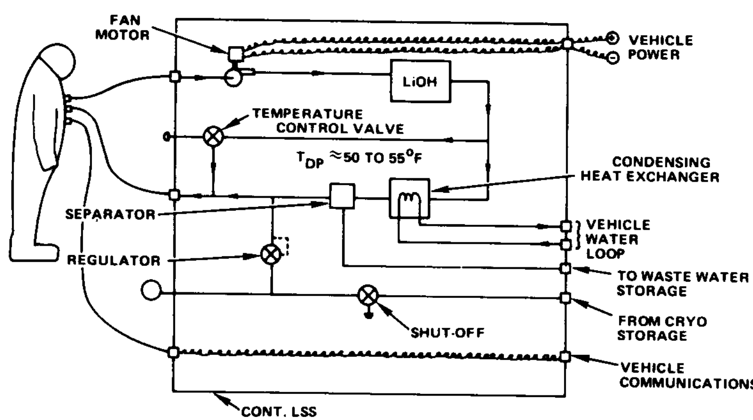
CONTINGENCY IV LSS CONCEPT



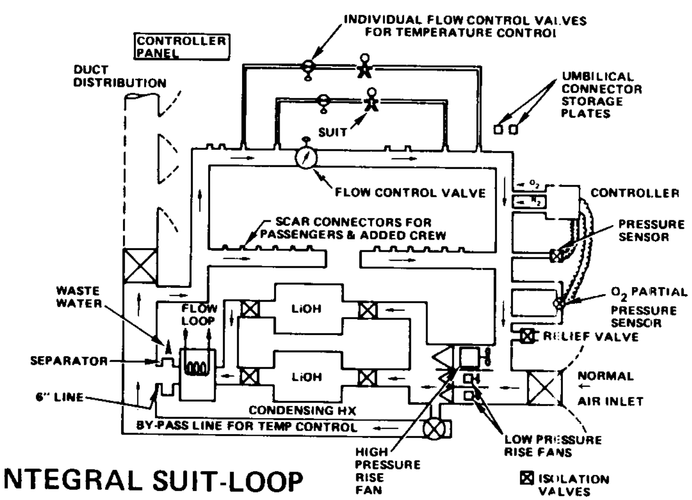
BREATHING VEST SYSTEM SCHEMATIC



EVLSS FOR IV CONTINGENCY LSS



CARRY ON UNDER THE SEAT
CLOSED VENT SYSTEM



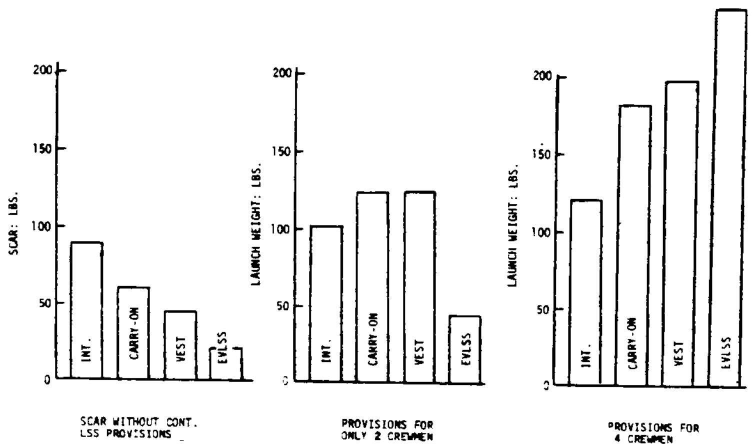
INTEGRAL SUIT-LOOP

COMPARISON OF CONTINGENCY IV LSS CONCEPTS

The opposing chart shows scar and launch weight penalties for the LSS concepts described on the previous chart. For the case of a 3-hour contingency LSS it is seen that the carry-on EVLSS provides the minimum scar, and also results in the least launch weight for a 2-man crew (since 2 EVLSS's are already required for other contingency reasons). For a four-man crew, the EVLSS becomes unattractive from a launch weight viewpoint, but still has the lowest scar and might be preferable if it were not for large vehicle airlock impacts required for four men to don EVLSS's while using the airlock as a temporary refuge. Only if adequate flood flow or a sufficiently small credible leak rate can be guaranteed to permit suit donning in the cabin, can the EVLSS remain a viable contender for the 3-hour case.

The integral suit loops are superior for the 10-hour contingency LSS based on launch weight, and are preferred. They are clearly the winner for longer duration, and thus integral suit loops are preferred for all cases.

COMPARISON OF CONTINGENCY IV LSS CONCEPTS

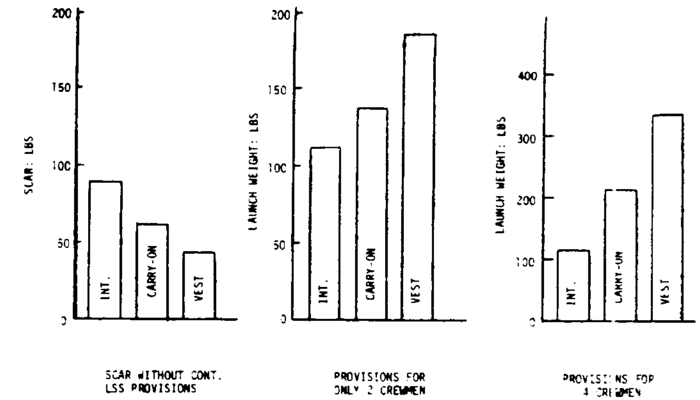


COMPARISON OF 3 HR. CONT. LSS CONCEPTS

2-MEN: PREFER EVLSS

OR

4-MEN: PREPER INTEGRAL SUIT LOOPS



COMPARISON OF 10 HR. CONT. LSS CONCEPTS

96 HR CONT. LSS CONCEPTS

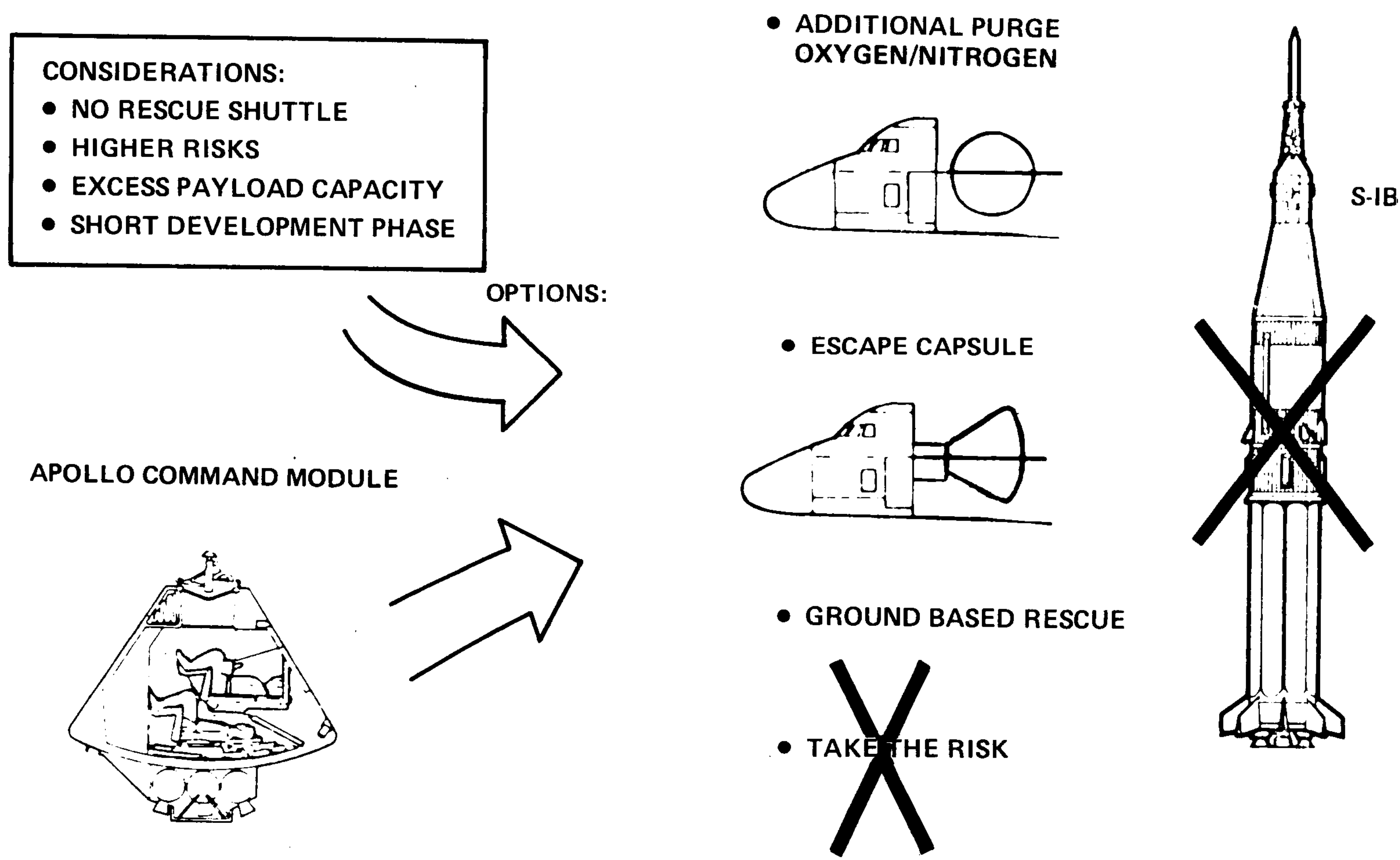
PREFER INTEGRAL SUIT LOOPS

DEVELOPMENT FLIGHTS

During development flights and until the shuttle program becomes operational to the extent that on-orbit rescue is feasible, survival will not be possible with any contingency precluding re-entry. In addition, risks are greater. This demands building all the safety reasonably possible into early flights. Since EVA is an important inspection/repair tool, it is certainly required at this stage.

The Rockwell "Safety in Earth Orbit" study determined that an excape capsule is preferred over a ground based rescue attempt, and they recommended a modified Apollo Command Module. In addition, because of excess cargo area likely to be available, additional purge gas could be stored to extend the response/repair time to any emergency. The basic recommendation here is an escape capsule, to be discussed in more detail in a subsequent chart.

DEVELOPMENT FLIGHTS



PRELIMINARY EMERGENCY SYSTEM

PRELIMINARY EMERGENCY SYSTEM

ACCIDENTAL DECOMPRESSION

1. PROVIDE FLOOD FLOW CAPABILITY FOR SHIRTSLEEVE 95 MINUTE RETURN FOR EFFECTIVE HOLE DIAMETERS UP TO 1/2 INCH:
   - COVERS LARGE NUMBER OF CASES, INCLUDING MOST VEHICLE FAILURES
   - MAINTAIN REDUCED CABIN PRESSURE OF 8-10 PSIA, USE OXYGEN MASKS BELOW 10 PSIA
   - 95 MINUTE PANIC MODE RETURN IS PROVIDED BY:
     - — BASELINE EMERGENCY GAS (INCL. CRYO. O_2) FOR 8 PSIA CABIN
     - — BASELINE + 70 LB GAS FOR 10 PSIA CABIN
   - MODIFY VEHICLE FOR 8-10 PSIA CABIN RE-ENTRY
2. PROVIDE SUITS AND LSS IN CABIN FOR PROTECTION AGAINST IMPACT DEPRESSURIZATION AND WAIT FOR RESCUE.
3. CONTROL FLOOD FLOW RATE TO ALWAYS DEMAND MAINTENANCE OF 8 PSIA OR GREATER FOR 20 MINUTES (TO PERMIT LONG-STAY CONFIG. SUIT DON)
   - SIZE LINES FOR 450 pph MAX. FLOOD FLOW RATE
   - RETAIN EMERGENCY GAS CAPACITY REQUIRED BY SHIRTSLEEVES RE-ENTRY
   - USE O_2 MASKS
   - THIS WILL PROVIDE FOR SAFE SUIT DON TO APPROXIMATELY 1" HOLE
4. INSTRUMENT FOR:
   - LEAK ALARM
   - LEAK RATE INDICATOR (FOR DECISION ON RETURN MODE, SUITS)
   - IMPACT DETECTOR (TO WARN AGAINST POTENTIAL EXTERNAL DAMAGE)

PRELIMINARY EMERGENCY SYSTEM (CONT'D)

5. DIRECT EGRESS FROM ATTACHED MODULE TO CABIN (VIA AIRLOCK USE) FOR MODULE LEAK; USE OXYGEN MASKS
    - QUICKEST OPTION TO SAFETY
    - NO FLOOD FLOW TO MODULES OF CURRENT SIZES IS REQUIRED
6. PROVIDE AVIONICS CAPABILITY TO STABILIZE ON ORBIT FOR RESCUE WITH DEPRESSURIZED CABIN

CONTAMINATED ATMOSPHERE

7. DEPRESS/REPRESS CABIN CAPABILITY SHOULD BE PROVIDED (ALTERNATE ECS SCRUB TO CLEAR SMOKE)
    - DON SUITS AND REMAIN IN CABIN
    - OXYGEN MASKS
8. CONTAMINATED MODULE:
    - OXYGEN MASKS
    - EGRESS TO AIRLOCK, PURGE AIRLOCK
    - THEN EGRESS TO CABIN
    - PAYLOAD OPTIONAL : DEPRESS/REPRESS MODULE
9. PORTABLE FIRE EXTINGUISHERS IN CABIN AND MODULE

INABILITY TO RE-ENTER

10. PROVIDE EVA CAPABILITY TO INSPECT FOR SAFE RE-ENTRY, CONDUCT MINOR REPAIRS, AND PROVIDE BACK-UP TO CRITICAL SEQUENCES
11. RESCUE SHUTTLE AND CONTINGENCY TRANSFER
12. ESCAPE CAPSULE ON DEVELOPMENT FLIGHTS

PRELIMINARY EMERGENCY SYSTEM (CONT'D)

STRANDED CREWMAN

13. DESIGN HATCHES, AIRLOCK SYSTEMS, AND EXPERIMENTS TO ACCEPTABLE RISK OF NO BLOCKED ACCESS
14. OPERATE WITH ALL CONNECTING HATCHES OPEN, AIRLOCK/CABIN HATCH CLOSED
15. PROVIDE STANDBY-IN-CABIN EVA RESCUE CAPABILITY

RECOMMENDED CONCEPT

The opposing chart briefly summarizes the recommended requirements for the orbiter and sortie module (given in the common requirements set) during the operational phase. The recommendations are basically the same for the 3 hour, 10 hour, and 96 hour cases.

All crewmen are normally in the shirtsleeve configuration. EVA suits and life support systems are provided for two crewmen, and IV suits are provided in the cabin for all others on board. Gas masks and oxygen are provided for all, where the 2 EOP's double as portable oxygen containers. Fire extinguishers and protective garments are provided in all manned compartments. Contingency transfer capability is brought up by the rescue orbiter.

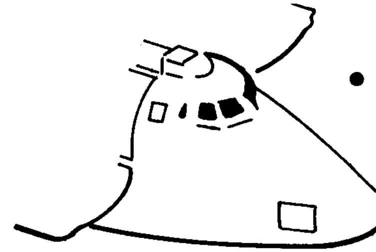
Suits are donned or panic mode re-entry is initiated as soon as a pressure loss failure is sensed, and adequate flood flow is provided to hold pressure. Integral suit loops are provided.

RECOMMENDED CONCEPT

EOP

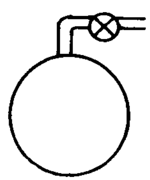
- TWO ON BOARD FOR EVA
- CONTINGENCY TRANSFER (RESCUE ORBITER BRINGS EXTRAS)
- GAS MASK PORTABLE OXYGEN (10 MIN.)
- 96 HR STAY OXYGEN SUPPLEMENT

CABIN DEPRESS/REPRESS CAPABILITY



- CLEAR CONTAMINATION

ADDITIONAL TANKAGE

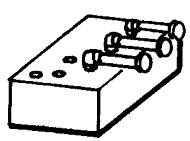


- DEPRESS/REPRESS PURGE + 96 HR WAIT (>2 MEN)
- NON-PORTABLE GAS MASK OXYGEN SOURCE FOR SUIT DON (24 MIN.)
- FLOOD FLOW

FLOOD FLOW

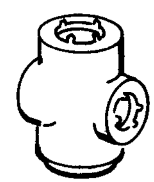
- HOLD CABIN PRESSURE FOR SUIT DON OR PANIC MODE SHIRTSLEEVE RE-ENTRY

SUIT LOOPS AND SUITS



- CONTINGENCY LSS, CABIN
- OXYGEN SUPPLY FOR NON-PORTABLE GAS MASKS
- TWO EVA SUITS & EVLSS
- IV SUITS FOR OTHERS

CONTINGENCY TRANSFER



- RESCUE SHUTTLE FOR ORBITAL RESCUE
- MOBILITY AIDS ON MANIPULATOR
- POSSIBLE MODIFIED DOCKING MODULE

COMMON REQUIREMENTS SET

BASELINE COMMON FUNCTIONAL REQUIREMENTS

Functional and location requirements for equipment found to be common to all the major contingency categories are indicated and form a baseline requirements set.

BASELINE
COMMON FUNCTIONAL REQUIREMENTS

ITEM	LOCATION			
	CABIN	EXTERIOR	AIRLOCK	SORTIE MODULE
· IV SUITS	√			
· EVA SUITS AND PORTABLE LSS			√	
· GAS MASKS & OXYGEN	√			√
· FIRE EXTINGUISHERS	√			√
· ALERTS	√		√	√
· COMPUTER DIAGNOSIS	√			
· FLOOD FLOW	√		√	√
· LEAK REPAIR KITS	√		√	√
· EXTERIOR REPAIR KIT & TOOLS			√	
· MOBILITY AND LIGHTING AIDS		√		
· GROUND COMMUNICATIONS	√			
· HARDLINE COMMUNICATIONS (TO SUITS OR HEADSETS)	√		√	√
· EVA RF COMMUNICATIONS		√		
· PAYLOAD JETTISON		√		

INTEGRAL SUIT LOOP LSS DESCRIPTION

The opposite chart presents the system schematic for integral suit loops. The system is an integral part of the primary life support system for shirtsleeve operations. All expendables for the system are the same as those for the 96 hour on-orbit wait for rescue (shirtsleeves).

ITEM	WEIGHT (LBS)
Valves, Isolation (6)	28.8
Flow Control Valve	5.4
6" Dia. Lines (0.032" Wall)	21.6
High Pressure Rise Fan (Mod From Low Pressure)	5.8
Modifications to Equipment For High Pressure Use	12.0
Oversized Separator	4.5
Modifications to Gas Composition Control System	2.3
Scar For Up to 10 Men	7.7
	88.1 lbs

PROVISIONS PER MAN	
Umbilical	5.6 lbs
Individual Flow Control Valve	2.0 lbs
Connector Stowage	0.4 lbs
TOTAL	8.0 lbs/man

The suit flow requirements are 12 ACFM/man with a dew point of 50°F or less. The peak metabolic load is estimated at 1200 BTU/hr. The average metabolic rates were estimated as the same as Apollo Command Module emergency depressurized cabin rates. The values (per man) from NASA CR-1205(III), page 10-41, are as follows:

METABOLIC RATES FOR PRESSURE SUITED OPERATION

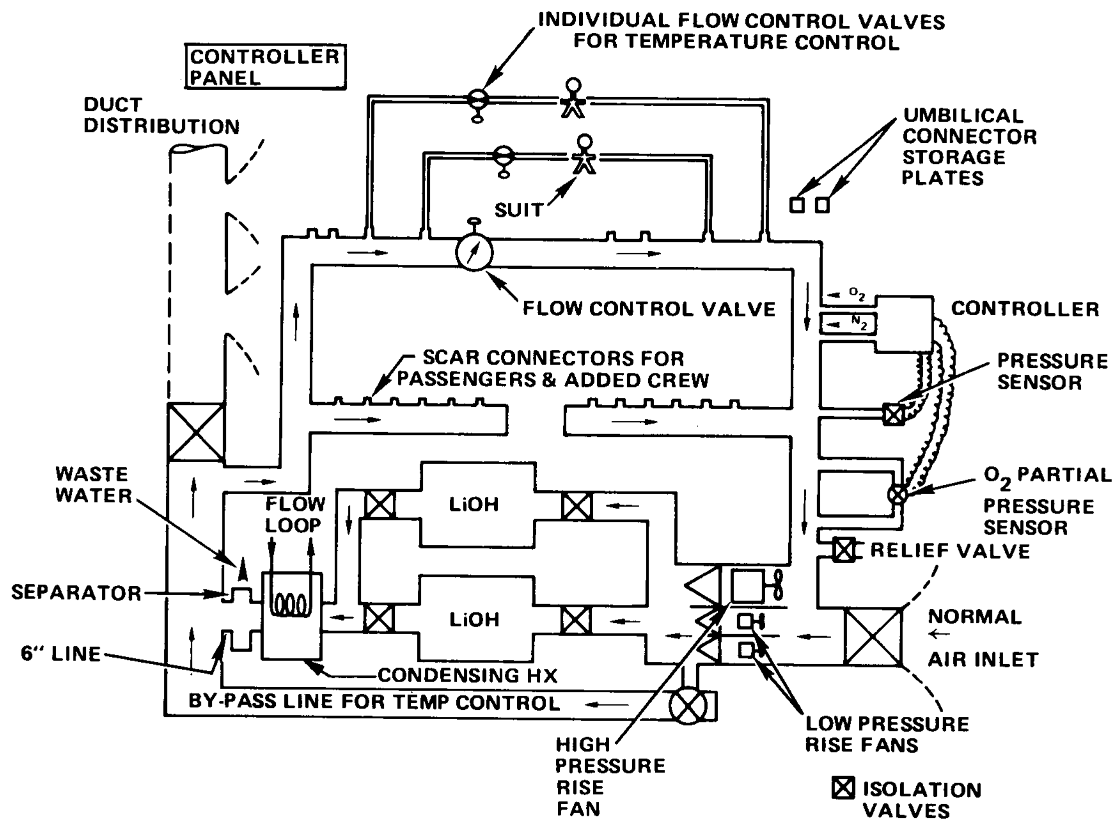
Peak	:	1200 BTU/hr	
On-Duty Average	:	780 BTU/hr (8 hrs)	Daily Avg : 500
Off-Duty	:	400 BTU/hr (8 hrs)	
Sleep	:	320 BTU/hr (8 hrs)	

To provide the variations from min. to max. metabolic loads an individual flow control valve is required.

The mixed gas system provides N_2 to prevent O_2 toxicity during a long term suited operation. Alternately, the suit pressure could be reduced below 8.0 psi with pure O_2 after the men have pre-breathed.

The suit loops are also used as a gas cooling system during suited IV-Standby (helmet and gloves off). The high pressure rise fan is activated, but the isolation valves remain open for normal cabin air circulation. A damper valve may be required in the return duct distribution system. The damper valve would increase the pressure drop available to the suits to provide sufficient flow at 14.7 psia.

INTEGRAL SUIT LOOP LSS DESCRIPTION



ESCAPE CAPSULE FOR DEVELOPMENT FLIGHTS

Rockwell evaluated the Apollo command module (CM) for use as an escape capsule, and recommended a modified version to support 6 men at an 8 psia oxygen pressure. A retro-rocket package would be added, or extra RCS tankage would be provided.

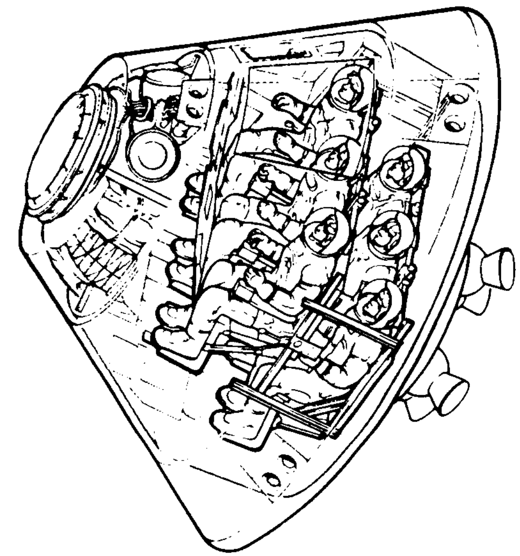
Because present studies have determined the need for contingency EVA equipment, the escape capsule requirements are somewhat changed. First, an adapter with an EVA hatch would be required. Second, prebreathing could be accomplished (about 2 hours) using the EVLSS, and the standard 5 psia CM atmosphere could be retained. If 3 or fewer men are used during development flights, the standard seating could be retained. Various other options, such as the Skylab rescue configuration (5 men) are, of course, open.

By requiring suits and EVLSS's for each crewman and donning space in the airlock/adapter, no other contingency LSS is required. The vehicle airlock water loop is used for thermal control during any temporary airlock refuge greater than 47 minutes for 4 men, which is adequate time to don the suits.

The cabin depress/repress capability is again recommended, and additional flood flow gas is highly desirable to extend the time duration available for any repair operations.

ESCAPE CAPSULE FOR DEVELOPMENT FLIGHTS

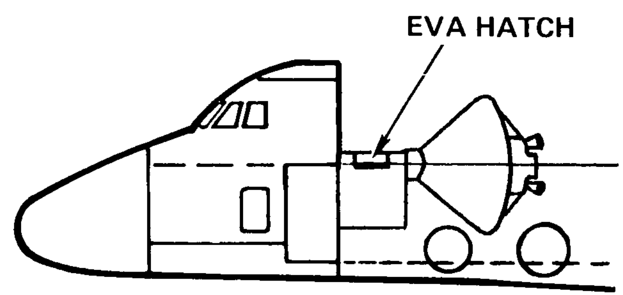
APOLLO COMMAND MODULE
- 5 PSIA O_2
- 3-MAN BASIC CREW
- STRAP ON RETRO ROCKETS
- ALTERNATE 6-MAN MODIFICATION
- ADAPTER/EVA AIRLOCK HATCH
- 10,000 – 15,000 LB



CABIN DEPRESS/REPRESS CAPABILITY

COMMON REQUIREMENTS SET

NO CONTINGENCY LSS REQUIRED *



ADDITIONAL OXYGEN/NITROGEN FLOOD FLOW

CONCLUSIONS & RECOMMENDATIONS

CONCLUSIONS AND RECOMMENDATIONS

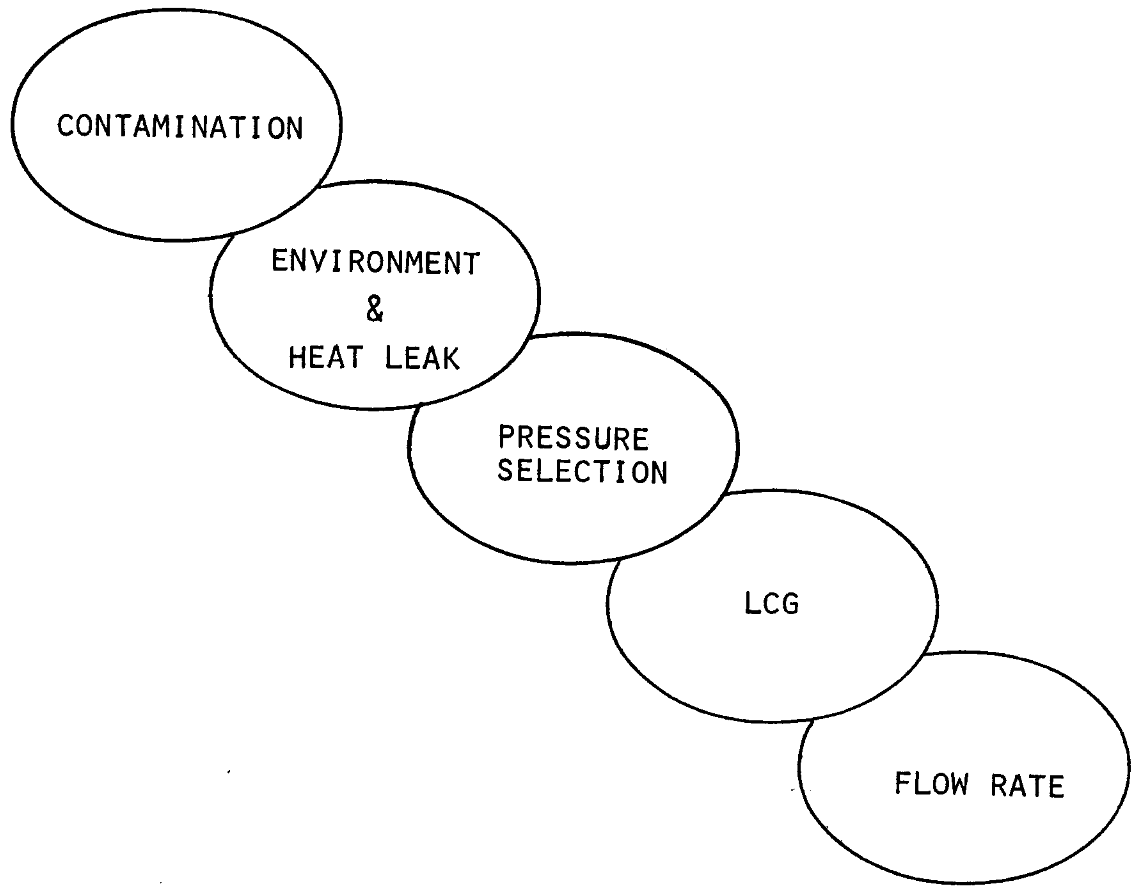
- ADDITIONAL STUDY ON CREDIBILITY OF HAZARDS IS NEEDED
- IMPLEMENT A TRACKING/COLLISION AVOIDANCE SYSTEM FOR ORBITING DEBRIS
- ACCIDENTAL DECOMPRESSION IS MOST LIKELY AT EFFECTIVE HOLE DIAMETERS OF 1/2" OR LESS, AND THE CAPABILITY FOR SHIRTSLEEVE RE-ENTRY SHOULD BE PROVIDED. A REDUCED PRESSURE CABIN IN THE 8-10 PSIA RANGE IS RECOMMENDED FOR SHIRTSLEEVE RE-ENTRY.
- ACCIDENTAL DECOMPRESSION IS LESS LIKELY BUT VIABLE FOR LARGER HOLES. PRESSURE SUITS SHOULD BE WORN DURING KNOWN HAZARDOUS OPERATIONS. FLOOD FLOW SUITABLE TO MAINTAIN CABIN PRESSURE DURING SUIT DONNING SHOULD BE PROVIDED TO PROTECT AGAINST HAZARDS WHICH CANNOT BE ANTICIPATED. FURTHER STUDY IS REQUIRED TO DETERMINE THE EFFECTIVE HOLE SIZE DESIGN VALUE.
- ACCIDENTAL DECOMPRESSION COMBINED WITH INABILITY TO RE-ENTER IS VIABLE, AND THE CAPABILITY FOR ON-ORBIT RESCUE OR ESCAPE SHOULD BE PROVIDED. PRESSURE SUITS PLUS RESCUE IS RECOMMENDED FOR OPERATIONAL FLIGHTS.
- DEVELOPMENT FLIGHTS REQUIRE SPECIAL PROVISIONS FOR SAFETY
- FURTHER DEFINITION OF AVIONICS CAPABILITIES AND IMPACTS TO PERFORM MINIMUM FUNCTIONS FOR REDUCED CABIN PRESSURE RE-ENTRY AND ON-ORBIT STABILIZATION IS NEEDED
- EVALUATE DOCKING MODULE FOR USE AS CARRY-UP RESCUE DEVICE
- INVESTIGATE CABIN SMOKE CONTAMINATION POTENTIAL AND EFFECTS ON VISIBILITY. EVALUATE ECS CAPABILITY/IMPACT FOR SMOKE SCRUBBING.
- NO REQUIREMENT IDENTIFIED FOR SUITS IN SORTIE MODULE
- NO REQUIREMENT IDENTIFIED FOR 15 SEC. EMERGENCY AIRLOCK REPRESS TO 3.25 PSIA
- PURSUE THE STUDY OF THE PRELIMINARY EMERGENCY SYSTEM, DEFINED ON THE PRECEDING PAGES, AND ITS DERIVATIVES

X SUPPORTING STUDIES

SUPPORTING STUDIES

Several areas of study apply to the EVA/IVA requirements in an overall way, rather than to one specific area. Discussion of these studies is grouped in this section.

SUPPORTING STUDIES



CONTAMINATION

CONTAMINATION EFFECTS

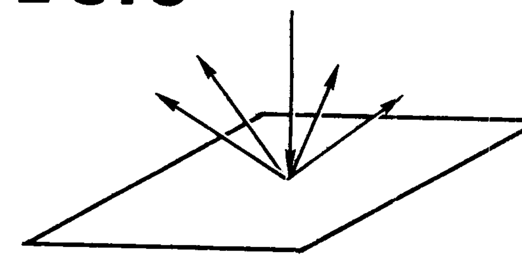
Contamination effects are divided into those resulting from deposition on sensitive optical or thermal control surfaces, and those resulting from obstruction of the field of view of sensors. The latter is generally less serious, because the contaminant cloud clears due to radial expansion and atmospheric/solar forces (if it is not resupplied).

Deposition on surfaces can be serious if the dwell time of the contaminant is long. It can cause spectral absorption, scattering if the film is not uniform, and optical interference. High-molecular-weight components, such as those off-gassed from greases, paints, adhesives and elastomers, and some biological trace contaminants are especially harmful because they become tenacious if photopolymerized by solar UV and other space radiation. In addition, many off-gassing products deposit and stick at room temperatures, as is commonly observed by the film inside car windows produced by the vinyl upholstery. Interference effects are illustrated in one of the curves, showing that a 5nm (50 Å) film of MgF_2 can decrease UV reflectance by 80%. Effects of film thickness on the emittance of a polished surface are illustrated on the other figure. Emittance, and, similarly, infrared absorptance, are adversely affected by water vapor and other films greater than about 0.1 micron thick.

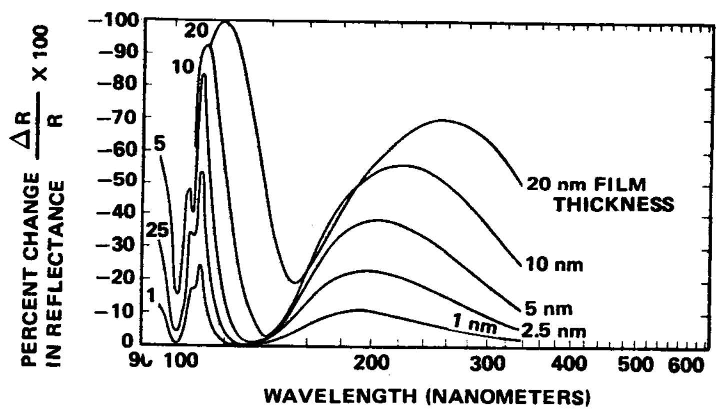
Particulate contamination such as lint is very serious as the particles cause diffraction and can obstruct spectrometer slits. Studies on the Large Space Telescope have shown that particulate contamination levels equivalent to a class 10,000, and extrapolated to 0.1 micron particle size, is required for that program. The EVA system can be a serious lint source.

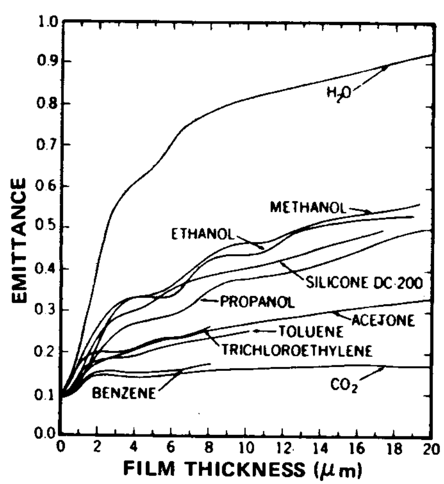
Scattering and absorption by the contaminant cloud is not expected to be a significant problem as long as the cloud contains only vapor constituents. This is true on Skylab, where the numbers of contaminant molecules are less than those in the residual atmosphere. If particulates are in the cloud, such as ice crystals or lint particles, scattering and absorption can be a substantial problem.

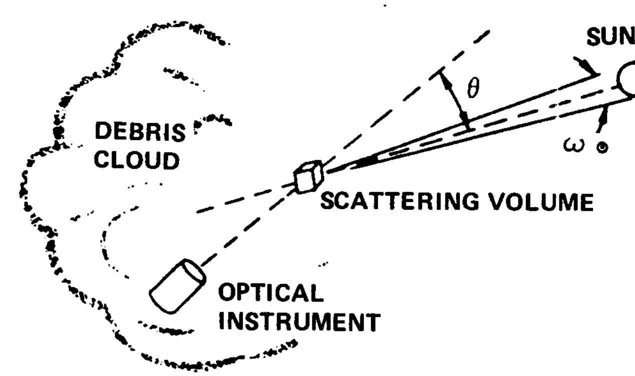
CONTAMINATION EFFECTS



- DEPOSITION
  - ABSORPTION & SCATTERING
  - INTERFERENCE FILM
  - CHEMICAL REACTION
  - PARTICULATE DIFFRACTION
- OBSTRUCTION
  - SCATTERING
  - ABSORPTION
  - COMPARISON TO UPPER ATMOSPHERE







THE CONTAMINANT CLOUD

Once an effuent is ejected from a spacecraft or astronaut, it will disperse at a rate dependent on the velocities of the molecules or particles. Vapor clouds expand quite rapidly, as molecular velocities are on the order of thousands of feet per second. Particle velocities are on the order of meters/second for ice crystals, and cm/sec for lint.

Return mechanisms include particle or molecule self scattering, gravitational forces, and electrical forces. Self-scattering returns some molecules or particles, but is generally small, and almost all vapor molecules will follow line-of-sight trajectories until they interact with aerodynamic drag or solar radiation pressure. Gravitational and electrical forces are also extremely small with vapors. Particles, on the other hand, can obtain significant electrical forces, and will tend to become trapped on surfaces. Thus, again, particles offer a serious problem.

Since effluents follow a line-of-sight trajectory until they interact with the residual atmosphere or other forces, an inverse square law approximation applies well to contamination of nearby objects by an astronaut.

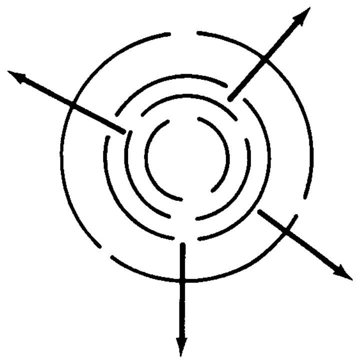
The figure presents analytical predictions of the rate at which 1-micron radius particles will be swept from the shuttle area by aerodynamic drag and solar radiation pressure. It does not include other force interactions. It is seen that clearing times are quite short.

Particle lifetimes in space are of concern, as water vapor from expendable heat rejection systems would be expected to experience some nucleation and form ice crystals. The ice crystals would then sublime in the presence of solar radiation, and decay exponentially. Including both sublimation and drag, a 1-micron ice particle has a life time of about 150 seconds in a 100 N.M. orbit, while a 10-micron particle has a lifetime of about 1000 seconds.

The significance of the clearing and subliming considerations is, from the ice particle viewpoint alone, that expendable heat rejection systems should not be used near a sensitive experiment on which nucleated ice particles could be trapped, or during a mission when the delay for clearing cannot be tolerated.

THE CONTAMINANT CLOUD

RADIAL EXPANSION



- MOLECULAR VELOCITIES O. M. THOUSANDS OF FPS
- PARTICULATE VELOCITIES O. M. CM/SEC TO METERS/SEC
- RETURN MECHANISMS
- LINE OF SIGHT TRANSPORT DOMINANT

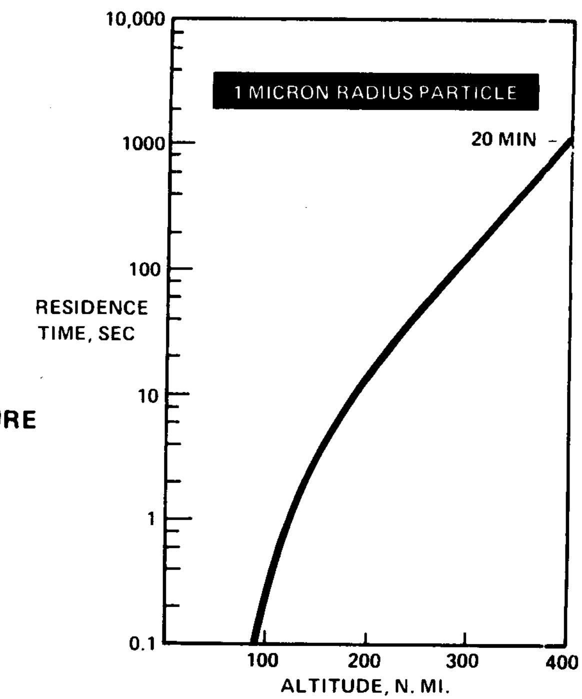
CLEARANCE

SWEEPING

- AERODYNAMIC DRAG
- SOLAR RADIATION PRESSURE

PARTICLE LIFETIME

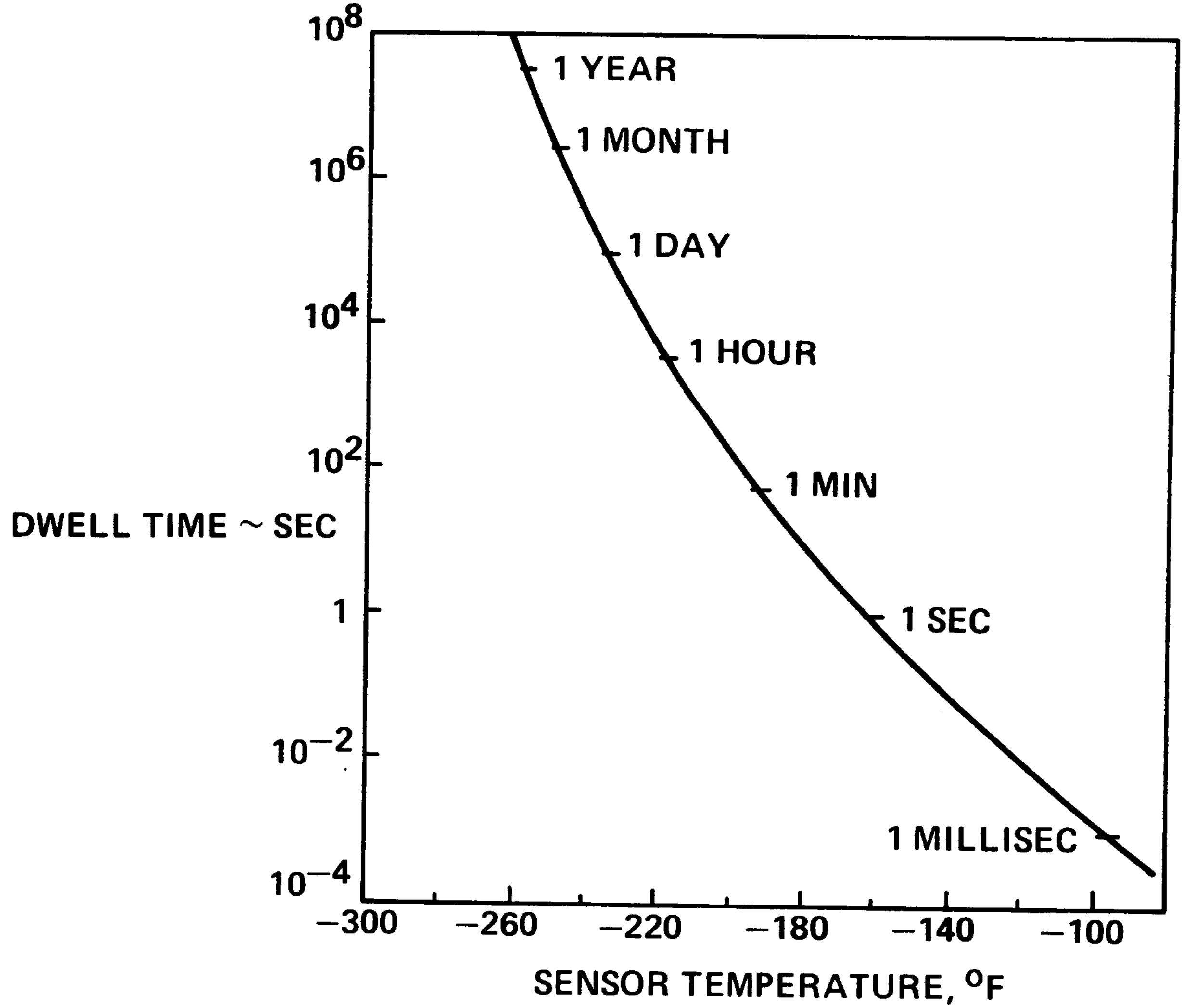
- SUBLIMATION



WATER VAPOR DWELL TIME

The opposing chart shows the dwell time for water vapor as a function of the sensor temperature. If the incident rate of water vapor is less than the surface density of water vapor divided by the dwell time, no accumulation will occur. After deposition of the first few monolayers of water vapor, the surface density remains constant at 1.038×10^{15} molecules/cm^2.

WATER VAPOR DWELL TIME



WATER VAPOR DEPOSITION CHARACTERISTICS

The opposing chart is very significant to considerations of open loop or expendable water evaporation or sublimation heat rejection systems, as well as space suit leakage. It shows the minimum allowable sensor temperature for zero frost accumulation as a function of the line-of-sight distance separating the source and sensor. It also illustrates the effect of directing the exhaust from the expendable water evaporation heat rejection system.

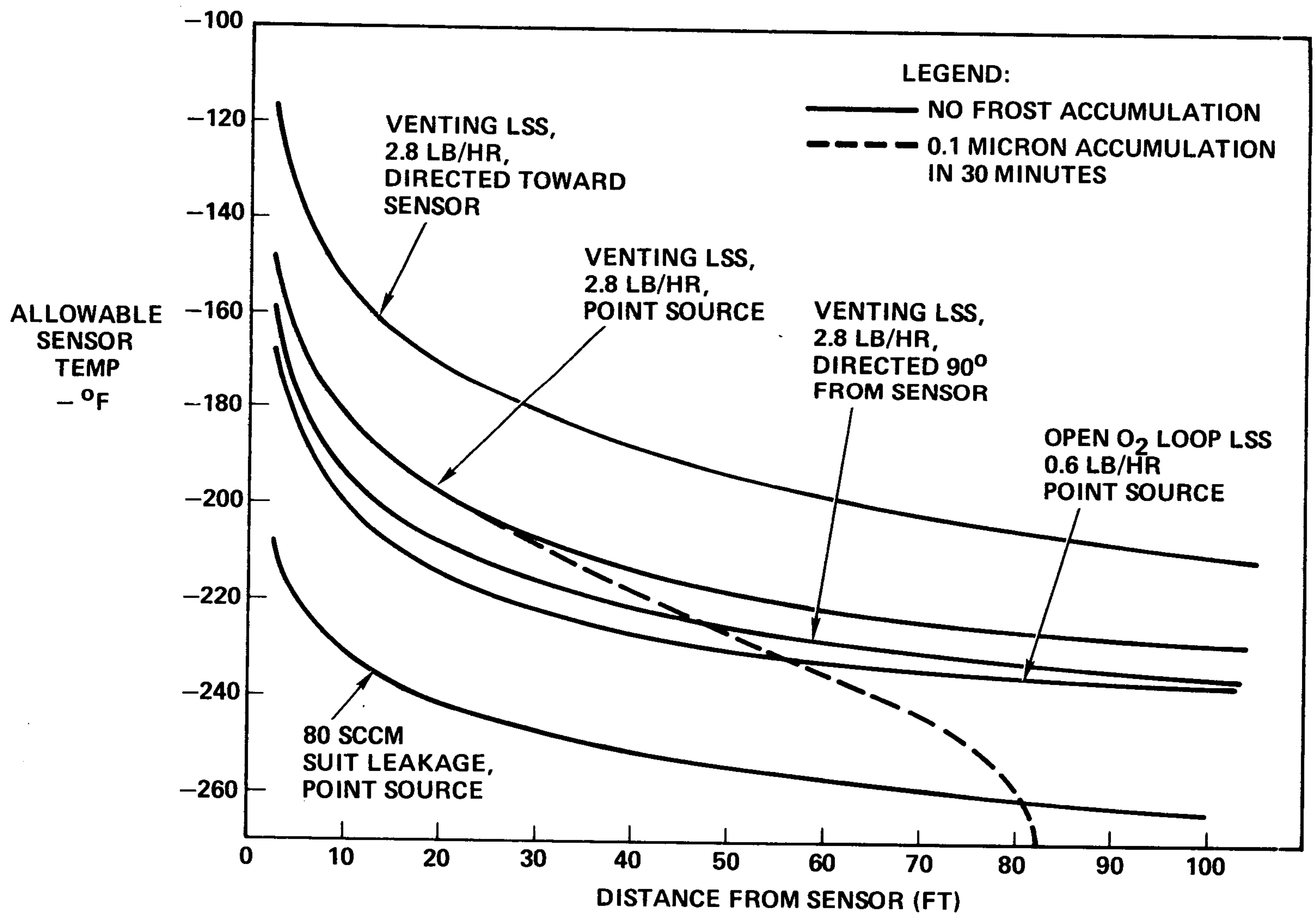
Maximum vapor production rate for a liquid cooled/open loop oxygen system (like the Skylab ALSA) is about 0.6 lb/hr, and for a closed-loop expendable water vaporization or sublimation system (like the Apollo PLSS) is 2.8 lb/hr (for the orbiter EVA metabolic rates). The figure shows the minimum allowable sensor temperature to be about -150°F for the expendable system when working nearby (2-1/2 feet away), if the vapor is allowed to uniformly distribute itself (point source). If a directed exhaust is employed, the allowable temperature drops to -160°F if the exhaust is never aimed within 90° of the sensor, and would be still lower if always aimed 180° away. When exhausted directly toward the sensor, the allowable temperature climbs to -120°F. By exercising reasonable operational caution, the directed vent appears to offer some advantage.

The open-loop system at 2-1/2 feet, calculated as a point source, permits working around -170°F surfaces. Water vapor in suit leakage, evaluated at maximum crewman moisture evaporation of 0.6 lb/hr and 80 sccm suit leakage rate, would prohibit working near surfaces colder than about -210°F.

The dashed line shows the venting LSS case (point source) for permitting a frost accumulation of 0.1 micron in 30 minutes, a practical concession for no significant effects. It is seen that no benefit occurs near the sensor. Another important conclusion which can be drawn from the figure is that cryogenically cooled sensors (for example, LN_2 at -320°F) will be sensitive to crewman water production, even at the opposite end of the payload bay.

By conducting a detailed payload sensor study of mission model payloads, these curves were used to identify their potential water vapor sensitivity. The next chart considers the credible conditions under which this potential may be realized.

WATER VAPOR DEPOSITION CHARACTERISTICS



CREDIBLE WATER VAPOR SENSITIVITIES

Current water vapor sensitive payloads are protected from frost deposition and retention by countermeasures, and shuttle payloads will, undoubtedly, also be protected. Contamination covers, deployed once the contamination has cleared, is a common approach, albeit not always a successful one.

Direct deposition occurs when no shield intervenes between the contaminant source and the cooled sensor. It can be expected to occur in several real EVA situations. One is EVA participation in sorties, such as infrared earth observations or astronomy, and can occur in two ways; (1) a cost-effective austere design that replaces automated contaminant cover actuation with simple EVA actuation, and (2) more likely, a save-the-mission EVA actuation of a malfunctioned cover. This latter is also very significant to the launch of satellite payloads by upper stages, where the contamination cover would probably be opened during escort checkout, before firing the upper stage. EVA could save the mission by manual removal of a malfunctioned cover. Deployment mechanisms, including contamination covers, are notoriously unreliable. To cite two unclassified examples, OV-1 and Ranger both probably experienced such malfunctions.

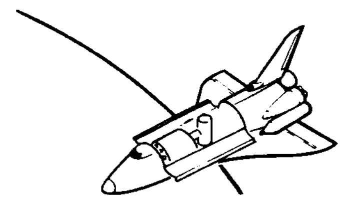
External temperatures on spacecraft (and inside the orbiter cargo bay) vary greatly, and can get extremely cold. For instance, during an earth observation sortie, the cargo bay may be about -20°F, while it can reach -115°F or less during an astronomy sortie. The cold side of a large attached free-flyer could drop below -200°F. Many physics satellites have experienced sensor frosting, thought to result from secondary evaporation. A delay or re-orientation to accelerate evaporation prior to opening covers or resuming observations would be highly undesirable, and restrictive to the use of a water vapor venting device. The magnitude of the problem is an individual payload consideration.

While a wait or re-orientation for re-evaporation of frost from a surface near a covered sensor is undesirable, it would be thought to be mainly an inconvenience. Experience on Nimbus, where it was calculated that frost on a sensor would completely clear in 9 days, showed that clearing did not occur during the entire 2-month lifetime of the experiment. In this case combined effects with other contaminants were thought to have prevented re-evaporation.

CREDIBLE WATER VAPOR SENSITIVITIES

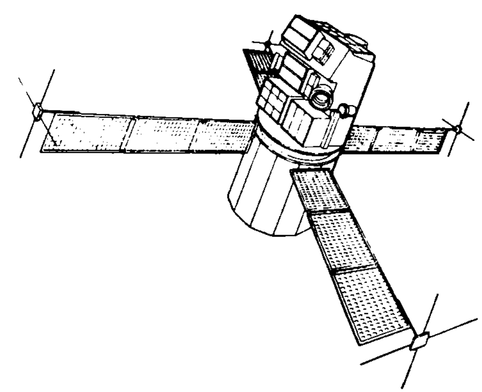
DIRECT DEPOSITION

- SORTIE EVA PARTICIPATION
- CONTAMINATION COVER MALFUNCTION



RE-EVAPORATION AND SECONDARY DEPOSITION

- WIDE STRUCTURAL TEMPERATURE VARIATIONS
- SORTIE PAYLOADS
- FREE FLYERS



DELAY FOR CLEARING

- NIMBUS

CONTAMINATION CONCLUSIONS

WATER VAPOR

- Credible cases exist where EVA is desired and direct or secondary deposition can occur on sensitive payload surfaces
- Current Skylab and Apollo LSS's are not suitable for use near surfaces cooled below -170°F and -150°F, respectively

PARTICULATE

- Potentially serious problem
- Improvement needed over particulate cleanliness of current suits and LSS's

ORGANIC CONTAMINANTS

- More detrimental than water vapor
- Improvement needed over current suits and LSS's

ENVIRONMENT

&

HEAT LEAK

EVA ENVIRONMENTS & CONTACT TEMPERATURES ANALYSIS CASES

A 55-node geometrical model was constructed to model the orbiter in the payload deployed and retracted positions indicated in the sketch. The astronaut was modeled by a unit cube and placed in the 10 locations shown. Analyses were carried out for the orbital conditions depicted, and worst case hot environments and contact temperatures were determined. A total of 13 computer runs were made by being selective in the combinations analyzed.

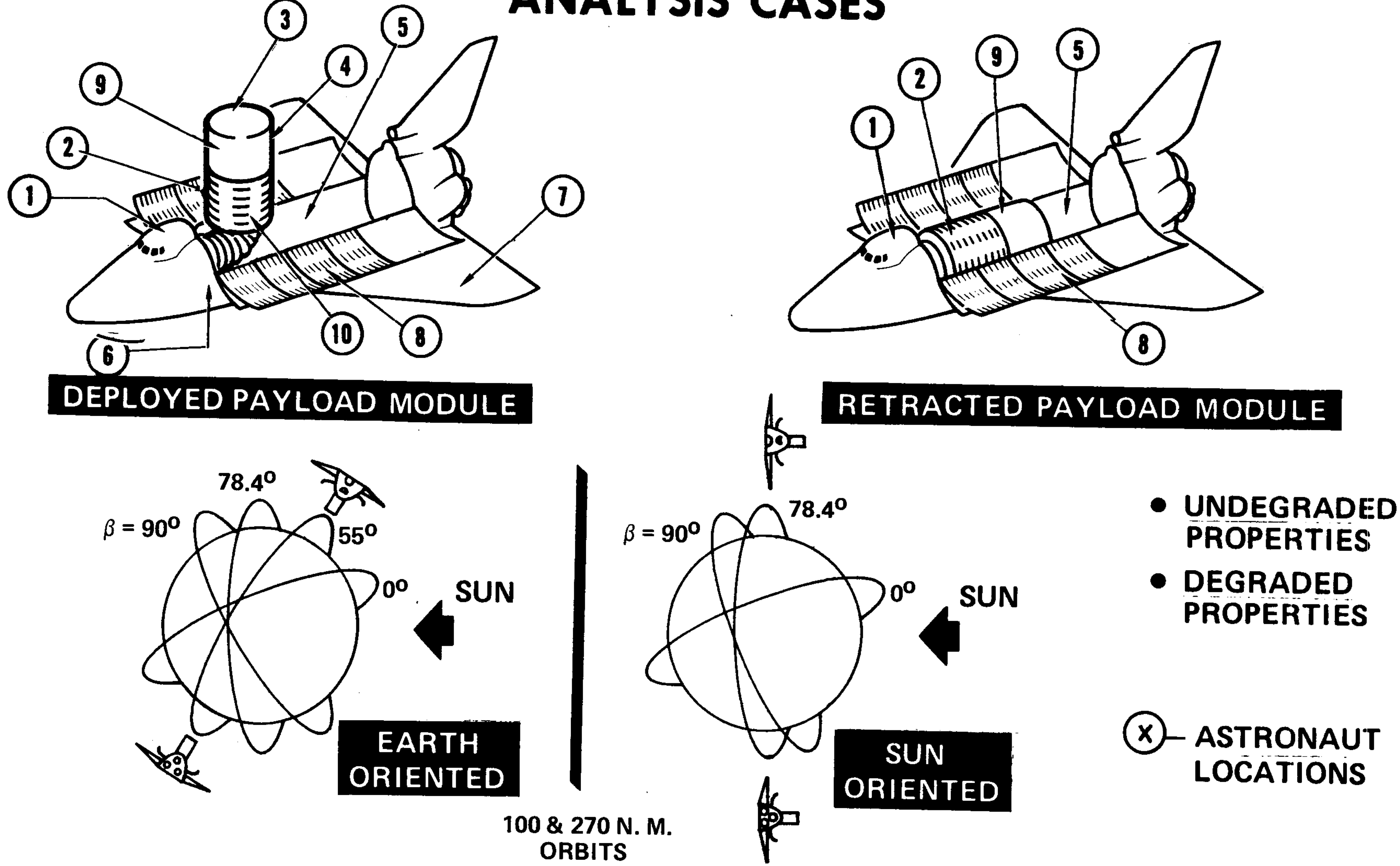
The LOckheed Heat Rate Package (LOHARP) computer routine was used to obtain incident fluxes on all astronaut and spacecraft nodes, including self-blockage and multiple reflections. Supplementary analyses were carried out to add radiant emission interchange by spacecraft surfaces and to determine contact temperatures for the worst case heating conditions. For this a steady-state adiabatic surface approximation was used (which is good for cases with small heating variations around an orbit, and applies to the worst case situations obtained).

Undegraded properties values of α/ε = .4, ε = .8 were used for all exterior orbiter surface areas and inside the cargo bay. Radiator properties of α = .2, ε = .92 were used (orbiter and module radiators), and also applied to inside the cargo bay door. Radiator temperatures of adiabatic +70°F were assigned. Module properties of α/ε = .3, ε = .9 were used. The module dimensions are 14 ft in diameter by 40 ft in length, with the first 20 ft being radiator surface.

For degraded properties, all α's were assumed to degrade to 0.8, except that the radiators were left unchanged.

EVA ENVIRONMENTS AND CONTACT TEMPERATURES

ANALYSIS CASES



MAXIMUM AND MINIMUM AVERAGE FLUX AND CONTACT TEMPERATURES

Maximum average incident flux values are given for both the deployed and retracted payload module configurations, with undegraded and degraded properties. Flux at solar and infrared wavelengths are distinguished so that the effect on absorbed energy may be determined during EMU design. To compute average fluxes on an astronaut, a model attributing 20% of his projected area to his back, front, and each side, and 10% to upward and downward projected areas, was used. The astronaut was then oriented in such a way as to obtain the maximum average flux. Resulting orientations are shown on the chart.

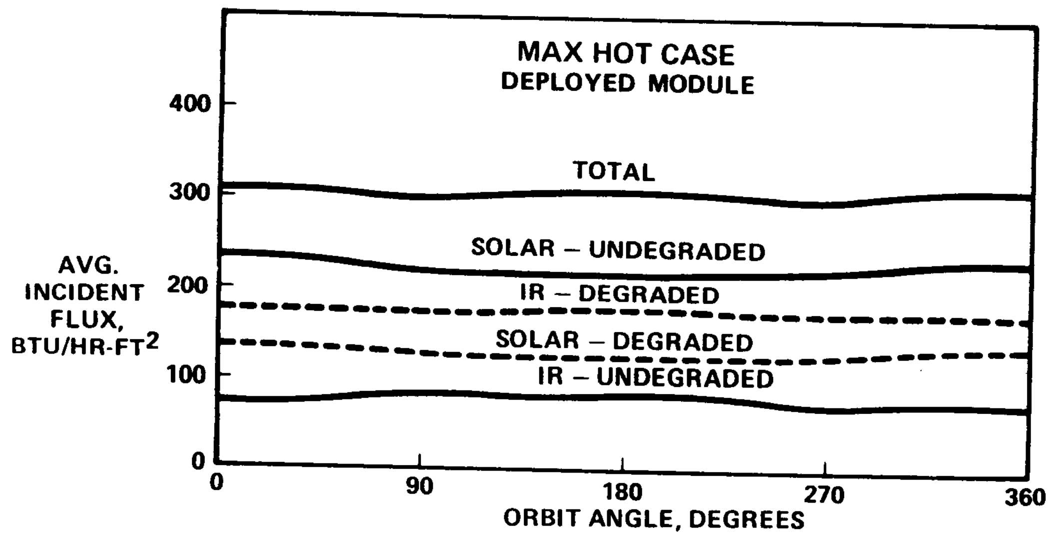
It is seen that the worst case for both solar and IR occurs with the astronaut in the cargo bay with the payload module retracted. The high average values are a result of cavity effects similar to lunar craters.

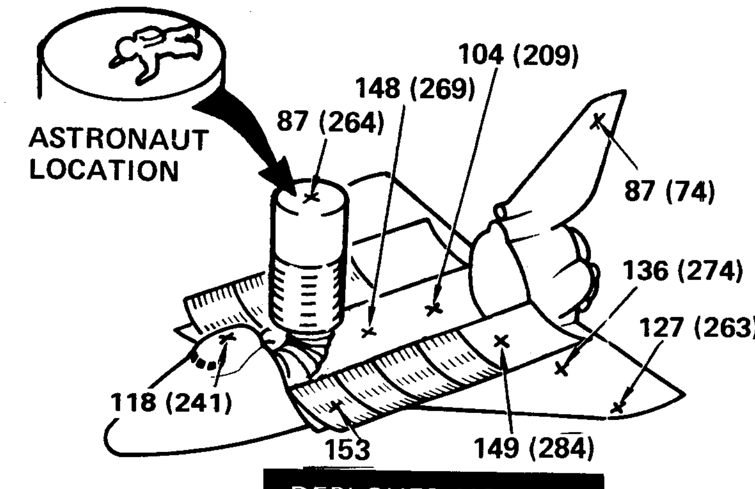
Contact temperatures are also given, and are similarly quite high, reaching 269°F in the cargo bay and 285°F on the cargo bay doors.

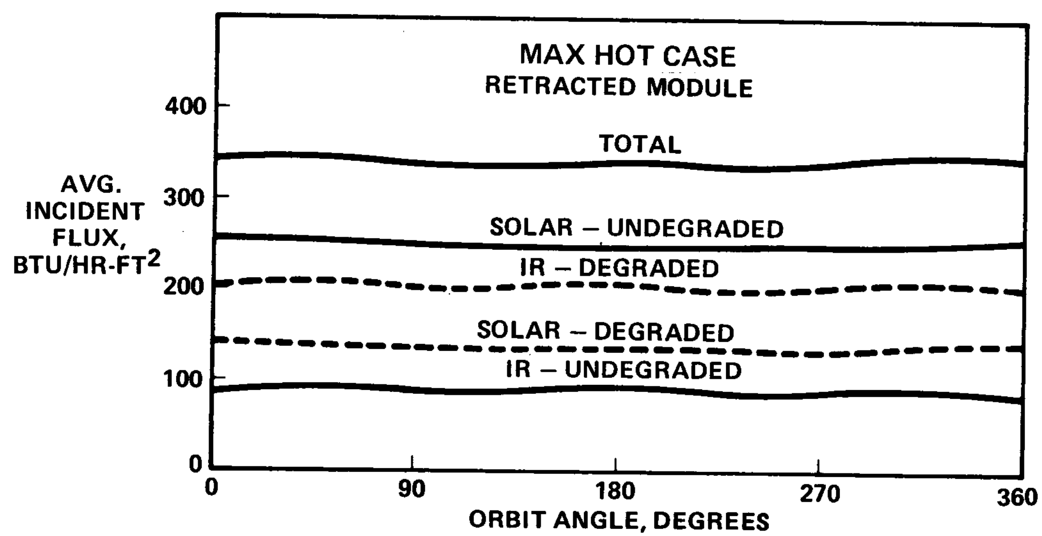
Worst cold case average fluxes and contact temperatures were computed based on Rockwell cold case temperature profiles. For an orbit with the solar vector perpendicular to the orbit plane and the belly earth-oriented, the cargo bay faces deep space and soaks to -263°F. The average environmental flux incident on an astronaut in the cargo bay is only about 1 BTU/hr-ft^2 under these conditions. For the same orbit, but the cargo bay earth-oriented, the minimum temperature occurs on the orbiter belly, and soaks to a value of -281°F. Corresponding average flux incident on an astronaut positioned there is only 0.7 BTU/hr-ft^2.

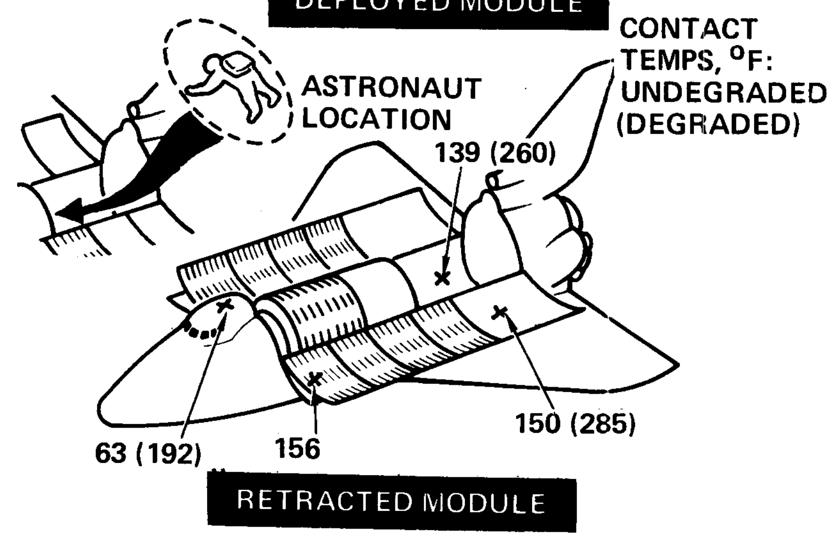
MAXIMUM AVERAGE FLUX AND CONTACT TEMPERATURES

β = 78.4°
SUN ORIENTED
100 N. M.







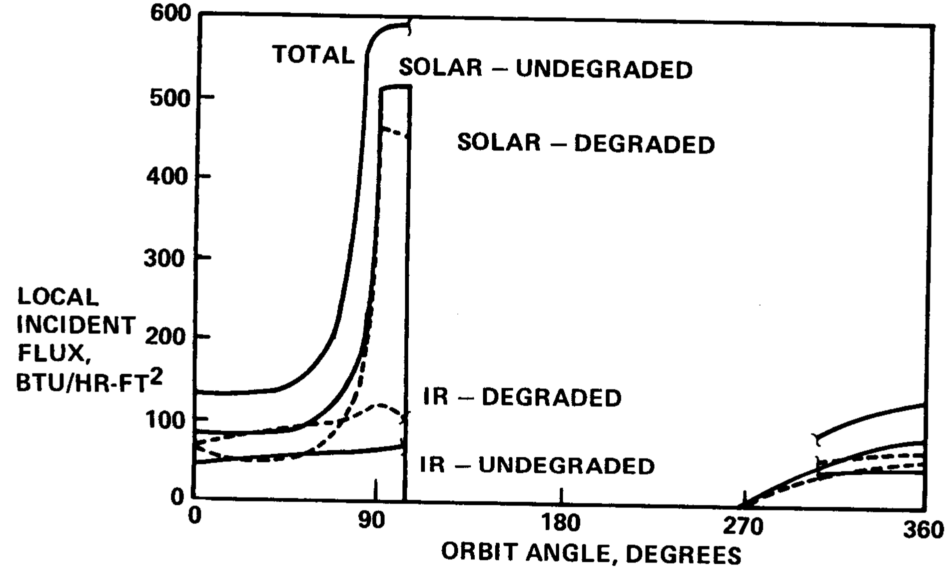


MAXIMUM AND MINIMUM LOCAL FLUX

Maximum local incident fluxes are given on the opposing chart. Maximum local IR occurs in the cargo bay for the same conditions as maximum average flux. Peak local solar flux occurs with the payload deployed at an orbit inclination of zero. The corresponding IR and total local fluxes are limit cases, as the model does not include thermal lag of the vehicle structure. The solar values, however, are independent of thermal lag, and are thus expected to occur.

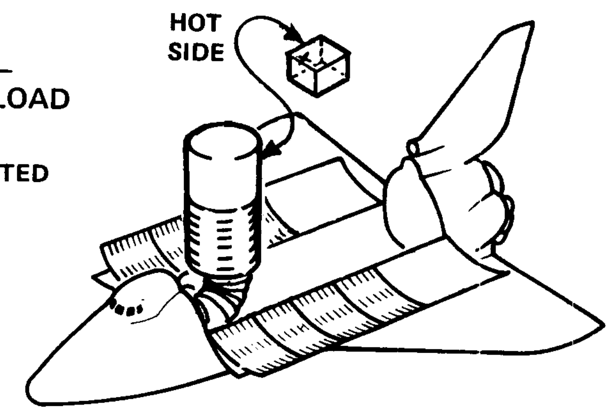
Minimum local flux valves correspond to the minimum cold case average fluxes cited in the previous chart, and approach zero for surfaces facing deep space.

MAXIMUM LOCAL FLUX

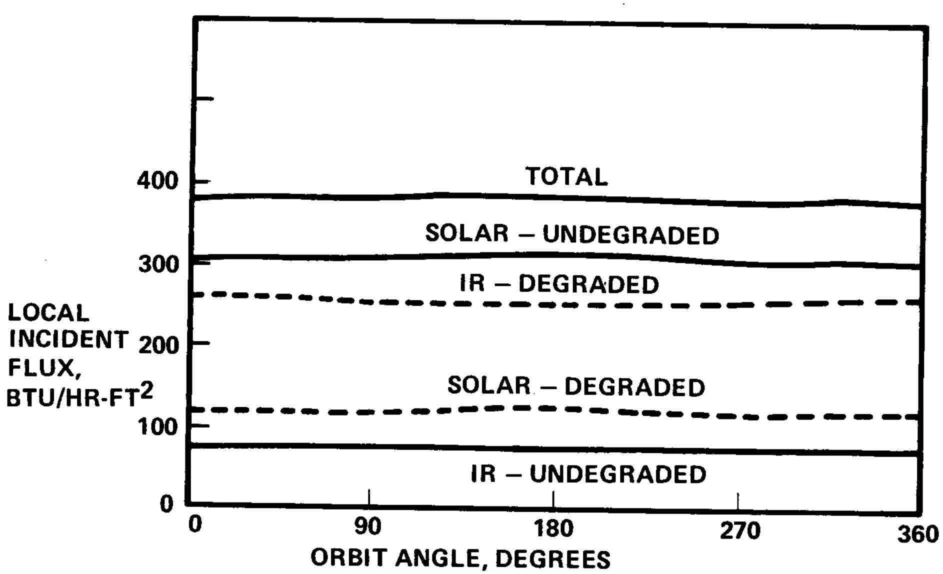


MAX HOT CASE –
DEPLOYED PAYLOAD

- $\beta = 0$
- EARTH ORIENTED
- 100 N. M.

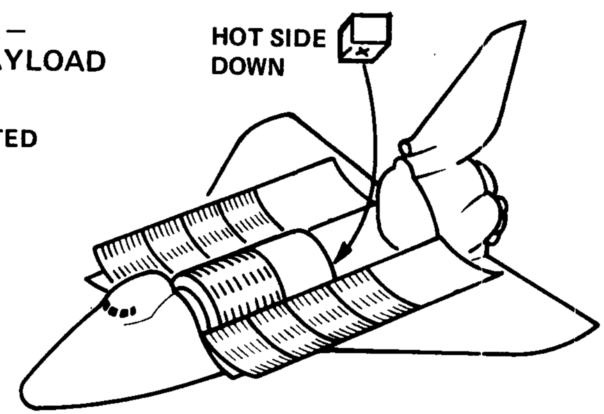


DEPLOYED PAYLOAD



MAX HOT CASE –
RETRACTED PAYLOAD

- $\beta = 78.4^o$
- SUN ORIENTED
- 100 N. M.



RETRACTED MODULE

HEAT LEAK

Based on thermal vacuum test results on Skylab and Apollo suits and EMU's, and geometric models developed by LTV for use with the EMU Digital Simulator, heat leaks were calculated for the worst case environmental conditions. Adjustments were made to account for Shuttle EMU areas and geometry. The results are given on the opposing chart. It should be noted that individual suit and EVLSS heat leaks sum to a number greater than the combined EMU, which results from blockage effects in the integrated configuration.

The preliminary recommendation is for Apollo suit-type insulation on the entire EMU, as these values are currently obtainable on the EVLSS, too, by judicious design. It is expected that careful design can result in very little mobility degradation using concepts previously identified by LTV. Further studies, however, should be carried out in insulation garment design and test; and environments should be refined by a more detailed transient analysis.

For the case of unpressurized IV emergencies, it is conceivable that cabin temperatures will become uncomfortably cold in the case of a 96 hour wait for rescue. Analyses indicate the average cabin temperature would approach -190°F as steady state conditions are approached. Again, transient analyses are needed. It is possible that a few layers of insulation should be integrated onto the IV emergency suit.

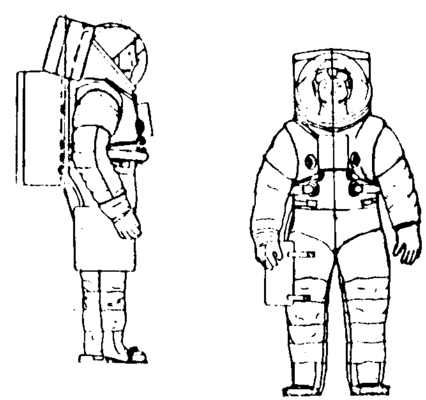
HEAT LEAK

Hot Case / Cold Case	Shuttle Suit Leak (BTU/HR)	Shuttle EMU Leak (BTU/HR)	Shuttle EVLSS, ETC. Leak (BTU/HR)
Skylab Suit Type Insulation	320 / -350	430 / -465	170 / -190
Apollo Suit Type Insulation	220 / -280	300 / -375	120 / -150
Apollo EMU Type Insulation	---	365 / -430	---
Apollo PLSS Type Insulation	---	---	210 / -225

CONSIDERATIONS:

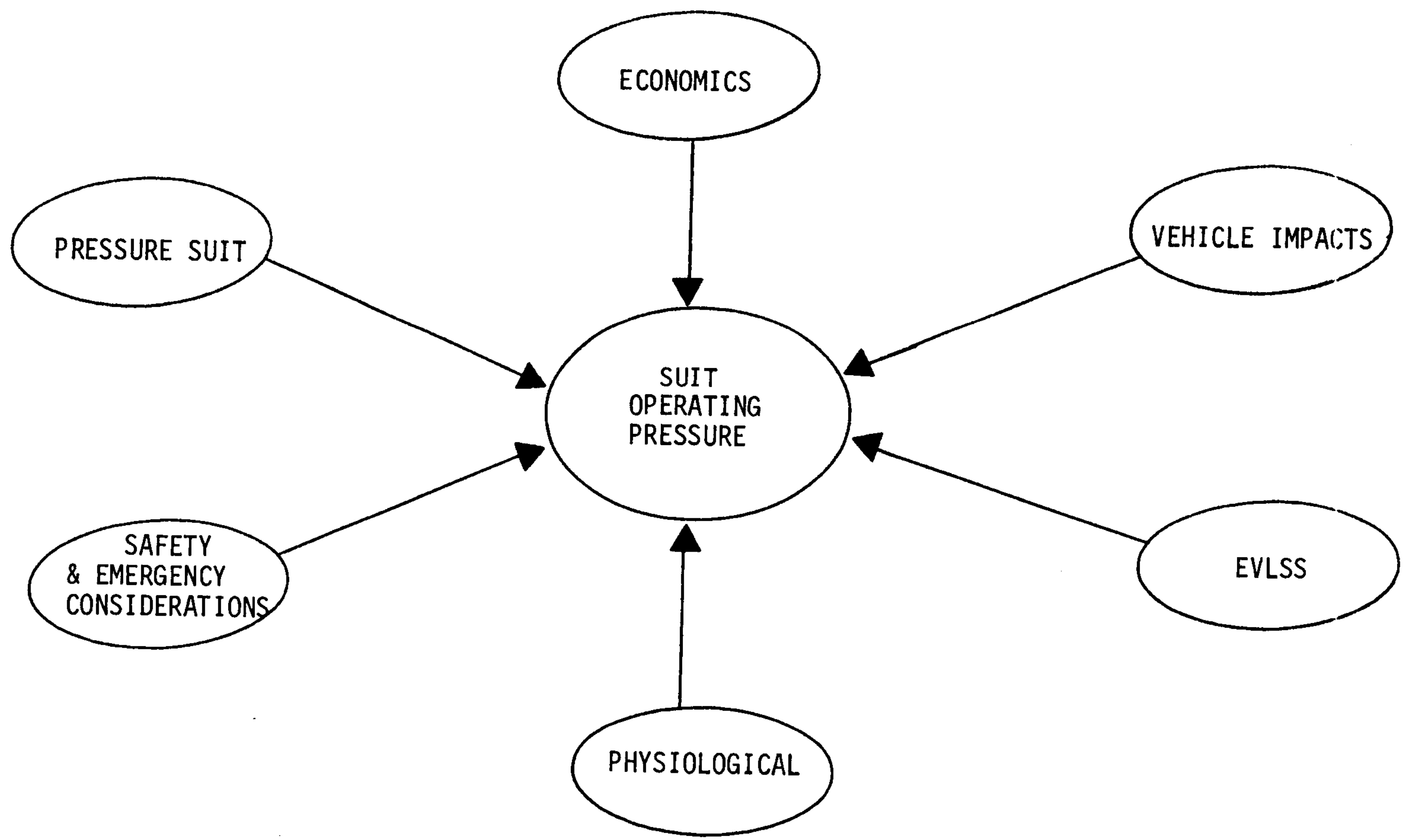
- Mobility
- Comfort
- Insulation Weight
- Heat Rejection System Penalty

RECOMMEND:
- Apollo Suit Type Values
- Insulation Integration Tests
- Further Environment Studies



PRESSURE SELECTION

EVA SYSTEM PRESSURE SELECTION ISSUES



EVA & IVA SYSTEM PRESSURE - PHYSIOLOGICAL CONSIDERATIONS

The human body is normally saturated with nitrogen at an equilibrium pressure equal, or nearly equal, to the ambient partial pressure. A reduction of the ambient pressure can lead to some of this nitrogen coming out of solution with resultant bubble formation and symptoms known as the "bends". This phenomena is the same as that sometimes encountered by divers and other hyperbaric workers. Bends are generally protected against by lengthy prebreathing of pure oxygen to eliminate the dissolved nitrogen prior to decompression or by slow, "stepped" decompression over an extended period.

The first graph (1) shows the prebreathing time required to prevent bends when decompressing from 14.7 psia. Exercise effects, which tend to increase bends incidence, are included. The curves are in agreement with other data (2) that indicate the lower curve represents approximately a 90% certainty that no subjects drawn from the population at large would suffer the bends for the decompression indicated. Similarly, the upper curve represents approximately a 99% probability of no bends for any subjects.

The "knee" in the curve at 5-6 psia final pressure suggests that a suit pressure selected at or above this level would minimize prebreathing requirements. For an EVA crew, where use of the lower curve is justified, a prebreathing requirements of 30 minutes to 6 psia could probably be incorporated during the donning checkout phase of planned EVA, and incur no actual time-lost penalty.

For IV emergency conditions no prebreathing should be required, in order to provide greatest safety. Even though "bends" symptoms do not usually appear for 15-20 minutes, it cannot be guaranteed that contingencies will not last longer, thus an 8 psia IV emergency suit/LSS capability should be provided.

The second graph shows the prebreathing time lost due to interruptions and breathing air. All data shown on this figure are for decompression from sea level to 3.5 psia. These data are significant since it may be necessary to interrupt the prebreathing period to allow donning of various components of the EVA/IVA protective gear. The data on which these curves are based (2) assumes that 50% of the subjects would suffer bends symptoms with no prebreathing. This corresponds to a condition of mild exercise.

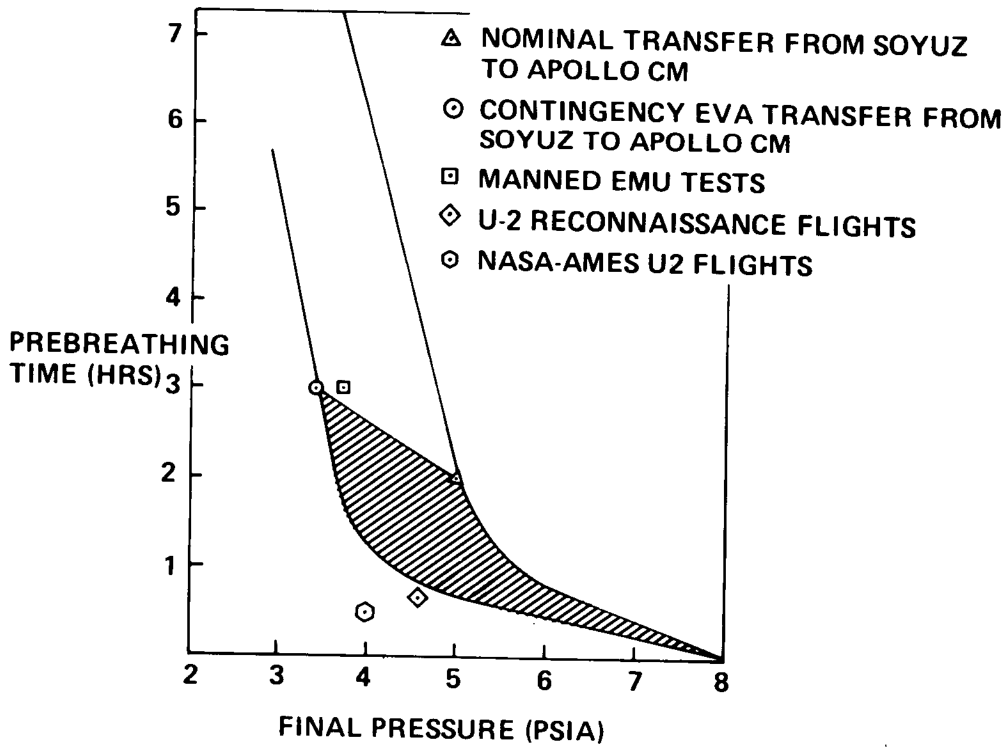
(1) Taken From: Pegner, E.A., et al, "Dissolved Nitrogen and Bends in Oxygen-Nitrogen Mixtures During Exercise at Decreased Pressures", Aerospace Medicine; May 1965.

(2) Taken From: "Compendium of Human Responses to the Aerospace Environment - Vol. III", NASA-CR-1205 (III); November 1968.

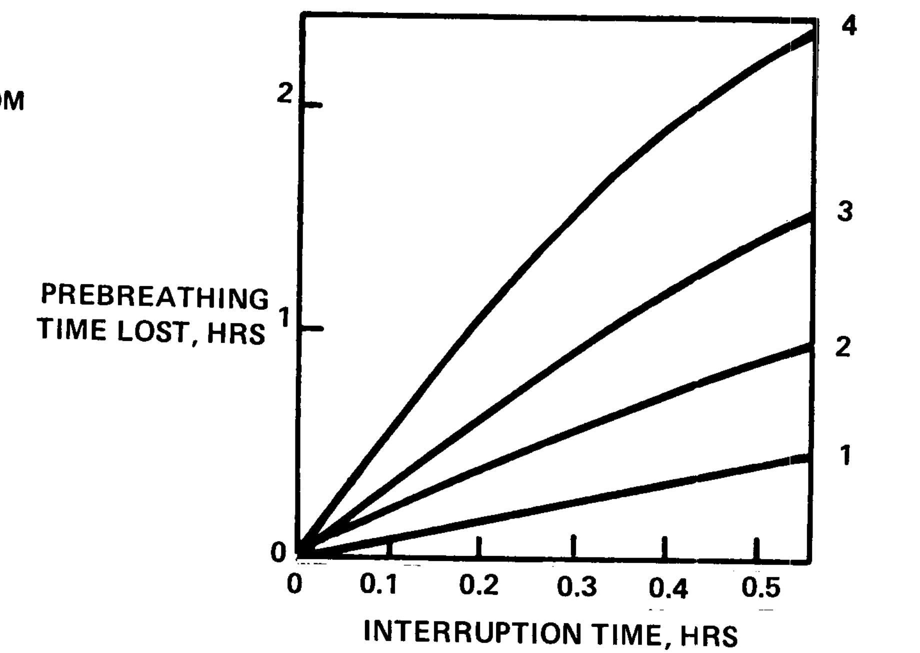
EVA & IVA SYSTEM PRESSURE

PHYSIOLOGICAL CONSIDERATIONS

PREBREATHING TIME AS A FUNCTION OF SUIT PRESSURE



PREBREATHING TIME LOST BY BREATHING AIR FOLLOWING DENITROGENATION



EVA SYSTEM PRESSURE SELECTION HARDWARE CONSIDERATIONS

The opposing chart shows hardware related penalties associated with EVA system pressure selection. All the trade curves are very preliminary in nature, but the trends should remain valid. The suit curves, repeated from the Pressure Suit section, illustrate little expected performance impact if a new suit design is used, as is probable from many other considerations enumerated there.

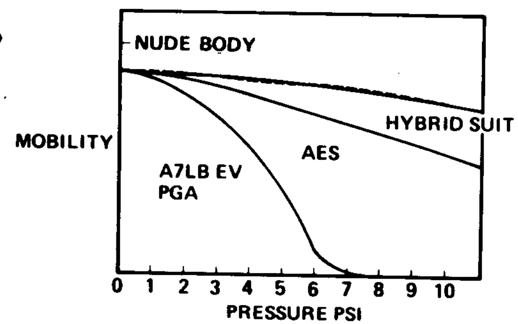
The vehicle scar curve shows that an open loop system is prohibitive at high suit pressures. The open loop system is also undesired from other considerations, such as contamination. The closed loop system oxygen weight is essentially constant with pressure. Either system requires about 28 lbs of prebreathing equipment and consumables at 3.7 psia, 17 lbs at 6 psia, and none at 8 psia (3 EVA's, 2 men each).

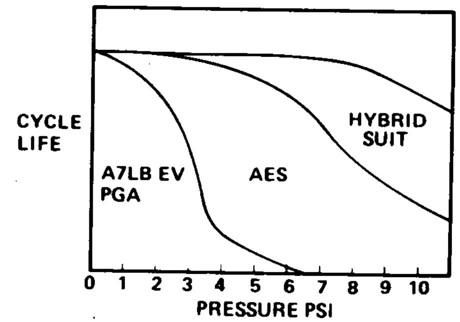
The EVA primary LSS oxygen supply subsystem packaged volume is shown to be almost unaffected by suit pressure. The emergency oxygen pack, to be used either EVA or IV, however, is seen to be quite sensitive to suit pressure. Indeed, it is a strong driver to minimize the suit pressure selected because of the adverse effect of a large EOP on EVA maneuverability and effectiveness.

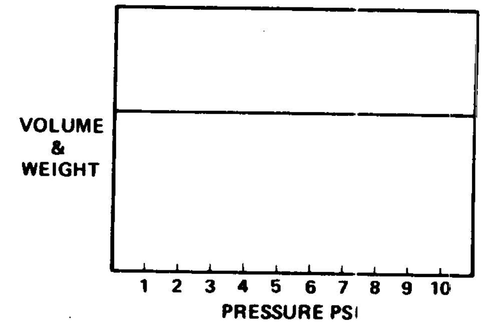
Not shown on the chart is the effect of pressure level on fan power. The power requirements increases with increasing pressure. Opposing this, suit purging during donning is required at pressures significantly less than 8 psia.

EVA SYSTEM PRESSURE SELECTION
HARDWARE CONSIDERATIONS

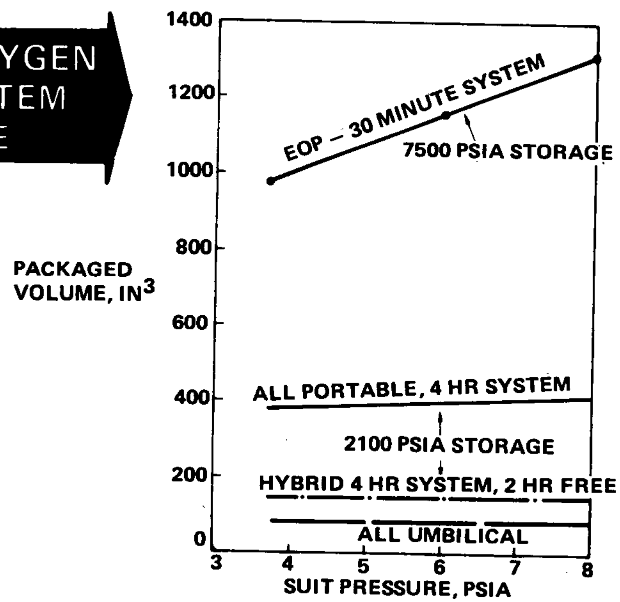
SUITS



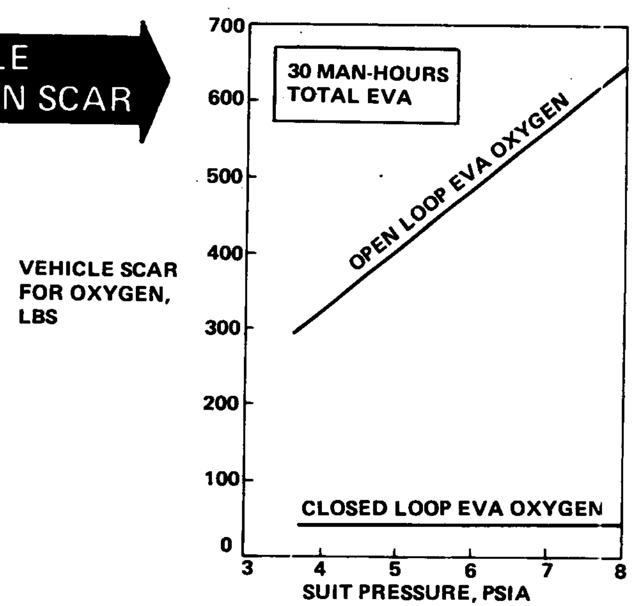




EVA OXYGEN SUBSYSTEM VOLUME



VEHICLE OXYGEN SCAR



EVA SYSTEM PRESSURE - ECONOMIC CONSIDERATIONS

Economic considerations relative to suit pressure selection center around two things - the increased EVA overhead associated with the time lost prebreathing, and the increase or decrease in hardware costs. Neither are straightforward issues.

The value of prebreathing time lost depends on many factors, not the least of which is detailed mission programming. Because of the significance of economics in general, it is safe to assume that operational shuttle flights will be planned to make the most efficient use of every man-hour available on orbit. Thus there is definitely a real cost savings to be realized, at least on some shuttle flights, by eliminating prebreathing. If one were to take a simple - minded approach and say that 10% of the flights needed every man-hour available to achieve the mission, and value the mission at a launch cost of $10M, a man-hour would work out to an average value of $1500 for a 7-day mission. This is in the same ball-park as estimates of man-hour costs relative to payload down-time during servicing of large observatories. Then if one were to assume the approximately 800 EVA's estimated in this study, the lost-time cost would run from $3.8M to $7.6M for a 3-hour prebreathing period to 3.7 psi, depending on whether one-man or two-man EVA's were involved.

Selecting an 8 psi pressure would eliminate the necessity for prebreathing hardware and extra on-board oxygen tankage capacity. The potential savings associated with these items should be considerably under $1M.

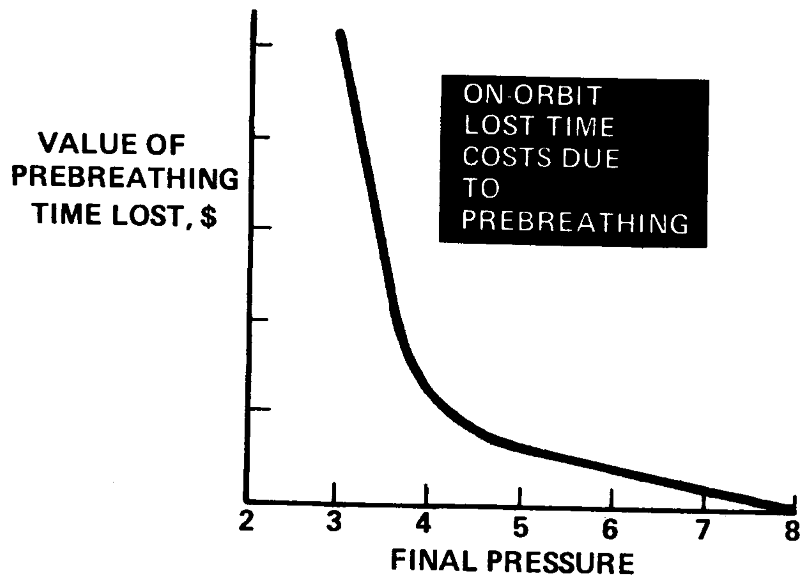
As already discussed, there are many reasons for developing a new EV suit, which in itself should be cost effective regardless of pressure. Nevertheless, if the current A7LB concept were to be used, only modified for suitability at higher pressures, there would be a stair-stepped increase in cost. Above 5 psi extensive redesign would be required. A complete redesign and development should be of the order of magnitude of $1M.

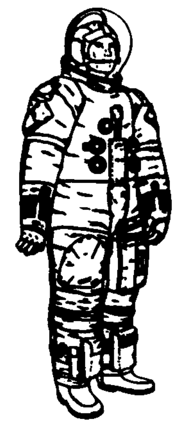
Again, there are many reasons for a new primary EVLSS suited to shuttle requirements. However, if the existing systems were used, changes in operating pressure should have relatively small cost impact, such as regulator and fan/power changes. However, if the Skylab open loop system were to be modified for 8 psi, the vehicle oxygen supply penalty would be severely increased in quantity and represent a significant cost impact.

The EOP represents the most significant hardware cost directly related to pressure, as its size increases almost in direct proportion with pressure. A redesign would be required over existing systems for significant increases above current operating levels. Development costs of a new EOP should not exceed a few $M.

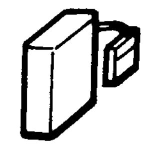
Considering all factors, economics probably favor a pressure in the 5-8 psi region, past the knee in the prebreathing curve.

EVA SYSTEM PRESSURE
ECONOMIC CONSIDERATIONS

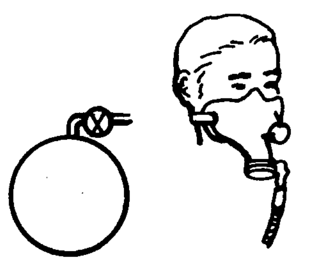




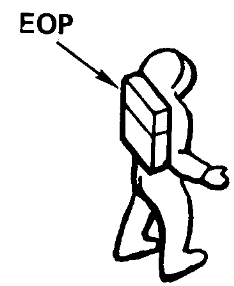
PRESSURE SUIT DEVELOPMENT



PRIMARY EVLSS DEVELOPMENT



PREBREATHING HARDWARE AND TANKAGE



EMERGENCY OXYGEN PACK DEVELOPMENT

EVA SYSTEM PRESSURE - SAFETY AND EMERGENCY CONSIDERATIONS

The opposing chart is largely self-explanatory, and shows a lower-than-8 psi EVA system pressure is favored. If commonality with IV emergency use of the suit and EOP is to be obtained, the suit and EOP must also function at 8 psia.

EVA SYSTEM PRESSURE - SAFETY AND EMERGENCY CONSIDERATIONS

EVA EMERGENCIES

- OXYGEN LEAK - MINIMUM SUIT PRESSURE FAVORED TO EXTEND CONSUMABLES DURATION

IV CABIN PRESSURE LOSS

- USE OF EVA SUIT FOR IV PRESSURE LOSS REQUIRES 8 PSI USEFUL <u>CAPABILITY</u> TO AVOID EMERGENCY PREBREATHING

DESIRED COMMONALITY OF HARDWARE

- EOP FOR IV OR EVA EMERGENCY REQUIRES 8 PSI CAPABILITY FOR IV PRESSURE LOSS, AND ALTERNATE LOWER PRESSURE CAPABILITY IF EVA SYSTEM PRESSURE IS LESS

EVA & IVA SYSTEM PRESSURE - ORBITER CABIN PRESSURE CONSIDERATIONS

The desire to provide as near to an Earth-like environment as possible has been a strong factor in the selection of a 14.7 psia, O_2-N_2 atmosphere for the shuttle orbiter. However, the selection of a somewhat lower pressure, still in the range between commercial aircraft cabin pressures of about 11 psia ($\approx$ 8000 ft. equiv. altitude) and normal sea level, offers many advantages for the EVA/IVA system, particularly during contingency and emergency situations.

The figure (1) indicates the influence of the pressure before decompression (cabin pressure) on the final pressure (suit pressure) that would not be expected to produce the bends. This figure illustrates both the wide range in bends tolerance among the general population and indicates that a reduction in orbiter pressure to 11 psia might allow current suit pressures, or at least in the 5 psia region, to be used without prebreathing.

The data in these curves do not include exercise effects, and are based on only limited data. Thus additional experimental study/verification is needed. Tests which will contribute to the definition of the applicability of this figure are currently under way at Brooks AFB in cooperation with NASA-JSC (2).

Because of the obvious advantages to the EVA/IVA system, and also overall vehicle safety, it is strongly recommended that physiological tests continue and that impacts to the orbiter/payload program be evaluated relative to a lower cabin pressure. The Appendix of this report considers 10 psia cabin impacts.

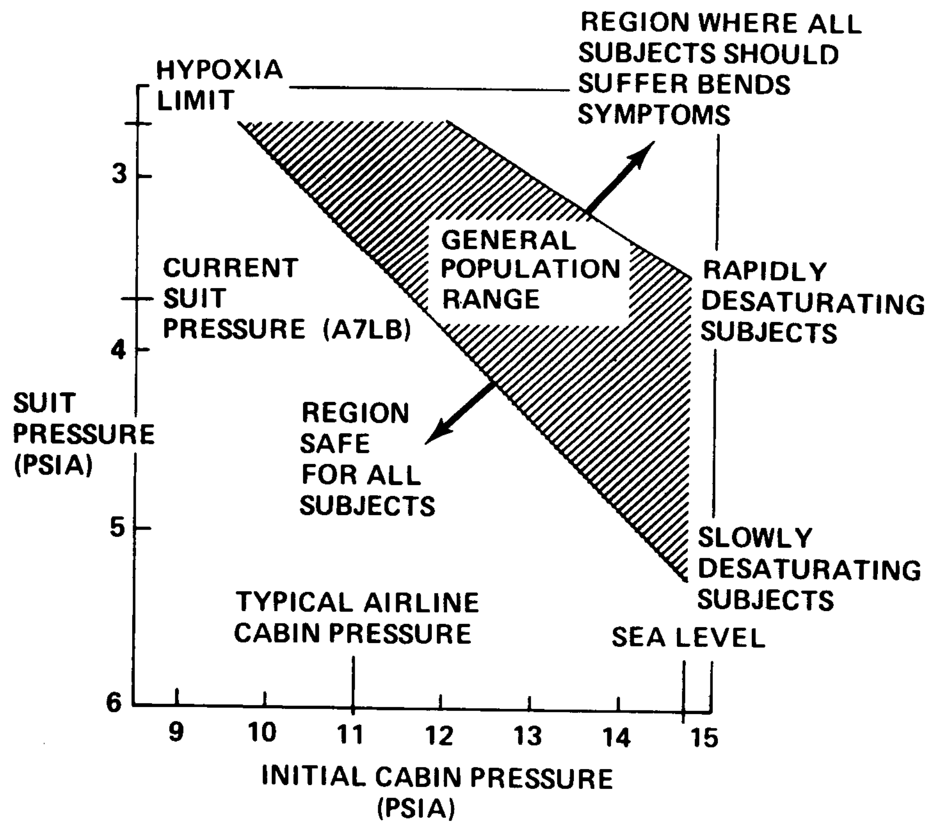
(1) Taken From: Decompression Sickness; W.B. Saunders Co.; Philadelphia; 1951; page 250

(2) Personal communications, D. Horrigan, September and October 1972.

EVA & IVA SYSTEM PRESSURE

ORBITER CABIN PRESSURE CONSIDERATIONS

EFFECTS OF ORBITER CABIN PRESSURE
ON SUIT PRESSURE WITHOUT PREBREATHING



EVA/IVA SYSTEM PRESSURE SELECTION SUMMARY AND CONCLUSIONS

From the preceding charts, summarized on the opposing page, it can be seen there are only two strong well-defined influences to be traded: the undersirable increase in size of the EOP at 8 psia vs the physiological requirement for prebreathing time loss below 8 psia. To really answer this trade, better data on prebreathing requirements in the 5-8 psia final pressure region is needed, and the use of mockups and zero-g simulations to better establish the loss in EVA effectiveness due to EOP size increase should be conducted. In addition, detailed consideration of donning/checkout/prebreathing airlock procedures is needed to see how much real time loss will result from combining these operations. Again, mockups and tests would be desired. Present estimates are that 15-30 minutes of prebreathing will be obtained in the airlock using only projected standard donning and checkout procedures. It is significant that the Russians go to 6 psi without special prebreathing; thus their airlock operations must provide adequate prebreathing.

A recommendation of an 8 psia suit, primary LSS, and EOP is made. If as much as 30 minutes effective prebreathing time can be guaranteed in the airlock, the EOP pressure can be safely reduced to 7 psia. This needs further study.

Reduction of orbiter cabin pressure to a 10-11 psia level should be explored from both vehicle impact and physiological viewpoints, as a real potential for both improved orbiter safety and EVA effectiveness exists. See the Appendix of this report.

EVA/IVA SYSTEM PRESSURE SELECTION

SUMMARY AND CONCLUSIONS

SUMMARY

	FAVORS
• PRESSURE SUIT	< 8 PSI (WEAK INFLUENCE)
• ECONOMICS	5-8 PSI
• VEHICLE	8 PSI (WEAK INFLUENCE)
• PRIMARY EVLSS	ALMOST INDEPENDENT
• EOP	< 8 PSI (STRONG INFLUENCE)
• PHYSIOLOGICAL	8 PSI (MODERATE INFLUENCE 5-8 PSI)
• SAFETY	< 8 PSI (WEAK INFLUENCE)

CONCLUSIONS

- 8 PSI EVA/IVA SYSTEM
- EOP COULD BE DESIGNED FOR 6-7 PSIA, WITH PREBREATHING OBTAINED WITHOUT PENALTY DURING DONNING, IF FURTHER STUDIES SUBSTANTIATE

LCG

LCG REQUIREMENTS

Computer analyses were conducted using the NASA-JSC Metabolic Man model to evaluate LCG inlet temperature requirements and to determine if it is feasible to obtain comfort with no diverter valve adjustment at all.

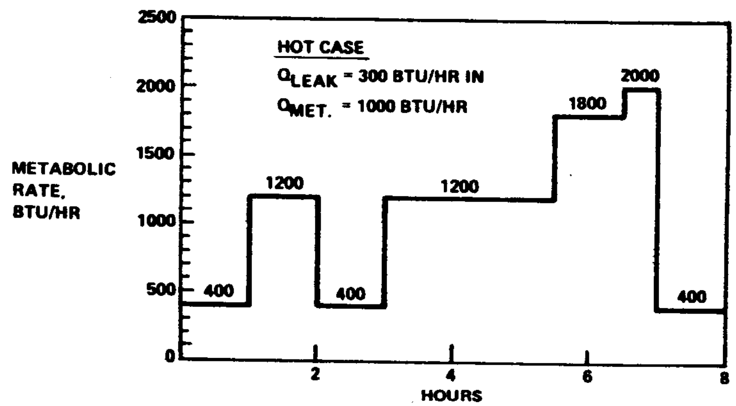
A worst hot case metabolic profile, averaging 1000 BTU/hr and peaking at 2000 BTU/hr was used in the analysis, as illustrated. Analysis conditions were a suit pressure of 8 psia, and an oxygen flowrate of 5.5 ACFM at an inlet temperature of 70°F and dewpoint of 50°F. Environmental heat leak in was 300 BTU/hr. Water inlet temperature was varied parametrically from 45°F to 80°F, and LCG overall conductance (UAG) from 43.5 BTU/hr-°F (nominal Apol-o value) to 400 BTU/hr-°F. Water flowrates of 60, 240 and 480 pph were run.

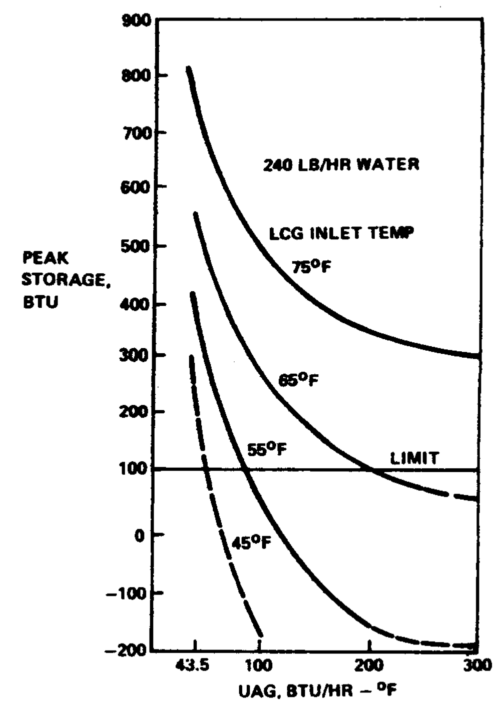
Heat storage profiles were plotted and peak storage values are cross-plotted at 240 lb/hr in the right side graph. For the normal-operation storage limit value of 100 BTU shown, an LCG UAG greater than 43.5 is required at 45° to avoid storing more than 100 BTU. This will likely occur automatically through improved contact when sweating commences, as can be inferred from analysis of Apollo test data.

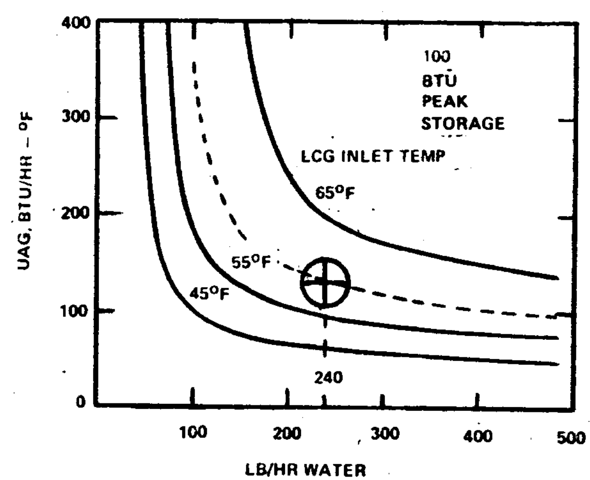
The lower curve is a cross-plot of overall conductance required vs water flowrate for three LCG water inlet temperatures, all at the condition of the 100 BTU peak heat storage limit. The curves all display a sharp knee in the 200-300 pph flow range, indicating that the judicious choice to minimize pump power while maintaining a reasonably low UAG is about the current 240 pph value. This flowrate value was chosen for the EVLSS requirement; at the design point 58°F water inlet temperature, the required UAG is 130 BTU/hr-°F. With an umbilical or ice pack non-venting heat rejection system, LCG inlet temperatures will be in the 55°F-65°F range. Studies at VSD in 1970-1971 have defined a practical concept for fabricating LCG's with UAG values approaching 400.

The LCG analysis was continued to see if use of a high LCG effectiveness, coupled with a high flowrate and inlet temperature, would permit comfort under all conditions without the need for a diverter valve. A number of cases were run, but the most favorable one (80°F inlet temperature, 480 pph, UAG = 400) showed that shivering would still occur at low work loads, while a peak storage of 340 BTU would result at the 2000 BTU/hr metabolic rate. Thus, elimination of the diverter valve based on changes to the transport water system/LCG is not feasible for the metabolic profile studied. Still, an increased effectiveness and inlet temperature would be desirable from the viewpoints of increased comfort and minimal adjustments.

LCG REQUIREMENTS







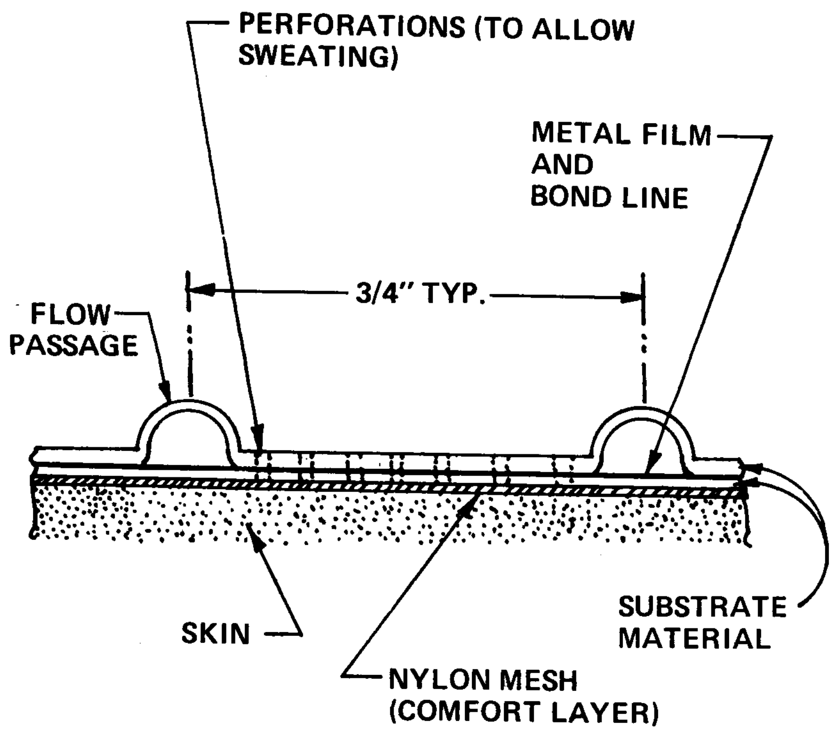
ADVANCED LCG CONCEPT

The accompanying sketch details the VSD high-conductance LCG concept and presents calculated performance. Basically, the concept acts as a finned-tube radiator. Metal film thickness can be considerably reduced by use of a higher conductivity material such as copper or silver. The required 130 Btu/hr-°F value is easily attainable.

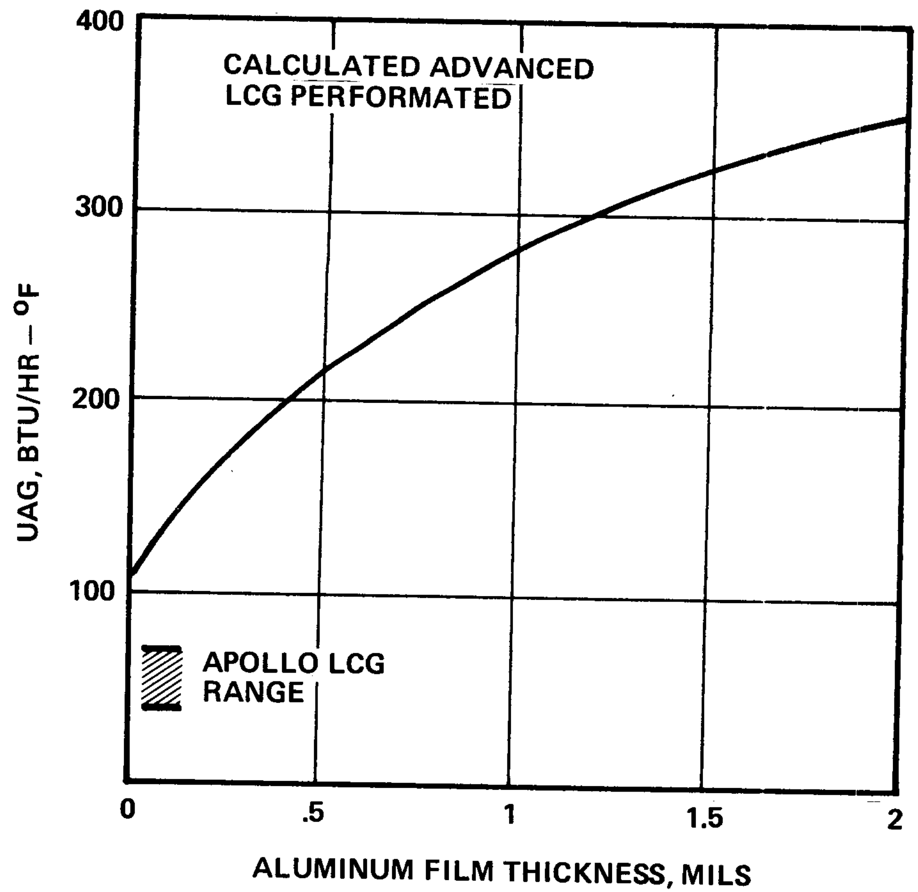
A number of techniques for fabrication of the advanced LCG have been explored. Results indicate the concept will lend itself to economical manufacture.

Several advantages exist for the high conductance LCG. One is that it should improve comfort and minimize sweating. Human sweating is regulated by both deep body and skin temperatures. In addition, the body's conductivity near the skin is a regulated variable, and is low at low skin temperatures. Increasing the LCG conductance will lower both skin and core temperatures, thus reducing sweating and moisture accumulation, all the while providing the astronaut with a more "normal" heat transfer mechanism.

ADVANCED LCG CONCEPT



ADVANCED LCG LAYUP



FLOW RATE

SUIT/EVLSS VENT FLOW

The ventilation flow must provide CO_2 removal and humidity control for the man. A low flow rate is desirable to minimize fan power requirements. Based on Apollo experience, 5.5 ACFM is satisfactory for CO_2 control.

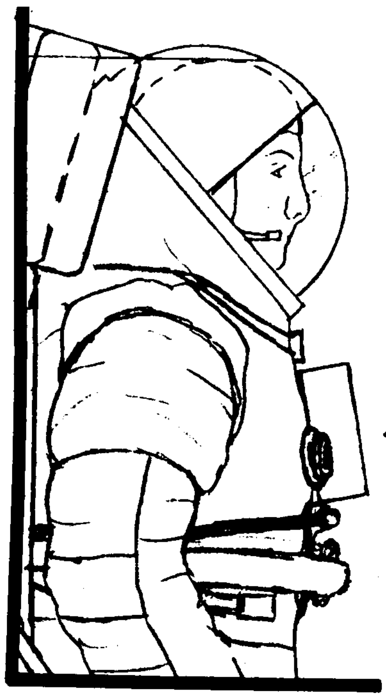
Humidity control requirements are determined by the water vapor output of the man, visor fogging problems, the inlet dew point, and the vent flow rate. A high dew point (60°F maximum) is necessary to minimize the size of a non-venting heat sink (or enable use of an umbilical heat sink). At 5.5 ACFM and 60°F dew point there is sufficient capacity to remove the expired breath water vapor. A thermal/humidity balance will be achieved over the body of the crewman, and comfort will not be impaired.

Visor fogging problems are related to two items; the visor temperature and the humidity in the vicinity of the visor. With proper selection of coatings the temperature can be maintained above the inlet dew point. Due to the high dew point in the man's breath (approximately 98°F) and uncertainties in the mixing of the breath with the vent flow, it is not known if fogging will occur with the same flowrate and visor emittance values as Apollo. However, previous studies at VSD have shown that addition of a second coating to the protective visor would considerably raise the helmet temperature, and almost undoubtedly eliminate potential fogging problems.

RECOMMENDATION:

- 60°F Inlet to Suit Dew Point
- 5.5 ACFM Flow
- Tests to Evaluate Potential Fogging Problems

SUIT/EVLSS VENT FLOW



60° D.P.
8 PSIA

UP TO SATURATED

- APOLLO EXPERIENCE
- CO_2 CONTROL
- HUMIDITY CONTROL
- VISOR FOGGING
- FAN POWER

RECOMMEND:

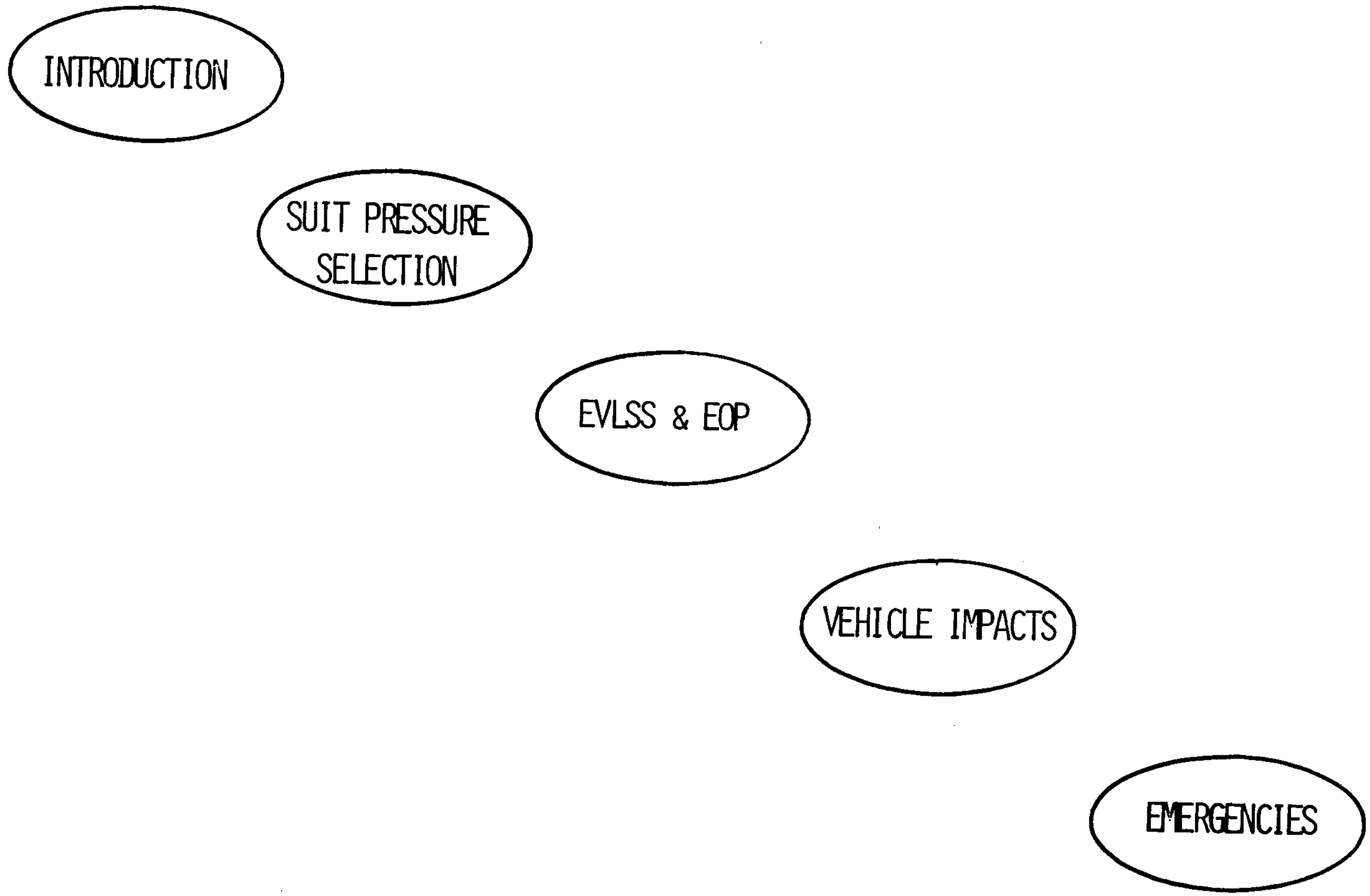
- 5.5 ACFM
- VISOR FOGGING TESTS

APPENDIX A

10 PSIA ORBITER CABIN IMPACTS

The work presented in this Appendix was conducted for NASA-JSC as a delta-task subsequent to completion of the basic contract effort. It was presented to NASA in an informal briefing on 5 April 1973.

10.0 PSIA CABIN IMPACT OUTLINE



INTRODUCTION:

- Summary of Impacts Orbiter Cabin Pressure Reduction
- Objectives
- Shuttle Cabin Conditions
- Impacts on Orbiter for 10 PSI Cabin

SUMMARY OF IMPACTS

ORBITER CABIN PRESSURE REDUCTION

EVA/IVA EQUIPMENT	BASELINE 14.7 PSIA	10.0 PSIA	COMMENTS
SUIT PRESSURE	8.0 ± .2	5.0 ± .15	AES Suits with minor upgrading possible.
EVLSS			
Battery	10 Lb	8 Lb	20% Power Reduction
Oxygen	1.04 Lb	Opt.1: 1.01; Opt.2: 1.04 Lbs.	
LiOH	5.8 Lbs	5.4 Lbs	
Fan	35.3 Watts	22.3 Watts	
Other Systems	-	-	Negligible Change
EOP	44 Lbs	32 Lbs	
RECHARGE EXPENDABLES			
Battery	90 WHr/Hr	72 WHr/Hr	
Oxygen	0.95 Lbs	0.92 to 0.95 Lbs	Maximum per one-man EVA
Other	-	-	Negligible Change
PROCEDURES			
Purge	No purge req'd	1/2 Min. Purge	.037 - .062 Lbs Purge Gas included above.
Prebreathing	None	None	

SUMMARY OF IMPACTS
ORBITER CABIN PRESSURE REDUCTION

VEHICLE	BASELINE 14.7 PSIA	10.0 PSIA	COMMENTS
AIRLOCK			
•Depress/Repress			
Normal	6.0 Min.	4.0 Min.	At Physiological Limits
Emergency	2.5 Min.	1.7 Min.	At Physiological Limits
•Expendables			
Gas	10.5 Lbs	8.25 Lb	Simple Vent
Gas + Tank	20.3 Lbs	13.3 Lbs	Per Operation
PROCEDURES			
Launch	No Venting	Vent Valve	To reduce cabin from ambient to 10 PSIA.
On-Orbit	-	-	Negligible Change
Re-Entry	No Repressurization	Repressurization Required	To raise cabin from 10 PSIA to Ambient
EMERGENCIES			
Launch	-	•Pre-Breathing •Fail-Safe Valving	Wear face mask or suit during launch
On-Orbit	-	Increased probability & severity of decompression	Due to large vent valve addition
Re-Entry	-	Fail-Safe Repressurization System	

OBJECTIVES

SUIT PRESSURE SELECTION	EVLSS & EOP	VEHICLE IMPACTS FOR EVA/IVA	IV EMERGENCIES
• PRE-BREATHING	• POWER REQUIREMENTS	• CONSUMABLES	• LAUNCH
• SUIT PURGE REQUIREMENTS	• O_2 REQUIREMENT	• EGRESS TIME	• ON-ORBIT
	• EOP RESIZING	• INGRESS TIME	

SHUTTLE CABIN BASELINE GROUNDRULES

TOTAL PRESSURE	:	10.0 ± 0.2 PSIA
O_2 PARTIAL PRESSURE	:	3.2 ± 0.1 PSIA
N_2 PARTIAL PRESSURE	:	6.5 TO 6.8 PSIA
FIRE HAZARD	:	30 TO 40% MAXIMUM O_2 PARTIAL PRESSURE
OTHER	:	SAME AS 14.7 PSIA CABIN

LAUNCH IMPACT FOR 10 PSI CABIN

REQUIREMENTS

1. LAUNCH PAD CABIN PRESSURE OF 14.7 PSIA
2. AVOID CABIN OVERPRESSURE ON ASCENT
3. MAINTAIN MINIMUM O_2 PP OF 3.2 AT 10 PSIA ALT. COND.

IMPACTS

1. RELIEF VALVE TO RELIEVE 14.7 → 10 PSI CABIN AIR IN APPROX. 2 MIN
2. OXYGEN RICH LAUNCH PAD CABIN ENVIRONMENT OF APPROX. 4.7 PSI (32% O_2)

SAFETY CONSIDERATION

- LARGE RELIEF VALVE EFFECTIVE AREA (1-1/2-2 SQ. INCHES) WOULD PERMIT RAPID DEPRESSURIZATION IF FAILURE - REQUIRES EITHER FAIL SAFE REDUNDANCY OR WEAR SUITS
- PRE-BREATHING PRIOR TO LAUNCH IN CASE OF A DECOMPRESSION DURING OR IMMEDIATELY AFTER LAUNCH

OUTLINE OF SUIT PRESSURE SELECTION

- ISSUES
- SUIT PRESSURE DEVELOPMENT STATUS
- EGRESS PROCEDURES FOR 3.85 ± 0.15 PSIA SUIT
- EGRESS PROCEDURES FOR 5.0 ± 0.15 PSIA SUIT
- EGRESS PROCEDURES FOR 6.0 ± 0.15 PSIA ON 8.0 ± 0.2 PSIA SUIT
- AEROEMBOLISM AVOIDANCE
- HYPOXIA AVOIDANCE
- LEAKAGE EFFECTS ON SUIT O_2 PARTIAL PRESSURE (5.0 PSIA SUIT)
- COMPARISON OF SUIT PRESSURE OPTIONS
- RECOMMENDED SUIT PRESSURE

SUIT PRESSURE ISSUES

AEROEMBOLISM

- 10 PSIA CABIN @ 3.2 PSI O_2
- HALDANE'S RULE*

$$\frac{P\ N_2(\text{initial})}{P_{suit}(\text{final})} \leq 1.5$$

DEVELOPMENT STATUS

- NEW TECHNOLOGY
- DEMONSTRATED TECHNOLOGY
- DEMONSTRATED IN FLIGHT

HYPOXIA

- ALVEOLAR O_2*

  $\geq$ 90 mm Hg

EGRESS PROCEDURES

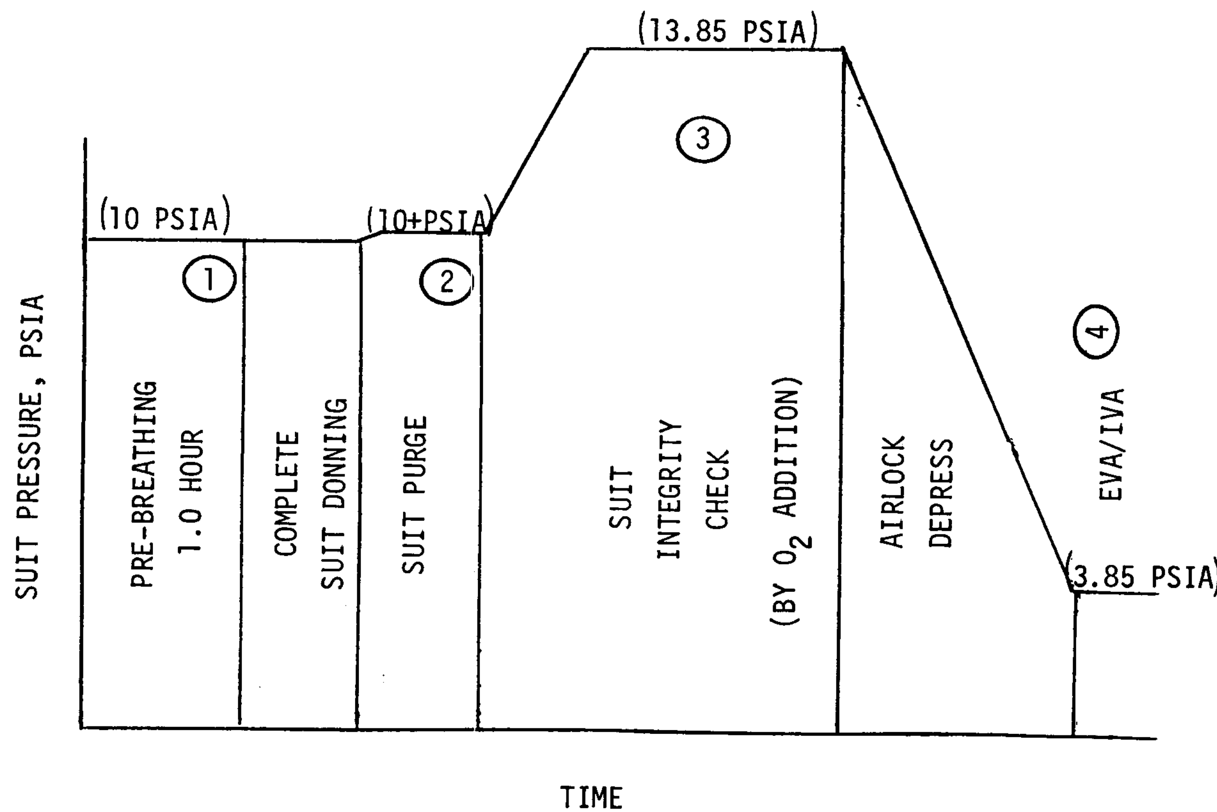
- PRE-BREATHING
- SUIT PURGE
- SUIT INTEGRITY CHECK

* DAVE HORRIGAN, TELECON 3-27-73

SUIT PRESSURE DEVELOPMENT STATUS

OPTION	STATUS	COMMENTS
8.0 PSIA	• WORK IN PROGRESS • NOT DEVELOPED	• UNNECESSARY HIGH PRESSURE • NO PRE-BREATHE • NO SUIT PURGE
6.0 PSIA	• NO WORK IN PROGRESS • MAY BE POSSIBLE TO UPGRADE AES SUITS TO THIS LEVEL	• NO PRE-BREATHE • NO SUIT PURGE
5.0 PSIA	• AES SUITS WITH MINIMUM UPGRADING CAN BE USED	• NO PRE-BREATHE • SUIT PURGE REQUIRED
3.85 PSIA	• CAN USE APOLLO/SKYLAB SUITS (AT REDUCED TASK EFFECTIVENESS, LIFE-TIME, ETC.) • OR USE ADV. TECH. SUITS WITH LESS UPGRADING	• PRE-BREATHE REQUIRED • SUIT PURGE REQUIRED

EGRESS PROCEDURES
FOR 3.85 ± .15 PSIA SUIT



(1) REQUIRES
- MASKS
- 1.69 LB O_2 @ 1/2 ACFM, 10 PSIA

(2) REQUIRES 3 SUIT VOLUME CHANGES TO REACH 6% N_2
- 0.372 LB O_2 @ 2.2 FT^3 SUIT 10 PSIA

(3) REQUIRES
- 0.048 LBS O_2
- 2.2 FT^3 SUIT

(4) REQUIRES
- 0.076 LB O_2 @ 2.2 FT^3 SUIT FOR INGRESS

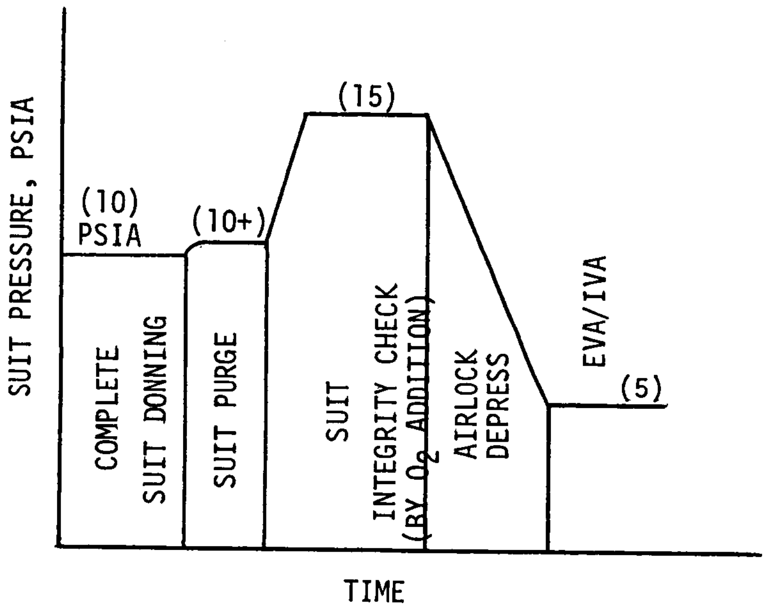
<u>TOTALS</u>

PRE-BREATHE & PURGE = 2.06 LBS O_2

CHECK & INGRESS = 0.124 LBS O_2

EGRESS PROCEDURES

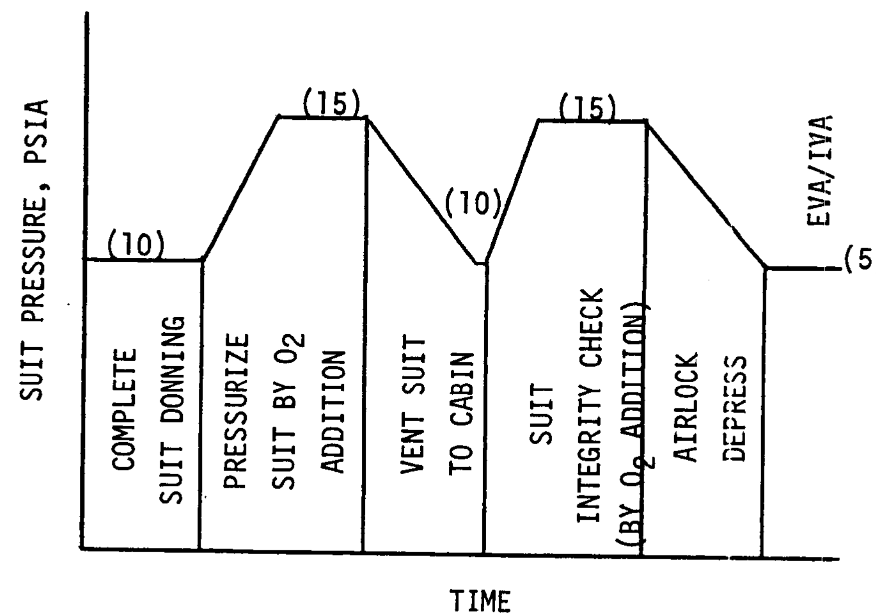
FOR 5.0 ± .15 PSIA SUIT



OPTION 1

- REQUIRES 0.124 LBS O_2 FOR PURGE (1 SUIT VOL. CHANGE)- MIN. PURGE WOULD BE 0.037 LB)
- 0.062 LBS FOR CHECK
- 0.062 LBS FOR INGRESS

TOTAL : 0.248 LBS (OR 0.161 LB FOR MIN. PURGE)



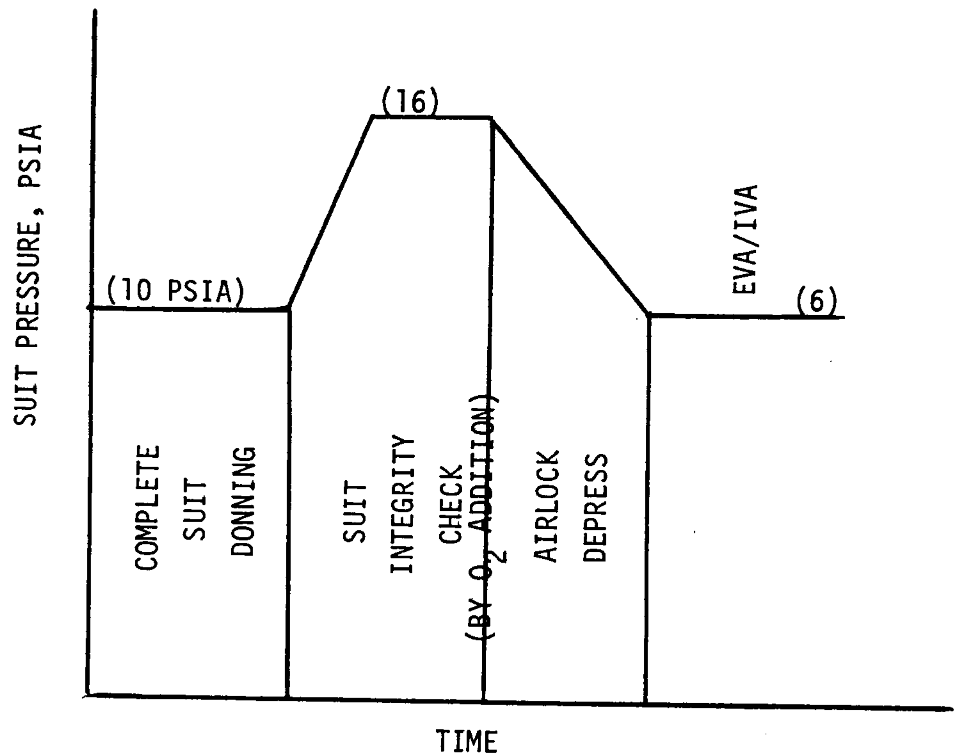
OPTION 2

- REQUIRES 0.062 LBS FOR PURGE
- REQUIRES 0.062 LBS FOR CHECK
- REQUIRES 0.062 LBS FOR INGRESS

TOTAL : 0.186 LBS O_2

EGRESS PROCEDURES

FOR 6.0 ± 0.15 PSIA or 8.0 ± 0.2 PSIA



6.0 PSIA SUIT

REQUIRES

- 0.075 LBS FOR CHECK
- 0.059 LBS FOR INGRESS

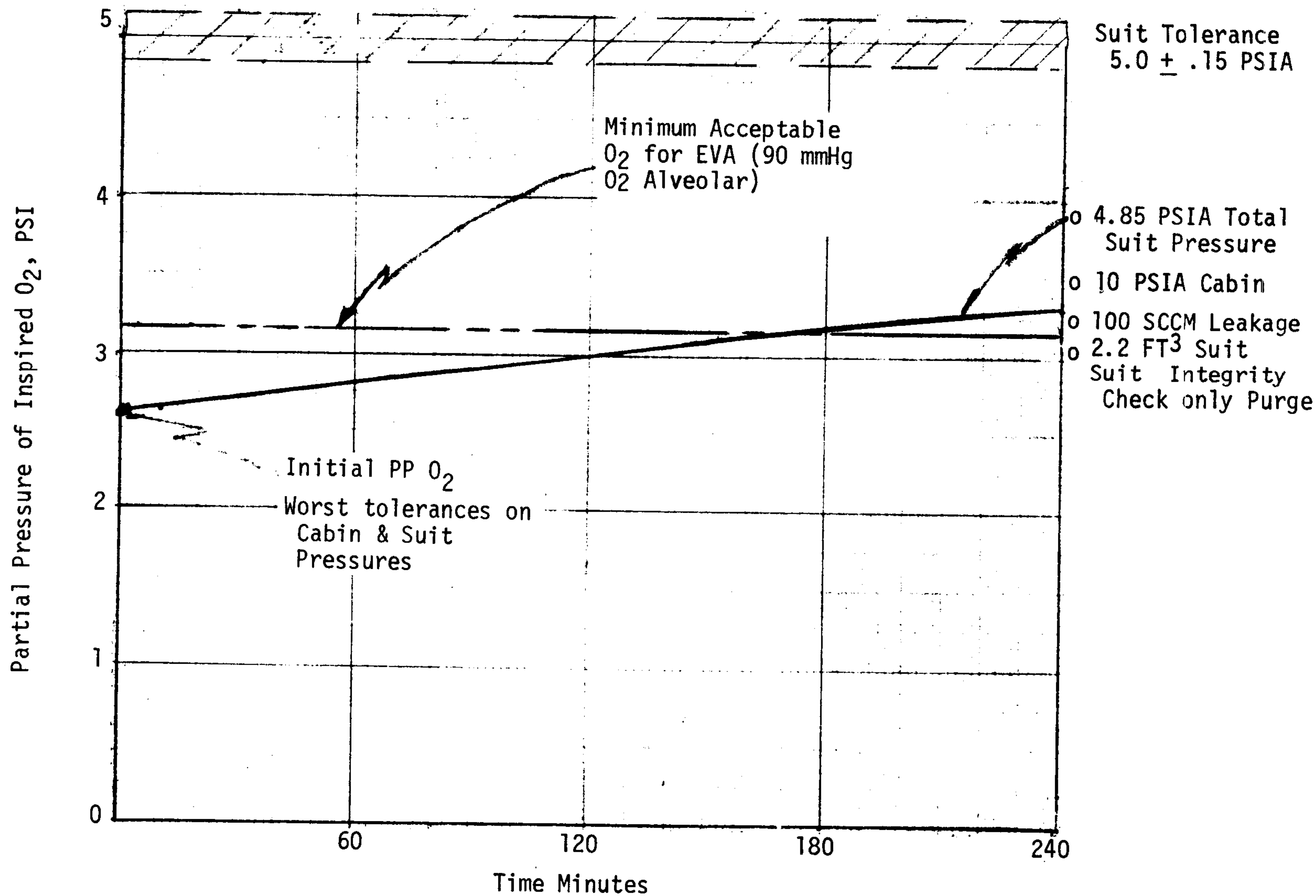
TOTAL : 0.124 LBS O_2

AEROEMBOLISM AVOIDANCE

OPTIONS	ADVANTAGES	DISADVANTAGES
Suit Pressure = 3.85 PSIA	Proven Technology	•One Hour Pre-Breathe •Suit Purge Required •Donning Impaired by Pre-Breathing Apparatus •Existing Suits Have Limited Mobility, Lifetime, etc.
Minimum Suit Pressure $\geq$ 4.5 PSIA	•No Pre-Breathing •5.0 PSIA Suit Demonstrated	No Flight Proven Suits

RECOMMENDED
- No Pre-Breathing
- Minimal Impact on Equipment
- Crew Acceptability

LEAKAGE EFFECTS ON OXYGEN PARTIAL PRESSURE (5 PSIA SUIT)



HYPOXIA AVOIDANCE

OPTIONS*	ADVANTAGES	DISADVANTAGES
6.0 PSIA OR 8.0 PSIA SUIT PRESSURE	NO PURGE REQUIRED	NOT PROVEN TECHNOLOGY
5.0 PSIA SUIT	PROVEN TECHNOLOGY	SUIT PURGE REQUIRED
a) PURGE AT 10 PSIA	a) REQUIRES 0.161-0.248 LBS O_2 (90 - 114 mmHg O_2 ALVEOLAR PP)	a) MANUAL SHUT-OFF REQUIRED • 1-1/2 MIN FOR PURGE
b) PRESS TO 15, DEPRESS TO 10, PRESS TO 15, DEPRESS TO 5	b) REQUIRES 0.186 LBS O_2 • ALVEOLAR $O_2 \geq 97$ mmHg • NO TIME CRITICAL OPERATIONS	b) ASTRONAUT EXPOSED TO 2 PRESSURE CYCLES • 5 MIN FOR PURGE
~~c) NO PURGE~~	c) SIMPLEST	c) NOT ACCEPTABLE ALVEOLAR $O_2 \geq 65$ mmHg (>50 REQUIRED TO SUSTAIN LIFE, BUT <90 mmHg REQUIRED)
~~d) 4.8 PSIA (MIN) O_2 PARTIAL PRESSURE IN CABIN~~	d) • SIMPLE • NO PRE-BREATHE • NO PURGE	d) NOT ACCEPTABLE FIRE HAZARD IN CABIN
3.85 PSIA SUIT	PROVEN IN FLIGHT	• PRE-BREATHING • SUIT PURGE • SPECIAL EQUIPMENT

* MINIMUM ACCEPTABLE ALVEOLAR $O_2 \geq 90$ mmHg
(REF. - DAVE HORRIGAN NASA-JSC, 3-27-73)

COMPARISON OF SUIT PRESSURE OPTIONS

Suit Pressure*	Pre-Breathe	Suit Purge	Pre-Breath, Purge & Pressurization Time	Total Serv. O_2/Man	Suit Dev. Status	EOP Impact**
8.0 ± 0.2 PSIA	No Req'd	Not Req'd	3.2 Minutes	0.178 Lb	Worst	Baseline (Worst)
6.0 ± 0.15 PSIA	Not Req'd	Not Req'd	2.4 Minutes	0.165 Lb	Fair	Good
5.0 ± 0.15 PSIA						
Option #1	Not Req'd	0.161 Lb O_2 Req'd(Min)	2.5 Minutes	0.199 Lb	Good	Better
Option #2	Not Req'd	0.186 Lb O_2 Req'd	7.0 Minutes	0.226 Lb	Good	Better
3.85 ± 0.15	Req'd	0.372 Lb O_2 Req'd	66 Minutes***	2.27 Lb	Best	Best

*Suit pressure is not expected to have a significant impact on suit weight and volume for a new suit.

**EOP = Emergency Oxygen Pack

***Sixty Minute Pre-Breath required (Ref: D. Horrigan telecon dtd 3-27-73).

RECOMMENDED SUIT PRESSURE

5.0 ± 0.15 PSIA

- Primary Advantages are:
  - Development Status
  - EOP Impact

- Primary Disadvantage is:
  - Suit Purge
  - (Safety is not jeopardized if purge is accidentally omitted; crewman will not lose consciousness)

Either Egress Option is Acceptable, Option #1 Preferred:

- Purge Suit at 10 PSIA (O_2 from EV Life Support System)
- Suit Integrity Check at 15 PSIA (Suit pressurization by O_2 addition from EV Life Support System)
- Depress Airlock to Vacuum, Suit to 5 PSIA

EVLSS & EOP OUTLINE

- EVLSS Impacts
- EOP Impacts
- EOP For 5.0 PSIA SUIT

EVLSS IMPACTS

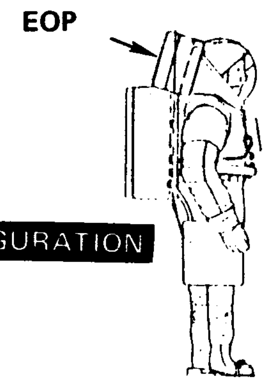
	CHANGE FROM 8.0 PSI to 5.0 PSIA SUIT
O_2 STORAGE	
°Press & Vent Suit to Purge (Option #2)	Same - 1.04 Lbs Design Value (0.95 Lbs Maximum Usage)*
°Purge at 10 PSIA (Option #1 - Min. Purge)	Decreased to 1.01 Lbs Design Value (0.92 Lbs Maximum Usage)*
LiOH	Decreased to 5.4 Lbs (was 5.8 Lbs)
Battery	
°Reduced Fan Power	Reduced to 8.0 Lbs (151,In^3)(was 10 Lbs, 190 In^3)
°Regulator	5.0 $\pm$ 0.15 PSIG (was 8.0 $\pm$ 0.2)
°Fan	Decreased to 22.3 Watts (was 35.3 Watts)

*Difference is 0.086 Lbs allowed for measurement system uncertainty.

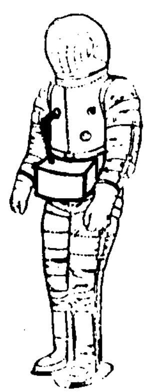
EMERGENCY OXYGEN PACK IMPACTS

REQUIREMENTS FOR 5.0 PSIA	24 MINIMUM DURATION	30 MINIMUM DURATION
°Flow Rate	9.8 Lb/Hr	12.0 Lb/Hr
°Usable O_2	3.82 Lbs	6.0 Lbs
°Total O_2 (At OPS Utilization Factor)	4.4 Lbs	6.9 Lbs
°Tank Material:	2.0 Lb (Tank + O_2)/Lb O_2	
Carbon Filament Glass Fiber Aged Cryoform SAE 302	T.B.D. in Detail Design	
°Thermal Heat Sink	T.B.D.	
(5.1 # Heat Sink included in EOP weight)	- OPS (5880 PSI) - Only tank H.X. - SOP (6000 PSI) - Internal Fin H.X. External H.X.	

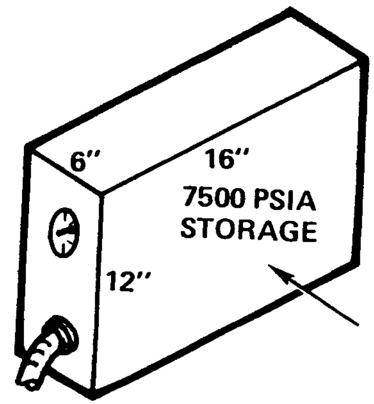
EMERGENCY OXYGEN PACK



EVA CONFIGURATION

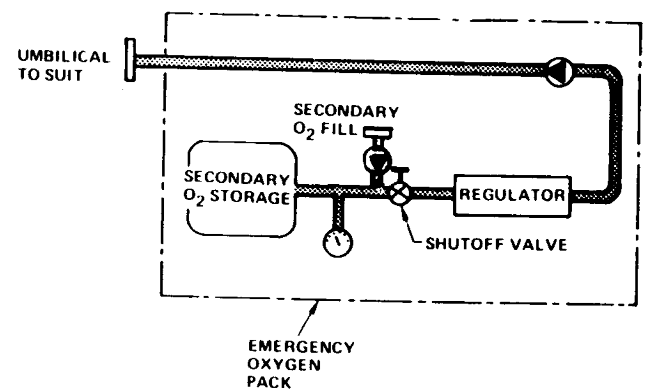


IV EMERGENCY - EVA
TRANSFER CONFIGURATION



24 MINUTES DURATION

8 PSIA EOP:	5 PSIA EOP:
44 Lb	32 Lb
1160 In^3	840 In^3
19.6 Lb/Hr	9.8 Lb/Hr
OXYGEN	OXYGEN



VEHICLE IMPACTS OUTLINE

- OXYGEN RECHARGE
- BATTERY RECHARGE
- EGRESS TIME
- INGRESS TIME
- COMPARISON OF LIQUID & GAS COOLING AT 10 PSIA
    - AIRLOCK LIQUID COOLING LOOP
    - VENT GAS COOLING
    - CREWMAN THERMAL STORAGE DURING EGRESS
    - COMPARISON OF SUIT COOLING CONCEPTS
    - CONCLUSION ON LIQUID VS GAS COOLING
- RECOMMENDED CREWMAN COOLING CONCEPT
- AIRLOCK OPERATION EXPENDABLES

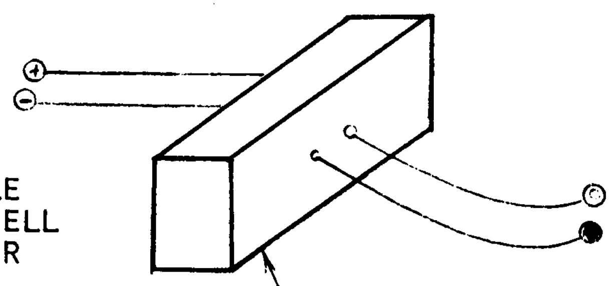
OXYGEN RECHARGE

OXYGEN REQUIREMENTS PER MAN

- Single EVA/IVA: Metabolic & Leakage: $\frac{0.1815 \text{ Lb}}{\text{Man-Hour}}$
- Multiple EVA/IVA: Metabolic & Leakage: $\frac{0.1493 \text{ Lb}}{\text{Man-Hour}}$

14.7/8.0 BASELINE		10/5 PSI ALTERNATE: Option #2 Pressurize & Vent	10/5 PSI ALTERNATE: Option #1 Vent at 10 PSIA (Min. Purge)
•Service For Egress/Ingress	: 0.224 Lb/Man Airlock Opening	0.226	0.199
•Maximum Consumption Per EVA/IVA (4 hrs)	: 0.950 Lb/Man	0.95	0.92

BATTERY RECHARGE



ITEM	REQUIREMENTS PER MAN 14.7/8.0 Baseline	10/5 Alternate
EVA/IVA Usable Power	264 Watt-Hours	210 Watt-Hours (4 Hrs)
EVA/IVA Battery (AG/ZN)	10 Lb; 190 In^3	*8 Lbs; 151 In^3
Recharger		4.2 Lbs; 230 In^3
Recharge Power	90 Watt-Hours / Hour	72 Watt-Hours / Manhour EVA
Recharge Time		Approximately 2.5 x Use Time
Recharge Penalty		Fuel Cell Reactants 1.54 Lbs/KWH

*Carry-on for back-to-back activities.

EGRESS TIMES

		Alternate 10/5 PSIA	
	14.7/8.0 PSIA Baseline	5.0 PSIA Suit Press & Vent Option #2	5.0 PSIA SUIT Purge at 10 PSI Option #1
TOTAL (Two men, Series DON)	76 Min.	78 Min.	73.5 Min.
**TOTAL Time without cooling	14 Min. (F.E.* on in Airlock)	16 Min. (F.E.)	12.5 Min. (F.E.)
	17.5 Min. Sublimator	19.5 Min. Sublimator	16.0 Min. Sublimator

*F.E. - Flash Evaporator

**Assumes vehicle cooling umbilical is disconnected at beginning of pressure integrity check or purge.

INGRESS TIME

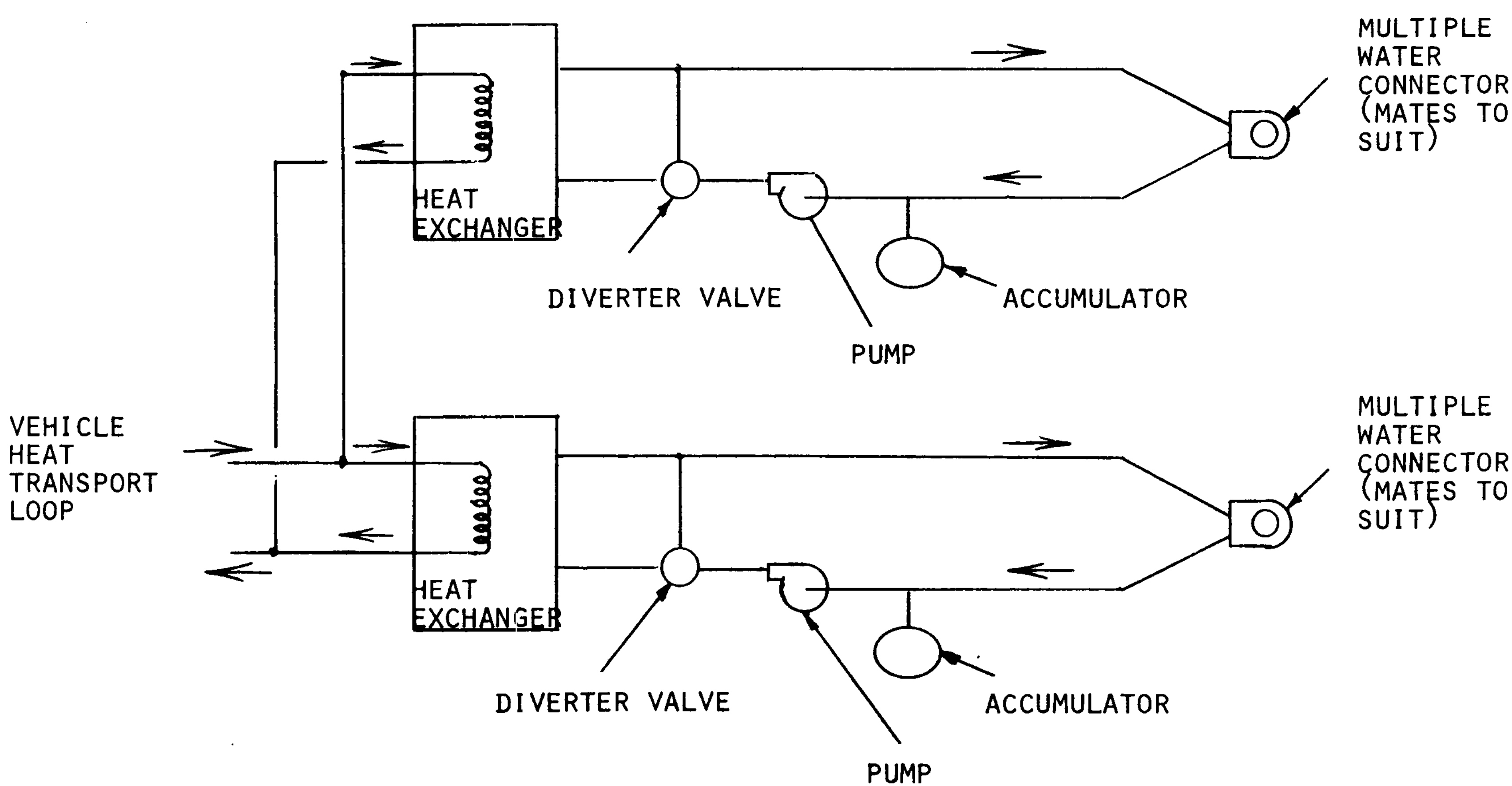
	14.7/8.0 BASELINE	5.0 PSIA SUIT PRESS & VENT OPTION #2	5.0 PSIA SUIT PURGE AT 10 PSIA OPTION #1
TOTAL - Includes Recharge	75 Min.	73 Min.	73 Min.
TIME Without Cooling	10 Min (F.E.)	8 Min. (F.E.)	8 Min. (F.E.)

COMPARISON OF LIQUID AND GAS COOLING

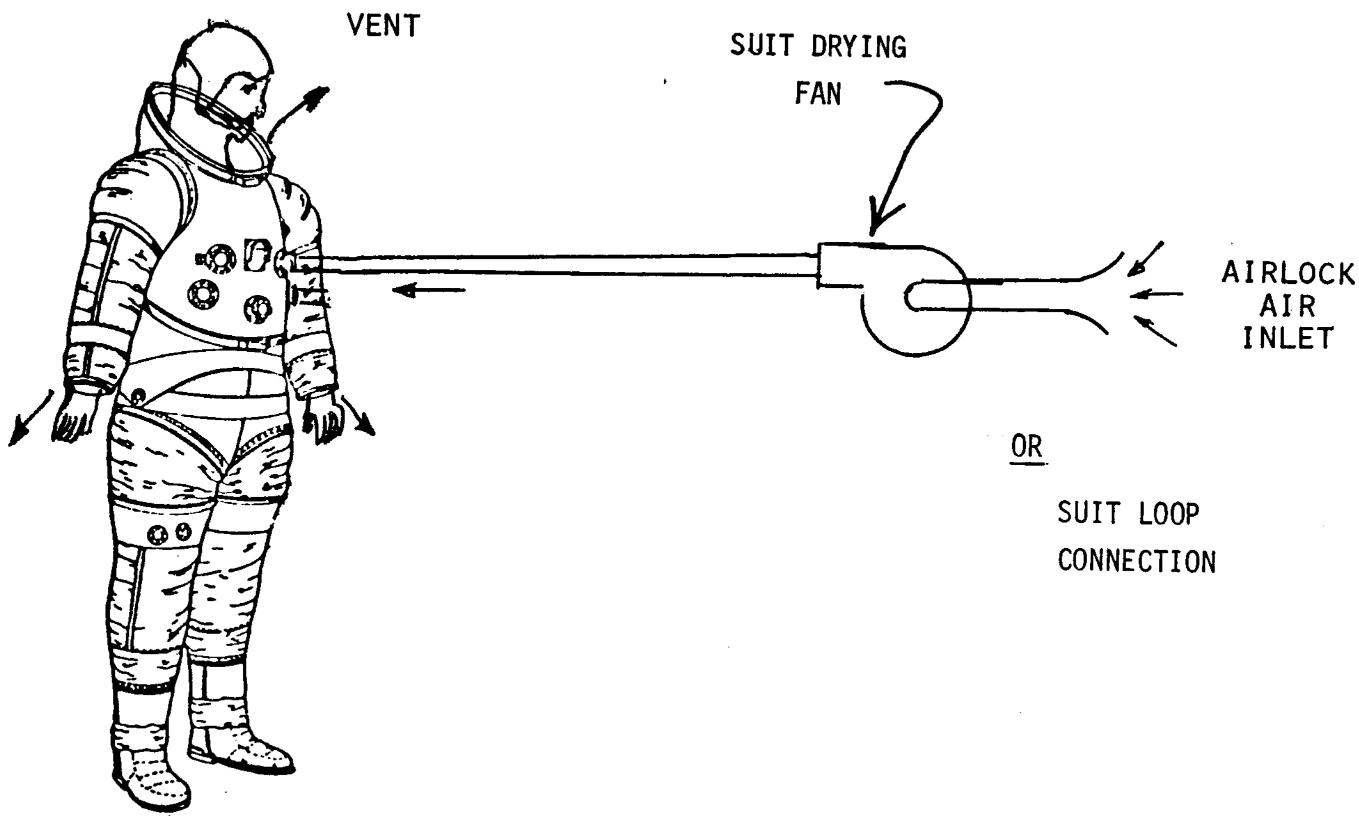
LOOPS TO SEE IF CHOICE IS IMPACTED

AT 10.0 PSIA

AIRLOCK LIQUID COOLING LOOP



VENT GAS COOLING



CREWMAN THERMAL STORAGE DURING EGRESS

SUIT PURGE FOR 10 PSIA CABIN, 5.0 PSIA SUIT	CREWMAN MAXIMUM THERMAL STORAGE, BTU (1) (6)			
	LIQUID COOLING LOOPS IN AIRLOCK (2)		VENT. GAS COOLING IN AIRLOCK (3)	
	FLASH EVAP. (4)	SUBLIMATOR (5)	FLASH EVAP. (4)	SUBLIMATOR (5)
Purge at 10 PSIA (Option #1 - Min.)	104	150	204	250
Press. & Vent Purge (Option #2)	162	210	262	310

NOTES: (1) Average Metabolic Rate, 800 BTU/Hr

(2) -50 BTU Initial Thermal Storage by Intentional Sub-cooling

(3) +50 BTU Initial Thermal Storage Unavoidable (Primary Cooling by Evaporation)

(4) Instant-On Device for Airlock $P \leq 0.0885$ PSIA

(5) 3.5 Min. Delay in Start-Up

(6) Cooling System Disconnected at Beginning of Suit Purge or Suit Integrity Check.

COMPARISON OF SUIT COOLING CONCEPTS

CONCEPT	COOLING CAPABILITY	STANDBY CREWMAN COOLING (One-Man EVA's)	NON-VENT HEAT SINK EVA		WEIGHT & VOLUME, POWER
			Umbilical	Ice Pack Refreezer	
Liquid Cooling Loop	Best (Q Stored Man 100 to 200 BTU)	Best	Good	Best	Good (1)
Vent Gas Cooling	Marginally Acceptable (Q Stored, Man = 200 to 300 BTU)	Acceptable	Not Acceptable	Poor	Best (2)

NOTES: (1) Pump/Motor and Heat Exchanger Required for Liquid Loops, as well as Suit Dryer (Fan)

(2) Suit Dryer Fan Used for This Requirement.

CONCLUSION ON LIQUID vs. GAS COOLING

- At 10 PSIA Cabin vs. 14.7 PSIA, Liquid Cooling is Still Preferred.
- At 10 PSIA Cabin vs. 14.7 PSIA, Gas Cooling is Still Marginally Acceptable Based on Egress Time Considerations. The Same Volumetric Gas Flow Rate is Required.

RECOMMENDED CREWMAN COOLING CONCEPT

PREFERRED: LIQUID COOLING LOOPS

- Meets All Requirements
- Modest Weight Increase
- Supplementary Vent Gas Flow Would Increase Comfort

ALTERNATE: VENT GAS COOLING

- Least Number of Components
- Requires - Either Ice Packs for Non-Venting Heat Sink (Thermoelectric Refreezer Will work, but at Increased Penalty)

  Or Carry On "Kit" With Penetrations In Air-lock Wall to Provide Umbilical Heat Sink

AIRLOCK OPERATION EXPENDABLES

ITEM	14.7 PSIA	10 PSIA
Equipment Weight/Volume	Same	No Significant Change
Decompression/ Repressurization Time		
°Normal @ 2.5 psi/min	6 min	4 min
°Emergency @ 6.0 psi/min	2.5 min	1.7 min
Expendables for 140 ft^3 airlock	10.5 lbs air/opening	8.25 $\frac{\text{lbs air}}{\text{opening}}$
O_2	2.44 lbs O_2*	2.53 lbs O_2*
N_2	8.05 lbs N_2	4.72 lbs N_2
Tankage & Gas Penalty Per Opening		
O_2 @ 1.24 $\frac{\#(O_2 + \text{Tank})}{\#O_2}$	3.03 lbs	3.14 lbs
N_2 @ 2.14 $\frac{\#(N_2 + \text{Tank})}{\#N_2}$	17.25 lbs	10.01 lbs
Total Penalty Per Operation	20.3 lbs	13.15 lbs
Expendables required for 2 Operations per Flight	40.6 lbs	26.3 lbs

* 3.2 psi O_2 partial pressure at 10 PSIA
3.1 psi O_2 partial pressure at 14.7 PSIA

EMERGENCIES OUTLINE

- LAUNCH
- PRE-LAUNCH OPTIONS
- PRE-BREATHING OXYGEN REQUIREMENTS
- LAUNCH DECOMPRESSION CONCLUSIONS
- ON-ORBIT
- RE-ENTRY

LAUNCH EMERGENCY

VENTING REQUIRED DURING LAUNCH	14.7 PSIA ON PAD TO 10 PSIA IN APPROXIMATELY TWO MINUTES.
INCREASED POTENTIAL FOR RAPID DECOMPRESSION	DUE TO LARGER VENT VALVE (1.2 - 2 In^2)

OPTIONS:

(1) Automatic Valving to Provide Fail Safe Pressure Relief System (Manual Override <u>not</u> Allowed due to Launch Loads on Men).

(2) Wear Suits, Fully Donned During Launch

(3) High Flood Flow and Reserve Gases

PRE-LAUNCH OPTIONS

For A Decompression During Launch

Problem: Bends would occur for direct decompression from Sea Level atmosphere to 5.0 PSIA Suit

Equilibrated Condition for Man	Cabin Environment	System Requirements	Comments
14.7 PSIA Total 3.1 PSI O_2 11.6 PSI N_2	14.7 PSIA Total 4.7 PSI O_2 10.0 PSI N_2	No Pre-Breathe	NOT ACCEPTABLE Men will receive bends.
14.7 PSIA Total 3.1 PSI O_2 11.6 PSI N_2	14.7 PSIA Total 4.7 PSI O_2 10.0 PSI N_2	-1.0 Hr Pre-Breathe and suit loops or face masks	
14.7 PSIA Total 4.7 PSI O_2 10.0 PSI N_2	14.7 PSIA Total 4.7 PSI O_2 10.0 PSI N_2	-0.5 Hr Pre-Breathe and suit loops or face masks	Order of 3 Hours Required to equilibrate to 10 PSI N_2
14.7 PSIA Total 7.4 PSI O_2 7.3 PSI N_2	14.7 PSIA Total 7.4 PSI O_2 7.3 PSI N_2	O_2 Enriched Cabin (No Pre-Breathe)	NOT ACCEPTABLE Fire Hazard.
14.7 PSIA Total 7.4 PSI O_2 7.3 PSI N_2	14.7 PSIA Total 4.7 PSI O_2 10.0 PSI N_2	Suit Loops Operating on pad	Several Hours to Equilibrate or Pre-Breathe 1.0 Hour prior to donning suits
14.7 PSIA Total 3.1 PSI O_2 11.6 PSI N_2	14.7 PSIA Total 4.7 PSI O_2 10.0 PSI N_2	8.0 PSI Suits (No Pre-Breathe)	New Suit Required
14.7 PSIA Total 4.7 PSI O_2 10.0 PSI N_2	14.7 PSIA Total 4.7 PSI O_2 10.0 PSI N_2	(No-Pre-Breathe) 6.7 PSI Suits	Over-pressure 5.0 PSI Suit with Suit Loops Set for 6.7 PSI

PRE-BREATHING OXYGEN REQUIREMENTS

PRE-BREATHE OPTION	OXYGEN REQUIREMENTS
1.0 Hour with Face Mask*	2.5 Lbs O_2/Man
0.5 Hour with Face Mask*	1.25 Lbs O_2/Man
Purge Suit Loops (One Volume Change, 10 Ft^3 Vol.)	0.83 Lbs
Suit Purge, Each (One Volume Change, 22 Ft^3 Vol.)	0.18 Lbs/Man
Face Mask Usage* For 15 Min. to Orbit	0.62 Lbs/Man
Face Mask Usage* For Pre-Launch Hold	T.B.D. (2.5 Lbs O_2/Hr)
Metabolic Consumption At 800 BTU/Hr	0.146 Lbs/Man-Hour

Total Consumption Depends Upon Pre-Launch Procedures Employed

*At 1/2 ACFM at 14.7 PSIA, Pure O_2 (2.5 Lb/Hr)

LAUNCH DECOMPRESSION CONCLUSIONS

- Pre-Breathing of Some Type is Required.
- Additional Work Required to Define Pre-Launch and Launch Procedures
- Recommended Baseline
  - -Men in Suits Equilibrate to 7.4 PSI O_2/7.3 PSI N_2 in Suit Loops
  - -Allows Men to Hold for Long Periods (Greater than 30 Hours without O_2 Toxicity)
  - -Men may Don Suits After Ingress to Shuttle
  - -Suits May be Pressurized to Slightly Above Ambient During Pre-Launch and Launch
  - -Requires Active O_2 Partial Pressure Control in Suit Loops as a Function of Total Pressure

ON-ORBIT EMERGENCIES

- Increased Decompression Rate Possible with Larger Vent Valves

RE-ENTRY EMERGENCY

REQUIREMENT: Repressurize Cabin From 10 PSIA to 14.7 PSIA in Approximately 300 Sec. (5 Minutes)

POTENTIAL EMERGENCY: Failed Pressure Equalization Valve May Damage Cabin Structure

OPTIONS:

(1) Design Valve to not Fail Closed

(2) Parallel Valves

(3) Repress with Either Stored Expendables or Ambient Air