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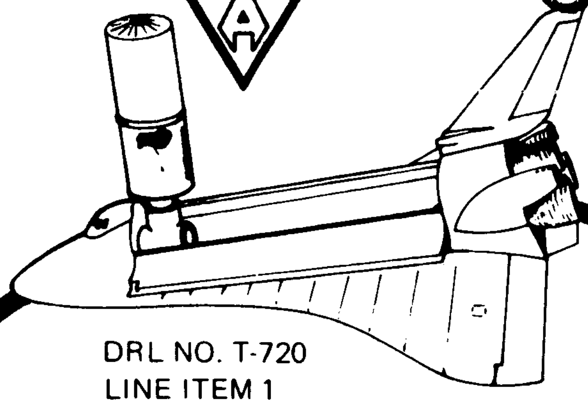

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LINE ITEM 1
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REPORT NO. T-192-RP05
CONTRACT NAS9-12507

study of space shuttle eva/iva support requirements

VOLUME II
EVA/IVA TASKS, GUIDELINES, AND CONSTRAINTS DEFINITION

30 APRIL 1973

VOUGHT SYSTEMS DIVISION

STUDY OF SPACE SHUTTLE
EVA/IVA SUPPORT REQUIREMENTS

VOLUME II

EVA/IVA TASKS, GUIDELINES, AND CONSTRAINTS DEFINITION

REPORT NO. T-192-RP05

30 APRIL 1973

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Under

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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, Jonnson Spacecraft Center (JSC), Houston, Texas, in accordance with Contract No. NAS9-12507, dated 28 March 1972. It is the Final EVA/IVA Tasks, Guidelines, and Constraints Definition Report, and fulfills part of the requirements of DRL No. T-720, Line Item 1, DRD MA-182-T. It contains detailed supporting final documentation on Work Breakdown Structure Subtask 1.1 EVA/IVA Tasks, Guidelines and Constraints Definition. It consists of updated briefing material used in the June 1972 Tasks, Guidelines, and Constraints presentation, plus Appendices on Representative Task Scenarios, Revised Shuttle Traffic Model, Timeline and Mission Analysis, and Prebreathing Requirements. The following volumes are also included in the final documentation:

Volume I - Technical Summary Report

Volume III Requirements Study For Space Shuttle Pressure Suits

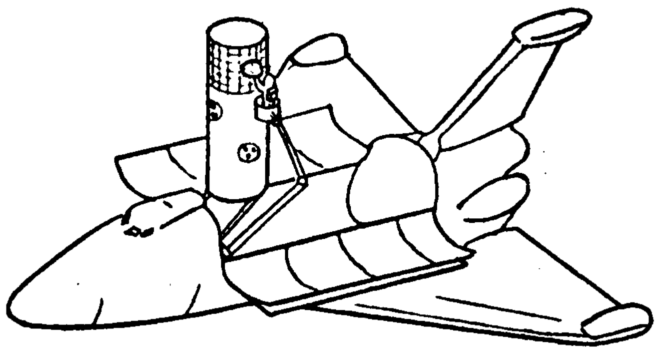
Volume IV Requirements Study for Space Shuttle Mobility Aids

Volume V - Requirements Study for Space Shuttle Emergency IV Support

A 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



TASKS
GUIDELINES
CONSTRAINTS
BRIEFING

JUNE 1972

This briefing was originally presented at NASA-JSC on 15 June 1972. Revisions have been made to several pages, and are so noted on those pages. The revised pages are:

21	110
58	112
60	118
90	119
106	120
109	

The four appendices add additional definition to the selected representative tasks, provide updated information on the Shuttle Traffic Model (developed by VSD to improve the March 1972 NASA Traffic Model to include the impacts of the June 1972 NASA Mission Model), present timeline and mission analyses of the representative tasks, and add further information relative to prebreathing requirements.

STUDY OF SPACE SHUTTLE EVA/IVA SUPPORT REQUIREMENTS

TASKS, GUIDELINES, AND CONSTRAINTS BRIEFING

NASA-MSC
JUNE 15, 1972

STUDY PRODUCT

The end products of the study are definitions of equipment requirements for the five areas listed. Today's briefing describes the tasks, guidelines, and constraints from which these requirements will be derived.

STUDY PRODUCT:

SHUTTLE EVA/IVA CONCEPT

- PRESSURE SUIT(S)
- LIFE SUPPORT SYSTEM
- MOBILITY AIDS
- VEHICLE INTERFACES
- EMERGENCY IV

SCOPE

The activities considered in the study are planned, unscheduled, and contingency EVA/IVA. 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.

The range of missions considered in the study includes the full repertory of shuttle capabilities, as illustrated in the list. Specific mission models will be presented later.

SCOPE

ACTIVITIES

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

MISSIONS

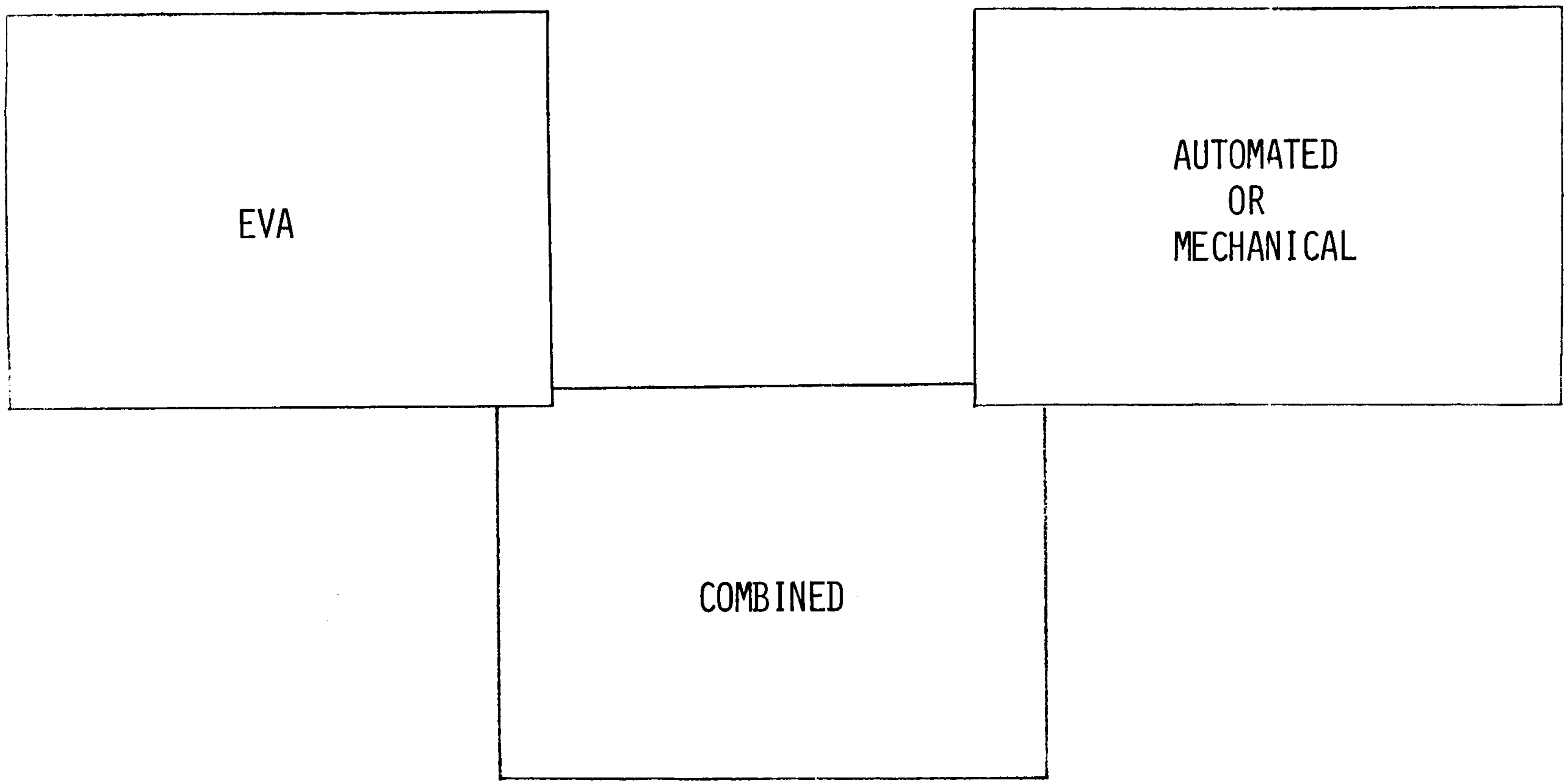
- SATELLITE PLACEMENT, RETRIEVAL, & SERVICE/ MAINTENANCE
- PROPULSIVE STAGES & PAYLOADS
- SORTIE
- LOGISTICS
- RESCUE

OPERATIONAL CHOICES

EVA, in the context of this study, is an operational alternate to some other way of accomplishing a task, or is a supplement used in conjunction with another device, such as the manipulator.

Potential EVA is identified when it is a viable primary, backup, or supplementary choice. No attempt is made to conduct trades to determine the optimum alternative.

OPERATIONAL CHOICES



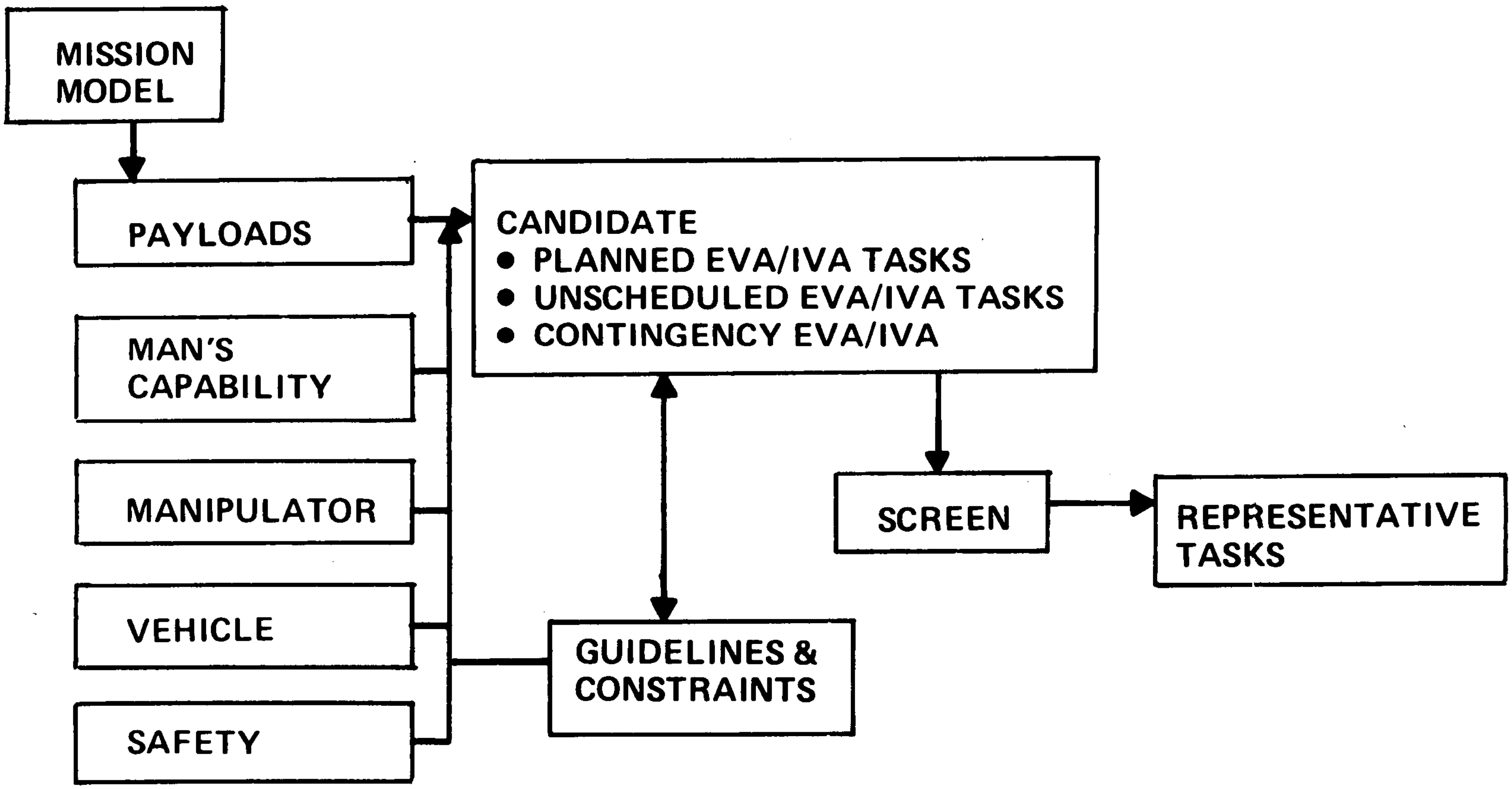
TASKS, GUIDELINES, AND CONSTRAINTS

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. The whole spectrum of credible contingency situations with a potential requirement for EVA/IVA has been retained at this point in the study.

This chart also serves as an outline for the remainder of the presentation.

TASKS, GUIDELINES, CONSTRAINTS



MISSION MODEL

The mission model is based on the August 1971 NASA Headquarters definition of the first 10 missions, and the March 1972 NASA-MSC traffic model. Detailed consideration of DOD missions is not included.

Candidate shuttle-launched payloads for retrieval were identified from the March 1971 Aerospace Corp. "Integrated Operations/Payloads/Fleet Analysis.

In addition, it may be desired to retrieve certain currently orbiting objects for scientific information or space housekeeping. The March 1972 NASA-GSFC "Satellite Situation Report" was used to identify orbital characteristics of these objects.

MISSION MODEL

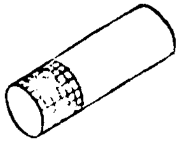
- FIRST 10 MISSIONS, AUGUST 1971
- MSC-06746, MARCH 1972 TRAFFIC MODEL, 1979-1990
- INTEGRATED FLEET ANALYSIS AND GODDARD SATELLITE STATUS FOR RETRIEVALS

FIRST 10 MISSIONS

These flights will progressively demonstrate the capability of the shuttle to deploy and retrieve payloads and to conduct orbital experiments. As described later, EVA could provide a valuable service on some of these missions. A large, simple satellite, the Meteoroid Exposure Module (MEM), will be deployed on Flight #1 to provide an early test for the shuttle deployment mechanism and to determine both space and cargo bay environmental data. Following a Dept. of Defense mission on Flight #2, the Large Space Telescope (LST) mirror will be tested under orbital conditions on Flight #3. Shuttle rendezvous and docking will be demonstrated by retrieving the MEM on Flight #4, which will also involve placement of a small Astronomy Explorer into orbit. Deployment of the High Energy Astronomy Observatory on Flight #5 will test the orbital checkout capability of the shuttle with a large sophisticated payload.

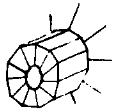
Flight #6 will be the first on-orbit servicing mission, which will involve refurbishment of an LST previously launched by a Titan III. Deployment of a Bioresearch Module and retrieval of one previously orbited by a Scout on Flight #7 will test shuttle operations using a free-flying teleoperator, and will impose payload thermal control requirements. Operation of a 1-meter astronomical telescope on Flight #8, and use of a Materials Science research module, will demonstrate shuttle capabilities in the sortie mode. Launch of an Educational Broadcast Satellite to geosynchronous orbit during Flight #9 will be the first mission requiring a kickstage. The Earth Observations Polar Sortie on Flight #10, which will include a Materials Science research module, will demonstrate a more comprehensive sortie capability.

FIRST 10 MISSIONS



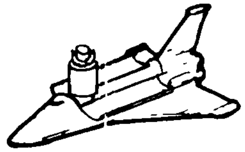
FLIGHT 1 - 1978

DEPLOY METEOROID EXPOSURE
MODULE (MEM)



FLIGHT 4 - 1978

DEPLOY ASTRONOMY EXPLORER
RETRIEVE MEM

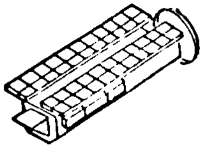


FLIGHT 8 - 1979

IR TELESCOPE AND MTLS. SCI.
SORTIE

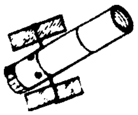
DOD

FLIGHT 2 - 1978



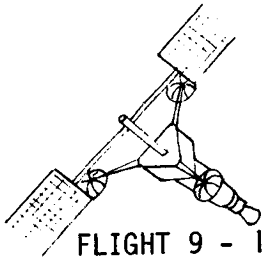
FLIGHT 5 - 1979

DEPLOY HIGH ENERGY ASTRONOMY
OBSERVATORY (HEAO)



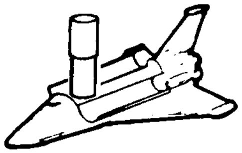
FLIGHT 6 - 1979

LST REFURBISHMENT



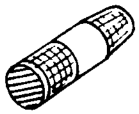
FLIGHT 9 - 1979

EDUCATION BROADCAST SATELLITE
PLUS KICKSTAGE



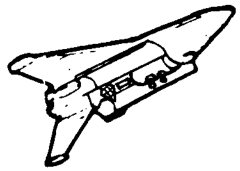
FLIGHT 3 - 1978

LARGE SPACE TELESCOPE
(LST) MIRROR TEST



FLIGHT 7 - 1979

DEPLOY BIORES. MODULE NO. 2
RETRIEVE BIORES. MODULE NO. 1



FLIGHT 10 - 1979

EARTH ORBIT POLAR SORTIE
AND MTLS. SCI.

NASA TRAFFIC MODEL

The NASA traffic model contains 80 generic payloads which are launched by 407 shuttle flights in the 1979-1990 time frame. 55% of these flights will require kick stages to boost them to higher energy trajectories than possible with the shuttle alone. The mission model baselines use of expendable kick stages prior to 1985 and a reusable earth based tug from 1985 on.

A significant number of viable EVA/IVA interfaces are expected to occur with a number of the satellite payloads, particularly the large astronomy observatories, such as the free flying Research and Applications Module (RAM) illustrated, which will be serviced on-orbit. As more utility of the shuttle is realized, it is also expected that smaller satellites such as the one illustrated will be designed for on-orbit maintenance during mission opportunities. Other EVA interfaces may exist in a backup save-the-mission capacity with critical opportunity missions such as the planetary probe shown.

A number of shuttle missions will involve on-orbit manned research within modules affixed to the shuttle - these are defined as sortie missions. The module can serve as either a support module or an experimental laboratory. It is often called a "sortie can" or an attached "Research and Applications" (RAM) module. A number of sortie missions are expected to benefit from EVA/IVA.

The illustrated Modular Space Station will consist of shuttle - transported subsystems, crew, cargo and RAM modules. Little EVA/IVA interface is expected while being delivered by the shuttle.

NASA TRAFFIC MODEL 1979-1990

PAYLOADS

12 ASTRONOMY SATELLITES

5 SPACE PHYSICS SATELLITES

11 EARTH OBSERVATION SATELLITES

17 COMMUNICATIONS/NAVIGATION SATELLITES

14 PLANETARY PROBES

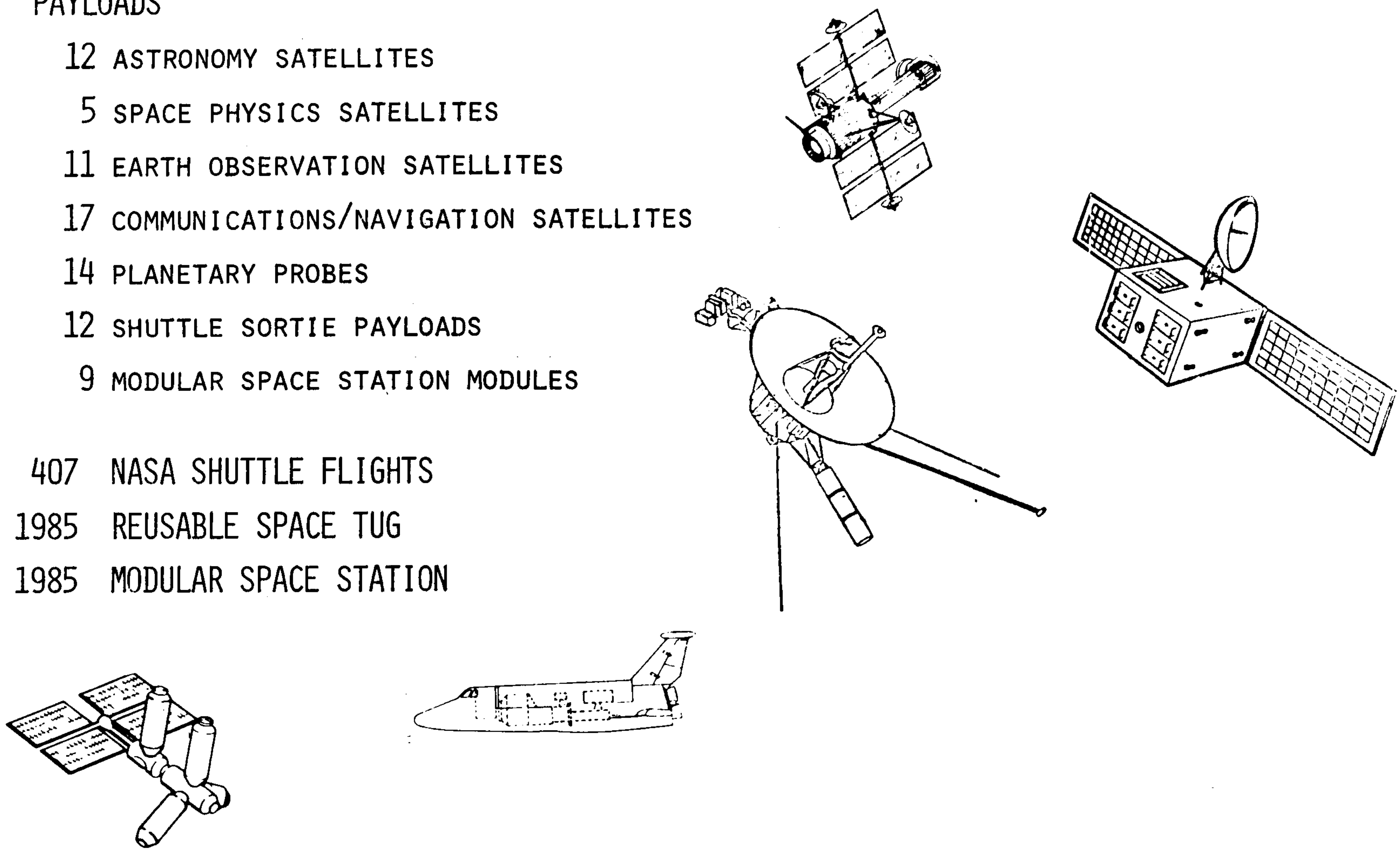
12 SHUTTLE SORTIE PAYLOADS

9 MODULAR SPACE STATION MODULES

407 NASA SHUTTLE FLIGHTS

1985 REUSABLE SPACE TUG

1985 MODULAR SPACE STATION

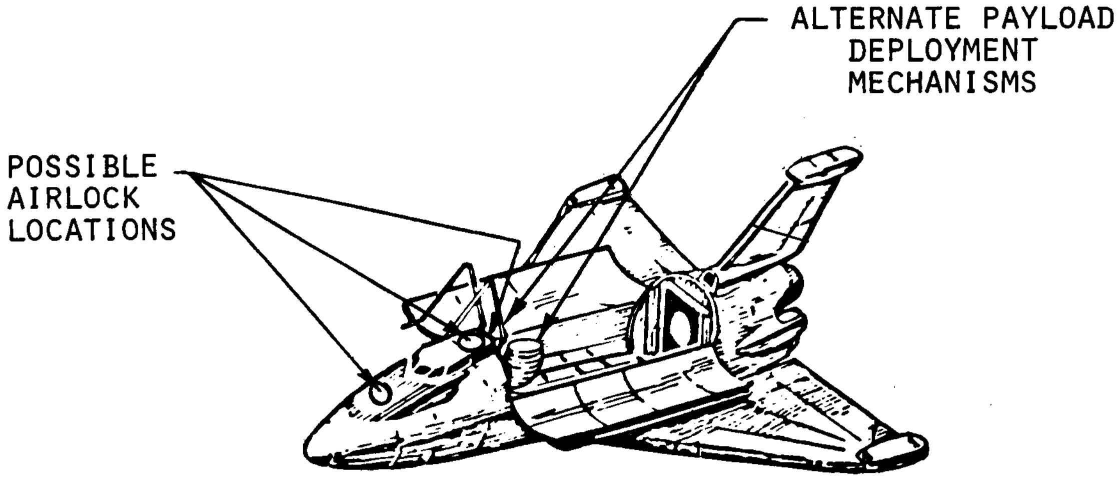


SHUTTLE ORBITER

The shuttle orbiter characteristics are defined in the Phase C/D RFP with detailed inputs from the Phase B extension studies and North American Rockwell (under a consultant arrangement). Two of the significant EVA/IVA interfaces are airlock location and alternate cargo handling devices, as illustrated.

Some other important interfaces will include mobility aids, lighting, communications, checkout and monitoring, stowage, electrical power, and environmental control/life support.

SHUTTLE ORBITER



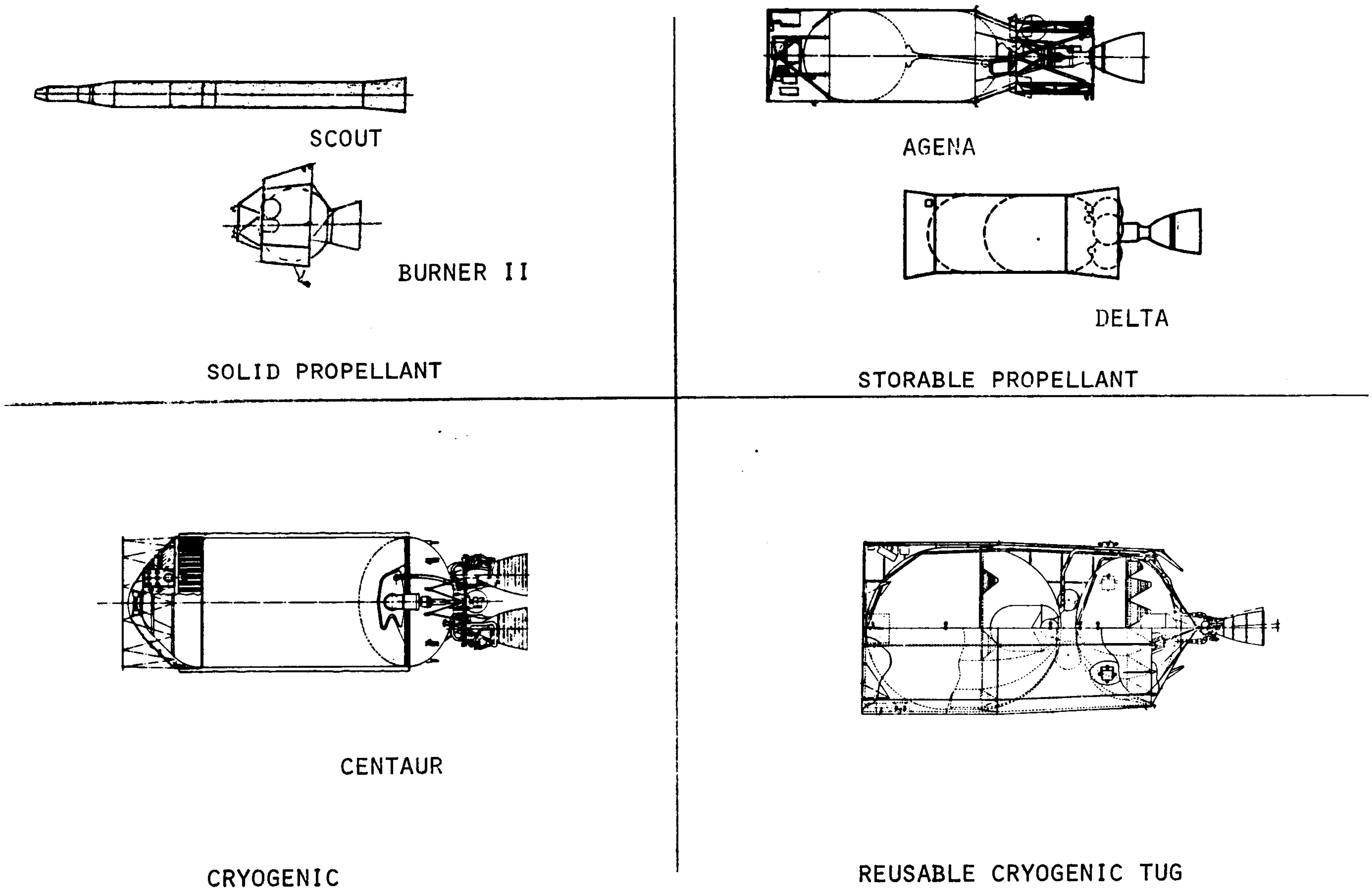
UPPER STAGES

About 55% of the NASA traffic model flights will require kickstages to transfer them from low earth orbit injection by the shuttle to high energy orbits or interplanetary trajectories. Prior to 1985, the mission model specifies adaptation of existing expendable stages to accomplish this purpose. The chart illustrates candidates from solid, storable, and cryogenic propellant classes. The stable of existing upper stages will be able to transport payloads up to about 13,000 lbs from a 100 N.Mi. shuttle orbit to a geosynchronous equatorial orbit.

After 1985 a ground based space tug is baselined by the traffic model to become available. It will be reusable for 20 missions and can deploy and/or retrieve payloads, including the capability for a 3050 lb payload deployment and retrieval to equatorial geosynchronous orbit from a 100 N.Mi. low earth orbit.

EVA or IVA into the cargo bay has potential with upper stages both as backup on-orbit "save-the-mission" replacement or assistance to malfunctioning components, as well as possible safing, securing, or reconnecting operations as a matter of routine.

UPPER STAGES



MANIPULATOR CHARACTERISTICS

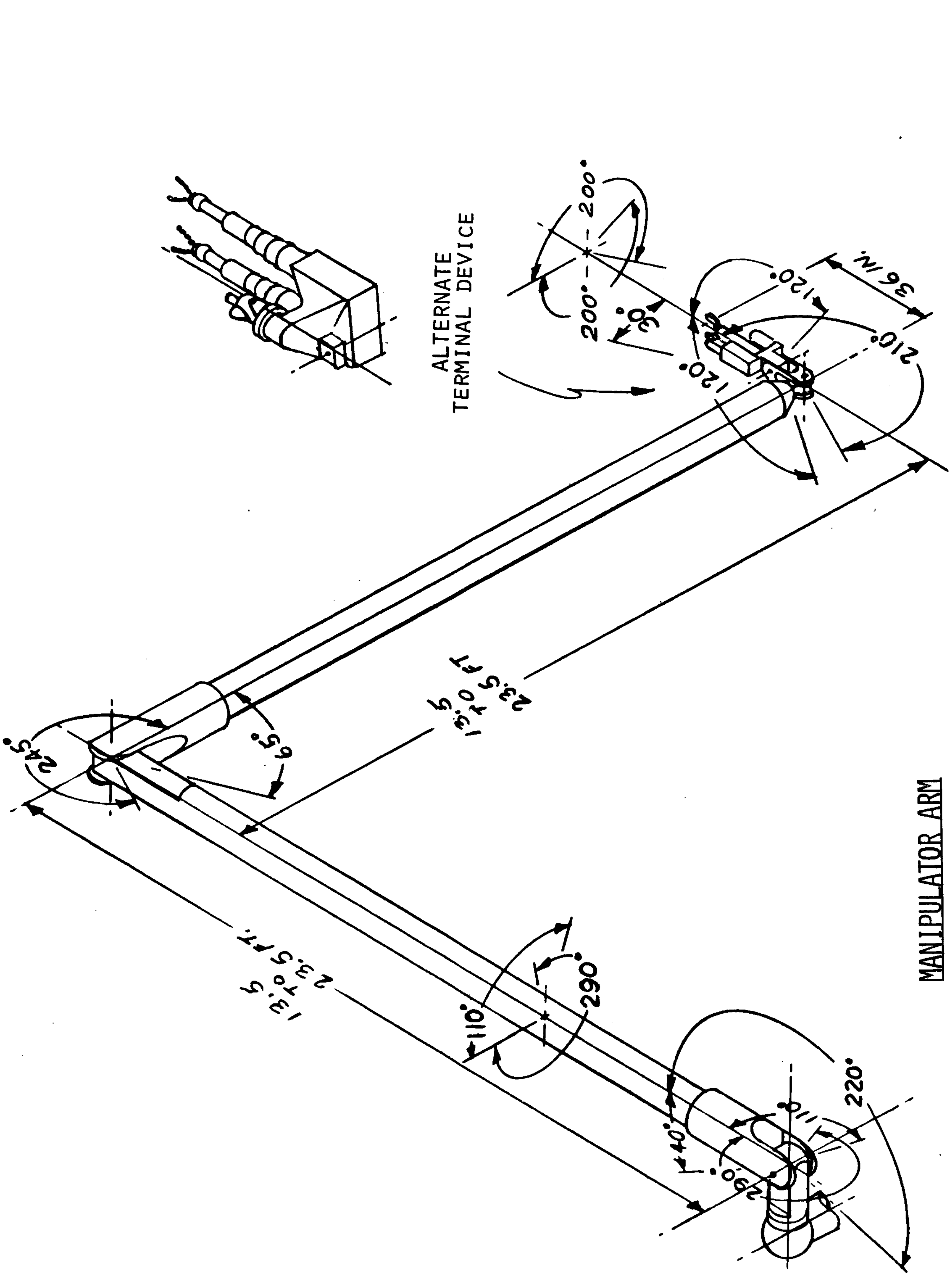
- TRANSLATION VELOCITY - 0 TO 0.2 FT/SEC (LOADED [1]) - 0 TO 1.5 FT/SEC (UNLOADED)
- ROTATION VELOCITY - 0 TO 0.2 DEG/SEC (LOADED) - 0 TO 3.0 DEG/SEC (UNLOADED)
- ACCELERATION RATE - 0 TO 0.005 FT/SEC^2 (LOADED) - 0 TO 0.5 FT/SEC^2 (UNLOADED)
- DECELERATION RATE - 0 TO 0.005 FT/SEC^2 (LOADED) - 0 TO 1.0 FT/SEC^2 (UNLOADED)
- REACH DISTANCE - 50 FT (FIRST GENERATION 30-40 FT)
- REACH ANGLE - LIMITED ONLY BY INTERFERENCE WITH ORBITER STRUCTURE
- POSITION ACCURACY - ± 2 INCHES
- ORIENTATION ACCURACY - ± 0.1 DEGREE
- TIP FORCE - 40-80 LB_F
- TIP DEFLECTION - 1 INCH/10 LBS
- FORCE FEEDBACK - 4-5 LBS

GND SIMULATION DEVICE

- VISIBILITY - DIRECT OR TV OR COMBINATION

[1] HANDLING 65,000 LBS PAYLOAD

Rev.

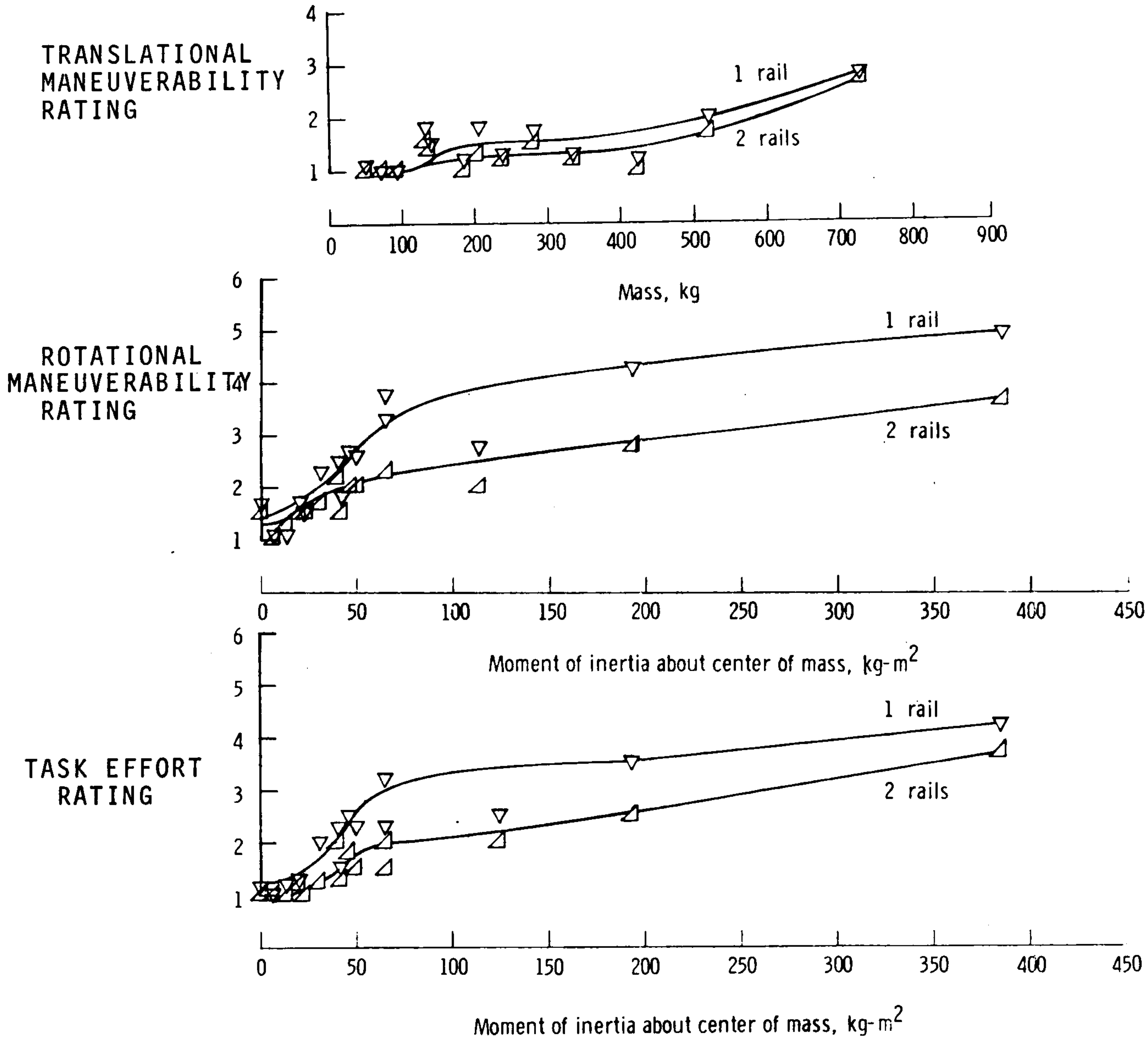


MANIPULATOR ARM

CARGO HANDLING CAPABILITY

The opposite chart, taken from recent neutral buoyancy tests at NASA-Langley, illustrates man's capability to handle cargo in zero gravity. Cargo masses up to 1600 lbs were handled satisfactorily. The subjective rating scale indicates a satisfactory performance for a value under 6 and good for a value under 3. It was found that the moment of inertia rather than the mass is the most critical factor in determining the ease of cargo manipulation. Packages with moments less than about 20 $kg\text{-}m^2$ could be maneuvered easily with a single hand hold. Between 20 and 70 $kg\text{-}m^2$ multiple hand holds are required, while packages with moments greater than 70 $kg\text{-}m^2$ have considerable inherent stability so that attitude control of the package does not become increasingly difficult. Another result obtained was that translation using two rails was significantly easier than using one.

Other recent tests, at NASA-Marshall, have demonstrated the capability of man to do useful work in the replacement of simulated electronics modules using only one hand, with the other providing restraint. Coupled with demonstrated zero-g capability during Apollo 15 and 16 transearth EVA's, man's capability to perform either planned or contingency zero-g activities seems to be much broader than previously anticipated.



From

NASA TN-D6774
April 1972

CARGO HANDLING CAPABILITY

CANDIDATE

PLANNED

EVA/IVA

CANDIDATE PLANNED EVA/IVA

The planned EVA/IVA tasks can logically be grouped according to the type work to be accomplished. This viewgraph presents the groupings, or classes, and a description of the type work each class includes. Examples of specific tasks to be performed in each class follow.

CANDIDATE PLANNED EVA/IVA:

CLASS I - MAINTENANCE/SERVICING OF LARGE ASTRONOMY OBSERVATORIES

CLASS II - ON-ORBIT MAINTENANCE/SERVICING OF RETRIEVED SATELLITE

CLASS III - DE-ORBIT READINESS OF PAYLOAD IN CARGO BAY

CLASS IV - RETRIEVAL OF EXPERIMENT PACKAGES INCLUDING SORTIES

CLASS V - FREE FLYING OPERATIONS

CLASS I - MAINTENANCE/SERVICING OF LARGE ASTRONOMY OBSERVATORIES

Large Astronomy Observatories of the type listed as representative payloads will be deployed to remain in orbit for long periods of time to locate, observe and interpret radiation from extragalactic, galactic, solar, and planetary sources in the different parts of the spectrum with resolution not achievable from earth sites. These observatories are to be designed for periodic on-orbit maintenance and servicing, which could be aided by EVA and IVA. The observatory shown is a Large Space Telescope with a compartment to provide a pressurized, shirt sleeve environment for maintenance and servicing.

The observatories have several common characteristics relative to EVA/IVA: their size exceeds the reach envelope of currently planned manipulator booms, all are of high value and are contamination sensitive, all require extensive on-orbit update, checkout and servicing, and all have various components suitable for external replacement.

CANDIDATE
PLANNED
EVA/IVA

CLASS I - MAINTENANCE/SERVICING OF LARGE ASTRONOMY OBSERVATORIES

REPRESENTATIVE PAYLOADS:

HIGH ENERGY ASTRONOMY OBSERVATORY (HEAO)

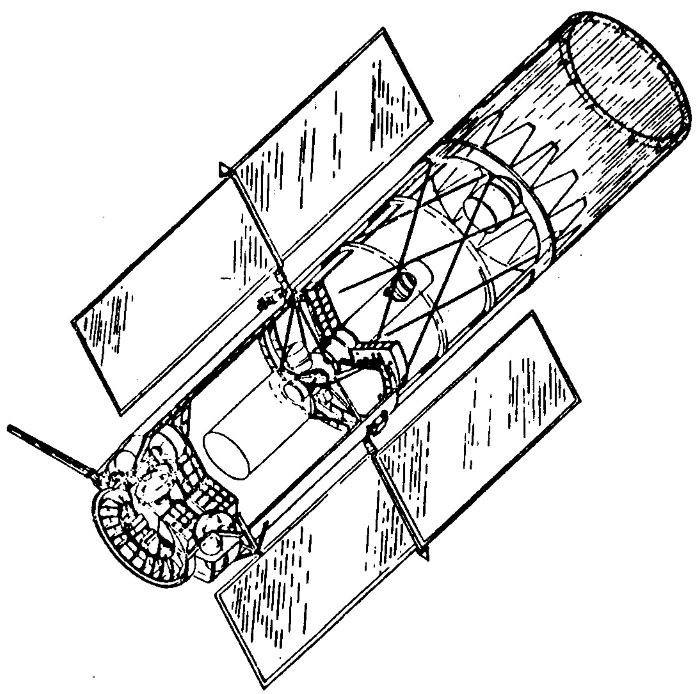
LARGE SPACE TELESCOPE (LST)

X-RAY ASTRONOMY OBSERVATORY
(RAM EQUIV. TO HEAO-C)

LARGE SOLAR OBSERVATORY (RAM)

HIGH ENERGY STELLAR OBSERVATORY
(RAM EQUIV. TO HEAO-D)

LARGE RADIO OBSERVATORY (RAM)



EVA EXAMPLE #1: PRESSURIZED LST

CONCEPT MAINTENANCE

The sketch shows a Large Space Telescope (LST) with a pressurizable compartment docked with the shuttle for on-orbit maintenance and servicing. A tunnel and sortie can are between the shuttle cabin and the LST allowing shirt sleeve access to equipment in the LST once pressurized and checked out.

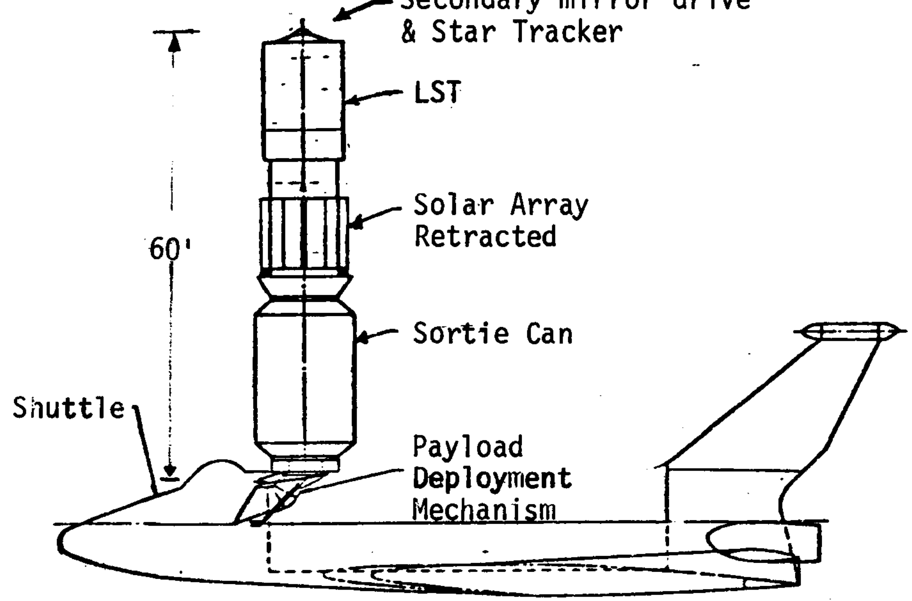
The EVA tasks listed must be accomplished outside the pressurized areas. Some of the equipment to be replaced, the secondary mirror drive motor and some star trackers, are outside the reach of the manipulators as currently configured. They are about 60 feet away from the shuttle while the manipulators can reach only about 50 feet.

These tasks would be accomplished by exiting the shuttle through an airlock and making a way along the surface of the shuttle, sortie can and LST to the proper position, making the replacement and returning to the cabin through the airlock.

CANDIDATE
PLANNED
EVA

CLASS I

EVA EXAMPLE #1: PRESSURIZED LST CONCEPT MAINTENANCE



	TASKS	SIZE	MODE
1.	Replace Star Tracker (5)	15 lb	Pri. EVA
2.	Replace Sec. Mirror Drive (1)	--	Pri. EVA
3.	Wide Angle Sun Sensor (5)	1 lb	Pri. EVA
4.	Sunshade Drive Motor (1)	--	Pri. EVA
5.	Telescope Light Cover Motor (1)	--	Pri. EVA
6.	RCS Thruster Module (4)	170	EVA Aid Manipulator
7.	Hydrazine Refuel, external	--	Pri. EVA
8.	Contamination Monitoring sensor on sec Mirror dome (2)	$\frac{1}{2}$ lb	Pri. EVA

EVA EXAMPLE #2: UNPRESSURIZED LST CONCEPT MAINTENANCE

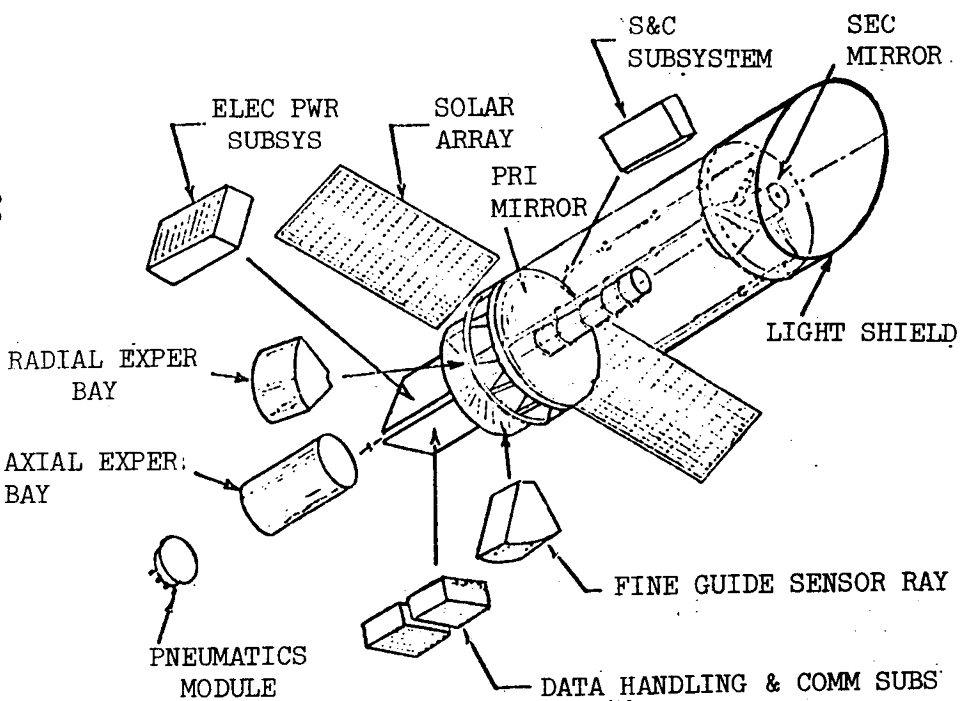
The sketch shows an LST without a pressurizable compartment for on-orbit maintenance; the LST is docked with the shuttle in a manner similar to the method shown for the LST in Example #1.

Replacement of aperture-located components would be similar to the pressurizable concept of Example #1. Replacement of subsystems and experiment modules, however, would now be somewhat different because of their size.

CANDIDATE
PLANNED
EVA

CLASS I

EVA EXAMPLE #2: UNPRESSURIZED LST CONCEPT MAINTENANCE



	TASK	UNIT WT (lb)	MODE
1.	Replace Subsystems Modules (4)	600-1800	EVA Aid Manipulator
2.	Replace Experiments Modules (5)	900	EVA Aid Manipulator
3.	Replace Sec. Mirror Drive	-	Pri. EVA
4.	Connect Monitoring Umbilicals	-	Pri. EVA

EVA EXAMPLE #3: PRESSURIZED X-RAY ASTRONOMY OBSERVATORY

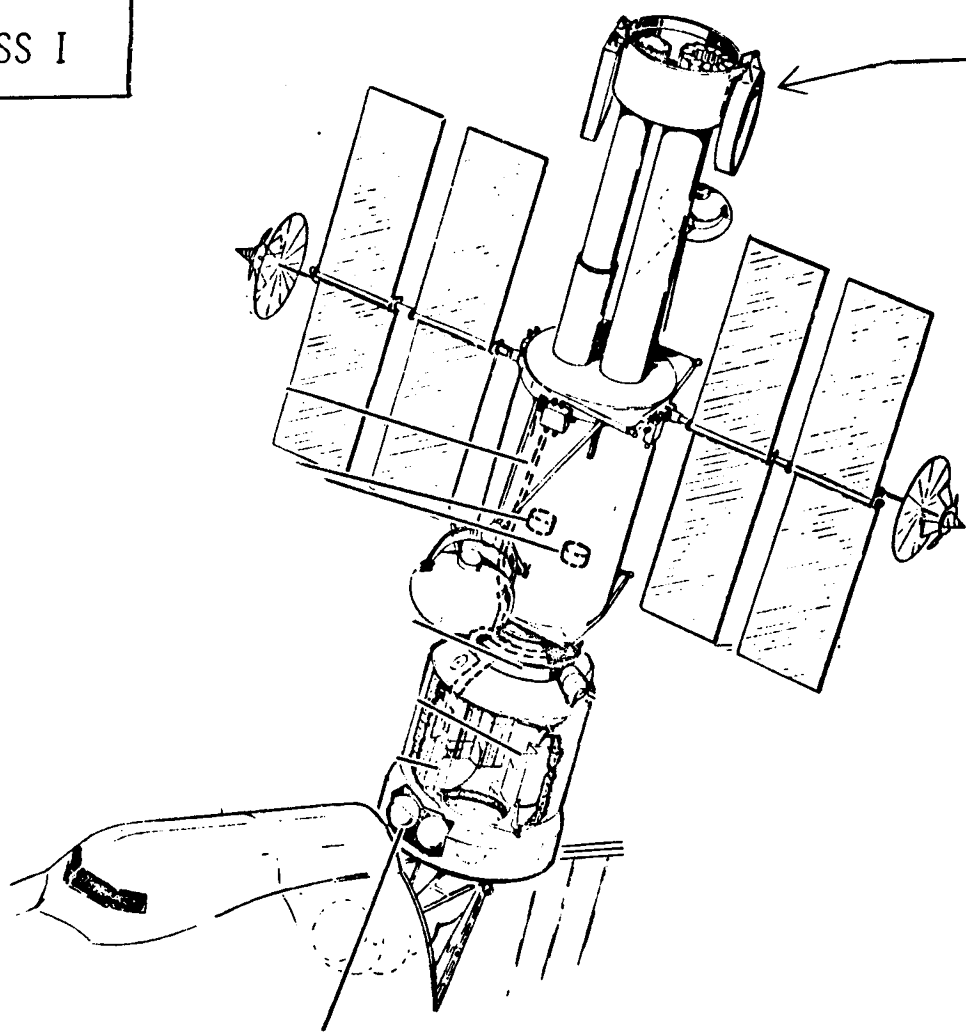
This observatory has a pressurizable compartment for access to experiments and some equipment. The tasks listed, however, must be accomplished outside the pressurized areas by EVA.

These tasks would be accomplished in the same manner as described for the pressurized LST previously.

CANDIDATE
PLANNED
EVA

CLASS I

EVA EXAMPLE #3: PRESSURIZED X-RAY ASTRONOMY OBSERVATORY



	TASK	QTY	UNIT WT (lb)	MODE
1.	Replace Optical Contam. Monitor	2	22	Pri. EVA
2.	Replace Contam. Monitoring Gage	6	0.5	Pri. EVA
3.	Mass Spectrometer Sensor	2	2	Pri. EVA
4.	Contam. Cover drive motor	2	-	Pri. EVA

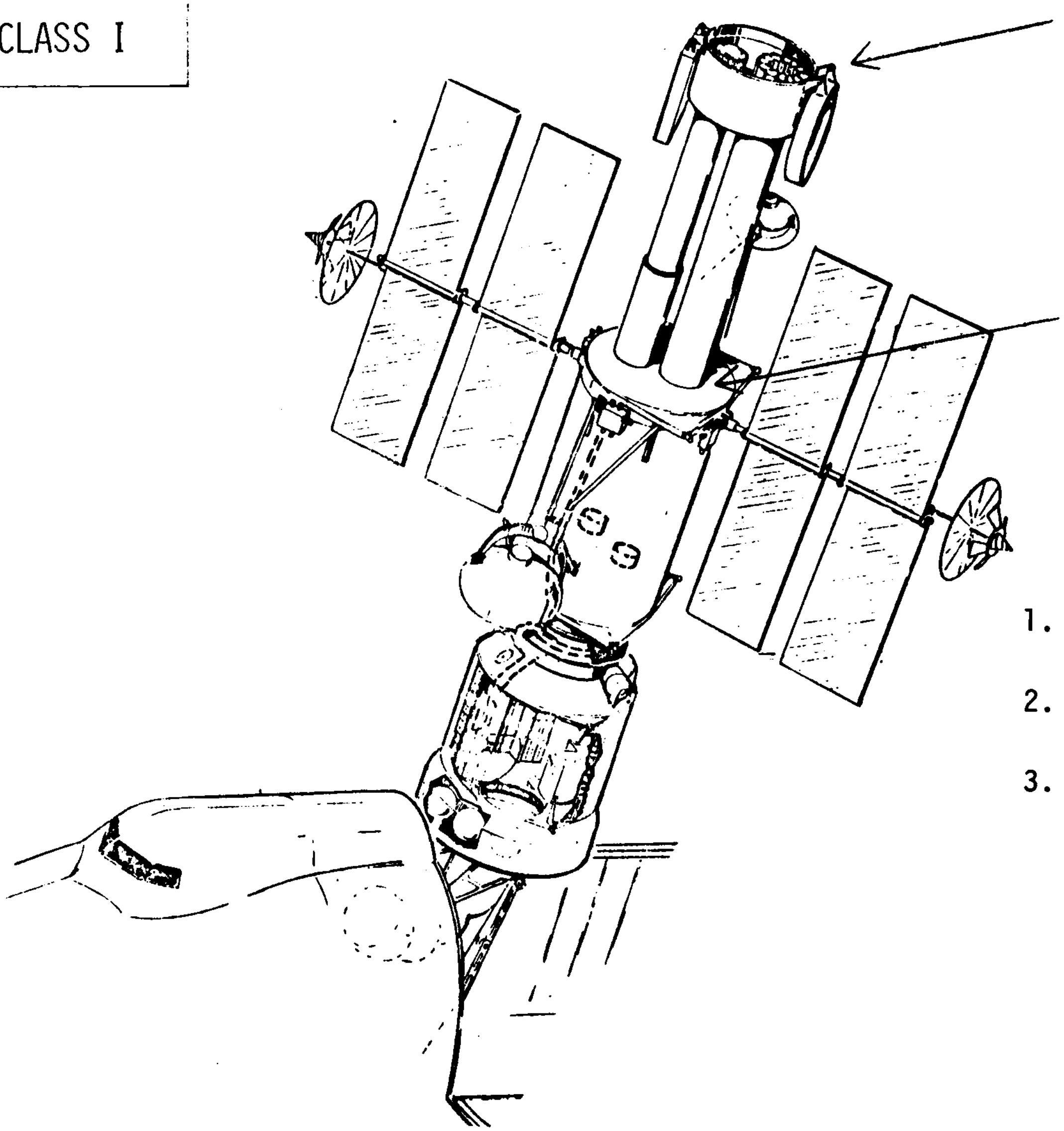
IVA EXAMPLE #1: PRESSURIZED X-RAY ASTRONOMY OBSERVATORY

In order to accomplish the tasks listed, the pressurizable compartment must be depressurized which allows access through the pressure bulkhead and through the telescope shroud to where the components are located.

CANDIDATE
PLANNED
IVA

CLASS I

IVA EXAMPLE #1: PRESSURIZED X-RAY ASTRONOMY OBSERVATORY



Replace components outside pressure bulkhead by unpressurized IVA through telescope shroud.

Pressure bulkhead

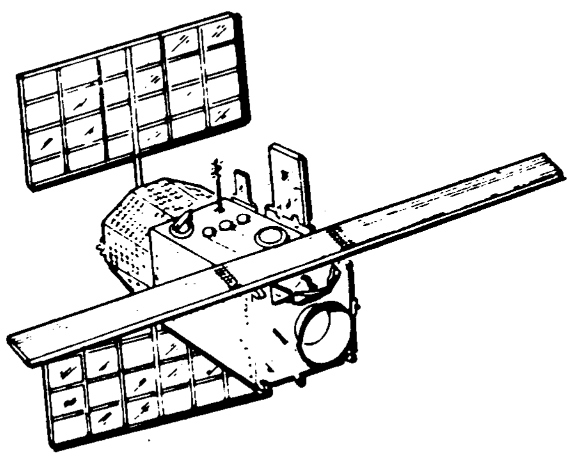
TASKS	UNIT Wt(lb)
1. Replace proportional Counter Array	166
2. Replace Scintillation Counter	286
3. Replace Flat Crystal Spectrometer	117

CLASS II - ON-ORBIT MAINTENANCE/SERVICING OF RETRIEVED SATELLITE

The representative payloads listed are satellites that could be designed for on-orbit maintenance or servicing. These satellites are at an altitude such that they may be reached by the shuttle for maintenance, and servicing is desired because of their value.

CANDIDATE
PLANNED
EVA/IVA

CLASS II - ON-ORBIT MAINTENANCE/SERVICING OF RETRIEVED SATELLITE



REPRESENTATIVE PAYLOADS:

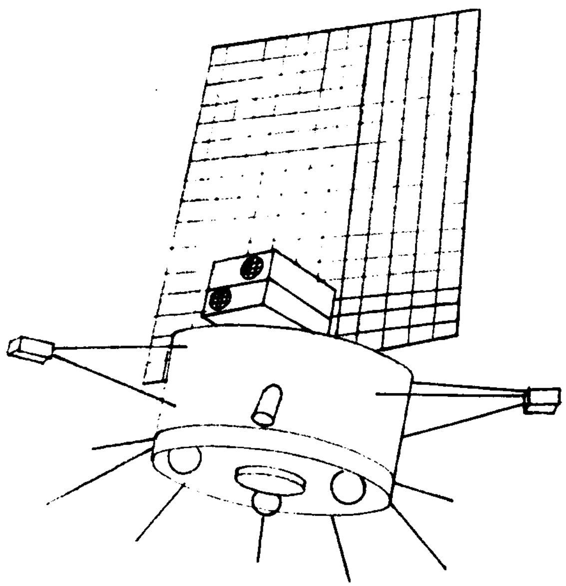
ORBITING SOLAR OBSERVATORY (NAS-15)
POLAR EARTH OBSERVATION SATELLITE (NEO-2)
EARTH PHYSICS SATELLITE (NEO-5)
POLAR EARTH RESOURCES SATELLITE (NEO-16,-17)

EVA EXAMPLE #1: ORBITING SOLAR OBSERVATORY

The sketch shows an advanced orbiting solar observatory planned for launch in 1980. The expected life is 1 year. This life could be extended by on-orbit replacement of depleted consumables or failed sensors and components as shown.

CANDIDATE
PLANNED
EVA
CLASS II

EVA EXAMPLE #1: ORBITING SOLAR OBSERVATORY



TASKS (All Pri EVA)	WEIGHT (LB)
1. Connect Umbilical	-
2. Replace Sensors	2 to 80
3. Replace Battery	≈ 120
4. Replace Propellant (3)	70 ea

CLASS III - DE-ORBIT READINESS OF

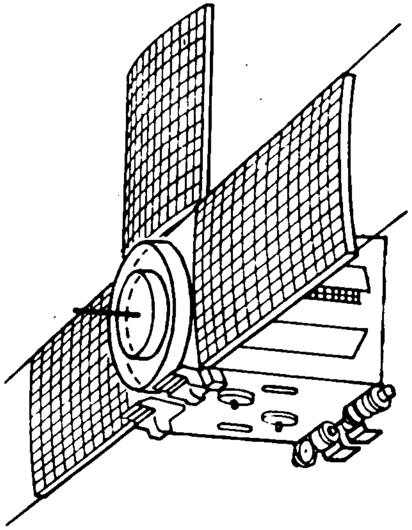
PAYLOAD IN CARGO BAY

The representative payloads listed all will require some preparation in order to get them into the Cargo bay and make them ready for de-orbit and landing in the shuttle. Example common tasks would be making umbilical connections, installing protective covers and aiding automatic systems in tying down.

The satellite shown is ITOS-D. This satellite could be designed with a docking fixture and the capability for refolding the solar cell panels. It could then be retrieved by a tug, refurbished and reused.

CANDIDATE
PLANNED
EVA/IVA

CLASS III - DE-ORBIT READINESS OF PAYLOAD IN CARGO BAY



REPRESENTATIVE PAYLOADS:

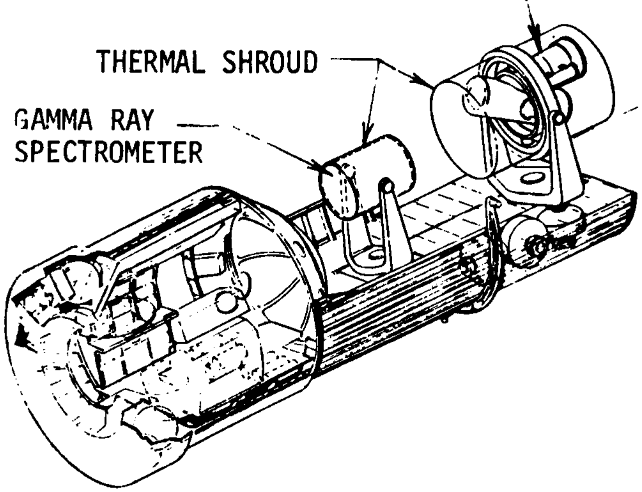
- AUSTERE SORTIE
- SATELLITE RETRIEVED BY SHUTTLE
- SATELLITE RETRIEVED BY TUG

IVA EXAMPLE #1: AUSTERE ASTRONOMY SORTIE

This is an example of a shuttle sortie mission designed to remain in the cargo bay. The measurement equipment is mounted on a pallet and the monitoring equipment contained within a pressurized sortie can. An austere design could involve several manual functions. The tasks listed would be accomplished as IVA, unpressurized within the Cargo Bay.

CANDIDATE
PLANNED
IVA
CLASS III

IVA EXAMPLE #1: AUSTERE ASTRONOMY SORTIE



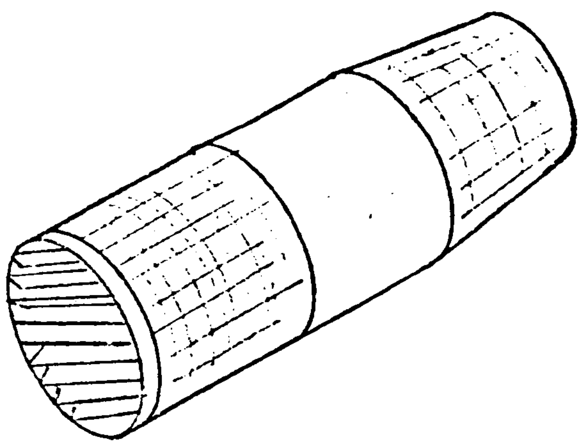
TASKS	SIZE
1. Replace Protective Shrouds	-
or	
2. Retrieve UV Camera	50 lbs
3. Secure Gimbal Latches	-

EVA EXAMPLE #1: SATELLITE RETRIEVED BY SHUTTLE

The Bioresearch Module will contain live biological specimens and must be handled carefully during retrieval and de-orbit. Once the module has been captured by shuttle equipment, the umbilical and cold plate would be attached and the module restrained within the cargo bay. The restraint design and cold plate attachment tend to be complex. EVA assistance is a viable alternate to a fully automated mechanical approach.

CANDIDATE
PLANNED
EVA
CLASS III

EVA EXAMPLE #1: SATELLITE RETRIEVED BY SHUTTLE



BIORESEARCH MODULE

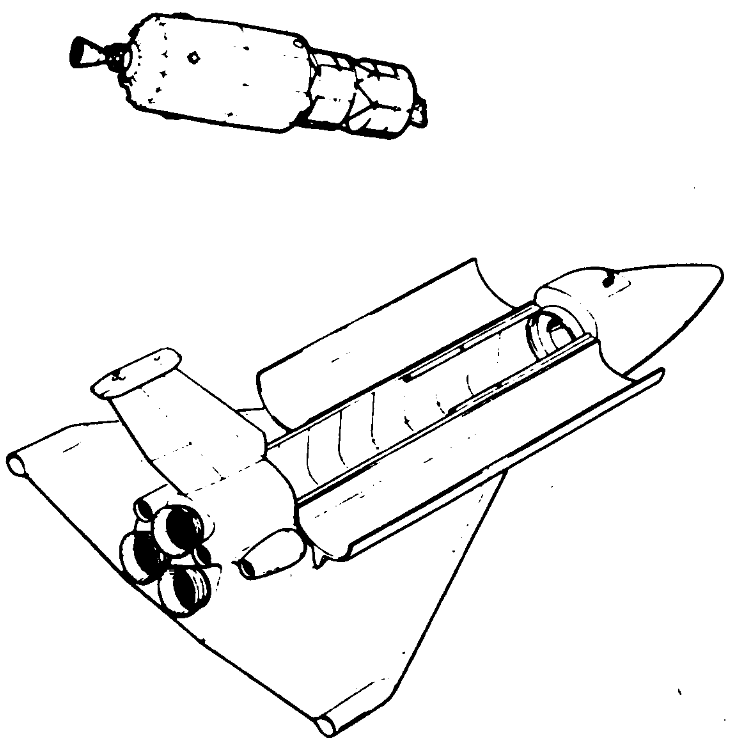
TASKS	MODE
1. Install support umbilical and cold plate	Pri EVA
2. Restrain in cargo bay	Aid Manipulator

EVA EXAMPLE #2: SATELLITE RETRIEVED BY TUG

The sketch shows the shuttle with a tug which has returned from a higher orbit with a satellite which is to be retrieved. The tasks shown could be accomplished by EVA either as a primary function or as an aid to the manipulators, again as a viable alternate to a universal or fully automated mechanical approach.

CANDIDATE
PLANNED
EVA
CLASS III

EVA EXAMPLE #2: SATELLITE RETRIEVED BY TUG



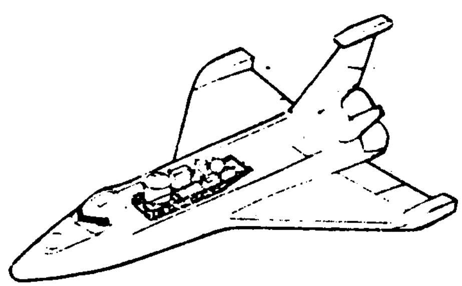
TASKS	MODE
1. Connect umbilicals	Pri EVA
2. Secure payload	Aid Manipulator
3. Add protective cover to payload	Aid Manipulator

CLASS IV - RETRIEVAL OF EXPERIMENT PACKAGES, INCLUDING SORTIE

These payloads all have packages within them which contain material which record the results of experiments. It will be desirable to remove these packages as a routine part of conducting the experiment. In the examples illustrated EVA would be a logical choice of modes.

CANDIDATE
PLANNED
EVA/IVA

CLASS IV - RETRIEVAL OF EXPERIMENT PACKAGES, INCLUDING SORTIE



REPRESENTATIVE PAYLOADS:

- AUSTERE SORTIE
- METEOROID EXPOSURE MODULE
- SHUTTLE CARGO BAY CONTAMINATION SPECIMENS

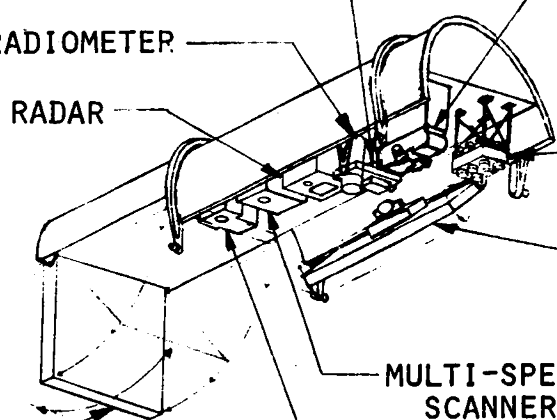
EVA EXAMPLE #1: AUSTERE EARTH OBSERVATION SORTIE

LAND USE MAPPING

This example shows Land Use Mapping experiment equipment mounted on a pallet. The experiment could be serviced and extended in duration by accomplishing the listed tasks by EVA.

CANDIDATE
PLANNED
EVA
CLASS IV

EVA EXAMPLE #1: AUSTERE EARTH OBSERVATION SORTIE LAND USE MAPPING



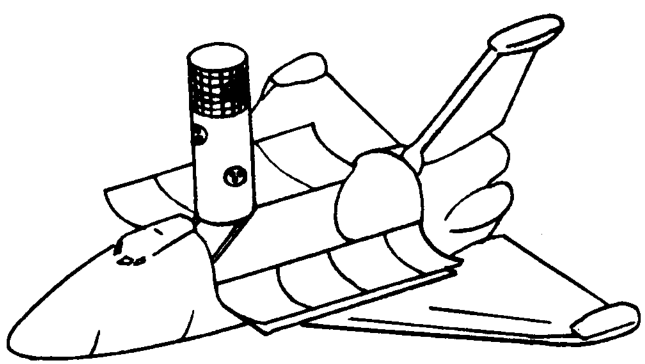
TASKS	UNIT WT(LB)	SIZE (IN)
1. Replace multispectral camera film	5	6x9x6
2. Replace metric camera film	45	50x15x20
3. Replace stellar camera film	5	6x9x6

EVA EXAMPLE #2: METEOROID EXPOSURE MODULE SAMPLE RETURN

Contamination exposure surfaces will be mounted on the Meteoroid Exposure Module to obtain data on the effects of cargo bay contaminants on payload surfaces during the delivery phase of the mission. These must be retrieved prior to release of the payload, and are likely candidates for EVA.

CANDIDATE
PLANNED
EVA
CLASS IV

EVA EXAMPLE #2: METEOROID EXPOSURE MODULE SAMPLE RETURN



TASKS	SIZE
1. Return contamination exposure surfaces (3) (Pri. EVA)	2 - 128 lbs

Rev.

CLASS V - FREE FLYING OPERATIONS

These tasks would be accomplished when it is desirable to keep the Shuttle some distance from the work area or when the Shuttle itself must be examined.

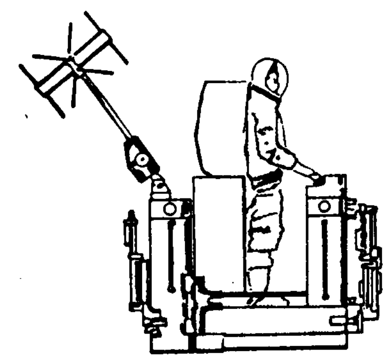
Contamination may be a problem when the Shuttle is brought close to optical devices in orbit. The work platform is an example of EVA required to work on devices which are subject to contamination.

The exterior surface of the Shuttle currently is easily damaged. It would be very desirable to have the capability to inspect the entire exterior surfaces of the Shuttle before de-orbit and landing. EVA utilizing a work platform or being supported by the manipulators are examples of methods of accomplishing this inspection.

CANDIDATE
PLANNED
EVA/IVA

CLASS V - FREE FLYING OPERATIONS

REPRESENTATIVE FREE FLYER:



MANEUVERING WORK PLATFORM

TASKS:

1. RETRIEVE SATELLITE TO SHUTTLE
2. MAINTAIN SATELLITE OUTSIDE CONTAMINANT CLOUD
3. SURVEY CONTAMINANT CLOUD
4. INSPECT/REPAIR SHUTTLE EXTERIOR

Rev.

CANDIDATE

UNSCHEDULED

EVA/IVA

CANDIDATE UNSHCEDULED EVA/IVA

Five classes of credible candidate unscheduled EVA/IVA have been identified.

Payload inspection and repair prior to deployment could be used to correct malfunctions discovered during payload checkout prior to release. Similar repair tasks could be carried out on a payload that indicates a failure immediately after shuttle release.

Manual deployment and activation of systems could be utilized following a failure of the automatic system.

Unpressurized IVA servicing would be required for a payload such as the pressurizable LST if the module could not be pressurized for some reason. Automated shuttle systems such as the cargo bay door mechanism, manipulators, payload service umbilicals, etc. can also fail and a backup, manual mode of operation could be used.

CANDIDATE UNSCHEDULED EVA/IVA:

CLASS I - INSPECTION/REPAIR OF PAYLOAD PRIOR TO DEPLOYMENT

CLASS II - DIAGNOSE/REPAIR/RETURN SATELLITE WHICH FAILS AFTER INJECTION

CLASS III - ASSIST AUTOMATED SYSTEM WHICH HAS MALFUNCTIONED

CLASS IV - UNPRESSURIZED IVA

CLASS V - INSPECT/ASSIST/REPAIR OPERATIONS

CLASS I - INSPECTION/REPAIR OF PAYLOAD PRIOR TO DEPLOYMENT

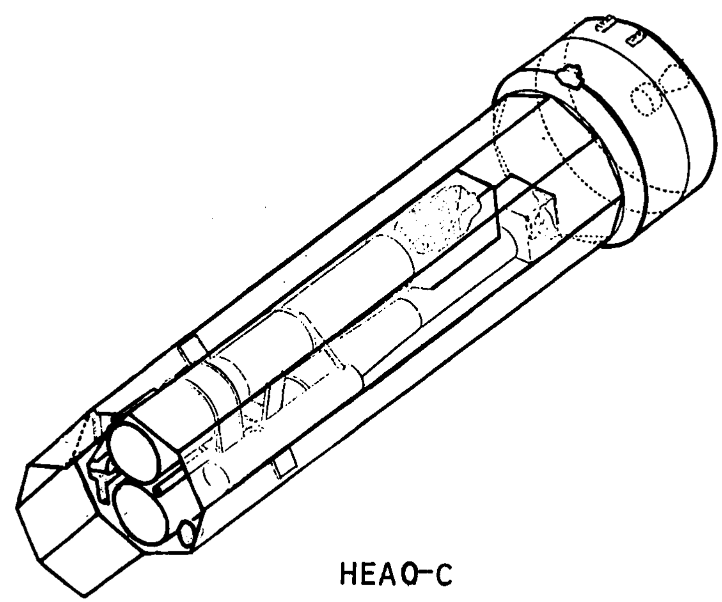
The payloads that are the most likely candidates for unscheduled EVA/IVA inspection and repair are those which are high value such as the large astronomy observatories and others such as planetary probes that have a narrow launch window.

CANDIDATE
UNSCHEDULED
EVA/IVA

CLASS I - INSPECTION/REPAIR OF PAYLOAD PRIOR TO DEPLOYMENT

REPRESENTATIVE PAYLOADS:

- LARGE ASTRONOMY OBSERVATORIES
- HIGH VALUE OR CRITICAL OPPORTUNITY PAYLOAD (PLANETARY TOUR)



HEAO-C

TASKS:

1. ROUTINE INSPECTION OF PAYLOAD UPON MALFUNCTION OF AUTOMATED SYSTEM
2. INSPECTION/REPAIR/REPLACEMENT OF MALFUNCTIONING SUBSYSTEM OR EXPERIMENT DURING ORBITAL READINESS TESTING
3. PROVIDE EXTERNAL CALIBRATION STIMULANTS TO EXPERIMENTS UPON FAILURE OF AUTOMATED SYSTEM

CLASS II - DIAGNOSE/REPAIR/RETURN PAYLOAD WHICH FAILS AFTER INJECTION

The same high value or critical opportunity payloads that are good candidates for on-orbit repair prior to release from the shuttle should be considered as likely candidates for repair if a failure occurs after injection into orbit. The driving factor is the same as the pervious case; the desire to save a valuable mission, but the tasks required may be different and therefore they must be separated into a distinct class.

CANDIDATE
UNSCHEDULED
EVA/IVA

CLASS II - DIAGNOSE/REPAIR/RETURN PAYLOAD WHICH FAILS AFTER INJECTION

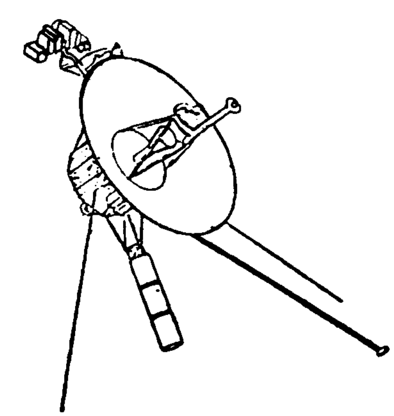
REPRESENTATIVE PAYLOADS:

LARGE ASTRONOMY OBSERVATORIES

HIGH VALUE OR CRITICAL OPPORTUNITY PAYLOAD (PLANETARY TOUR)

TASKS:

1. RECONNECT UMBILICALS
2. INSPECT/REPAIR/REPLACEMENT OF MALFUNCTIONING SUBSYSTEM OR EXPERIMENT
3. RETRACT DEPLOYED APPENDAGES
4. SECURE, SAFE & PROTECT PAYLOAD PRIOR TO DE-ORBIT



MARINER JUPITER SPACECRAFT

ASSIST AUTOMATED SYSTEM WHICH HAS FAILED

This class of unscheduled tasks encompasses a wide variety of potential EVA and IVA, and is expected to be one of the major areas in which man can contribute to the success of the mission. Functions range from simple inspection operations, to assisting electromechanical engagement/latching mechanisms, to manual deployment of sensors or arrays, to on-orbit repairs, to potential manual erection of sortie modules.

The illustrated example shows plasma wake measurements on a physics sortie. The booms are nomally motor driven and deployed from three small airlocks. They are periodically retracted for sensor changeout. A malfunction could require unpressurized IVA in the module to manually crank the boom mechanism, or EVA to assist the external mechanism or change sensors.

CANDIDATE
UNSCHEDULED
EVA/IVA

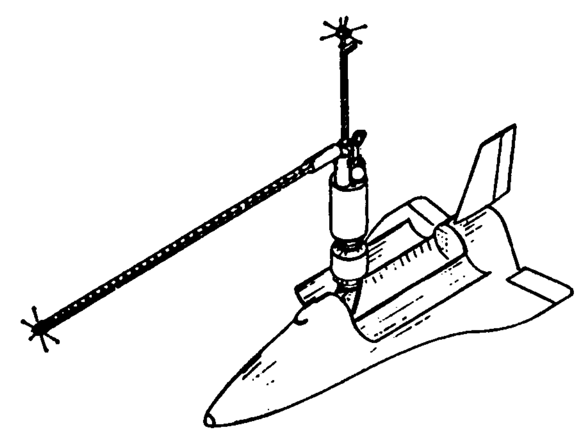
CLASS III - ASSIST AUTOMATED SYSTEM WHICH HAS FAILED

EXAMPLES:

PAYLOAD DEPLOYMENT MECHANISMS
SHUTTLE DEPLOYMENT MECHANISMS
EXPERIMENT ACTIVATION MECHANISMS

TASKS:

1. ENGAGE/DISENGAGE UMBILICALS/COLD PLATES
2. MANUALLY DEPLOY SENSORS, ARRAYS, ANTENNAS
3. ASSIST MANIPULATOR ENGAGEMENT/DISENGAGEMENT
4. UNLATCH/REMOVE/REPLACE SHROUD AND PROTECTIVE COVERS OR PAYLOAD HOLDDOWN
5. REPLACE DRIVE MOTOR MODULES
6. UNLOCK SORTIE GIMBALS
7. DETERMINE KICKSTAGE ALIGNMENT
8. MANUALLY ERECT/RETRACT MODULE OR BEAM
9. FREE PAYLOAD DOCKING COLLAR
10. GUIDE PAYLOAD RETRACTION



PLASMA WAKE MEASUREMENTS

CLASS IV - UNPRESSURIZED IVA

Some concepts for payloads requiring on-orbit servicing such as the LST utilize a pressurizable compartment to allow shirt sleeve servicing. The modules are unmanned and the compartment is normally unpressurized. If it could not be pressurized following docking with the shuttle, the servicing could be done by unpressurized IVA to save the mission. Similarly, if a support module could not be pressurized during a sortie, part of the value of the mission could be recovered by conducting critical or high priority functions by unpressurized IVA.

CANDIDATE
UNSCHEDULED
EVA/IVA

CLASS IV - UNPRESSURIZED IVA

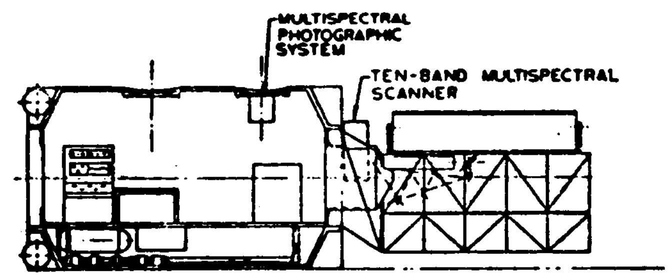
EXAMPLES:

LARGE ASTRONOMY PAYLOAD SERVICING

CONDUCT OF SORTIE EXPERIMENTS

TASKS:

1. SERVICING FREE FLYING ASTRONOMY MODULE IN EVENT OF INABILITY TO PRESSURIZE
2. PERFORM EXPERIMENT/CRITICAL OPERATIONS IN EVENT OF SORTIE CAN PRESSURIZATION FAILURE



SORTIE CAN EARTH RESOURCES
AND MATERIAL SCIENCES

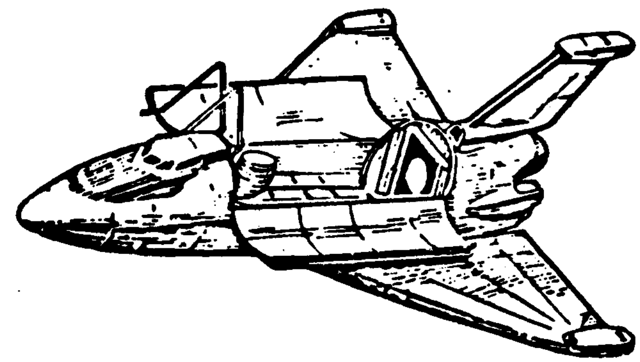
CLASS V - INSPECT/ASSIST/REPAIR OPERATIONS

ON SHUTTLE

EVA/IVA should be considered to be a backup mode to many of the payload related systems required on the shuttle. Failures of systems such as the manipulators, cargo bay door deployment mechanism, payload alignment, etc., might be easily corrected if provision were made for a manual backup.

CANDIDATE
UNSCHEDULED
EVA/IVA

CLASS V - INSPECT/ASSIST/REPAIR OPERATIONS ON SHUTTLE



EXAMPLES:

1. CARGO BAY CONTAMINATION SURVEY
2. ASSIST CARGO BAY DOOR DEPLOYMENT
3. INSPECT/REPAIR PAYLOAD SERVICES
4. BACKUP TO BASELINE PAYLOAD ALIGNMENT
5. BACKUP TO PROPELLANT TRANSFER

CANDIDATE

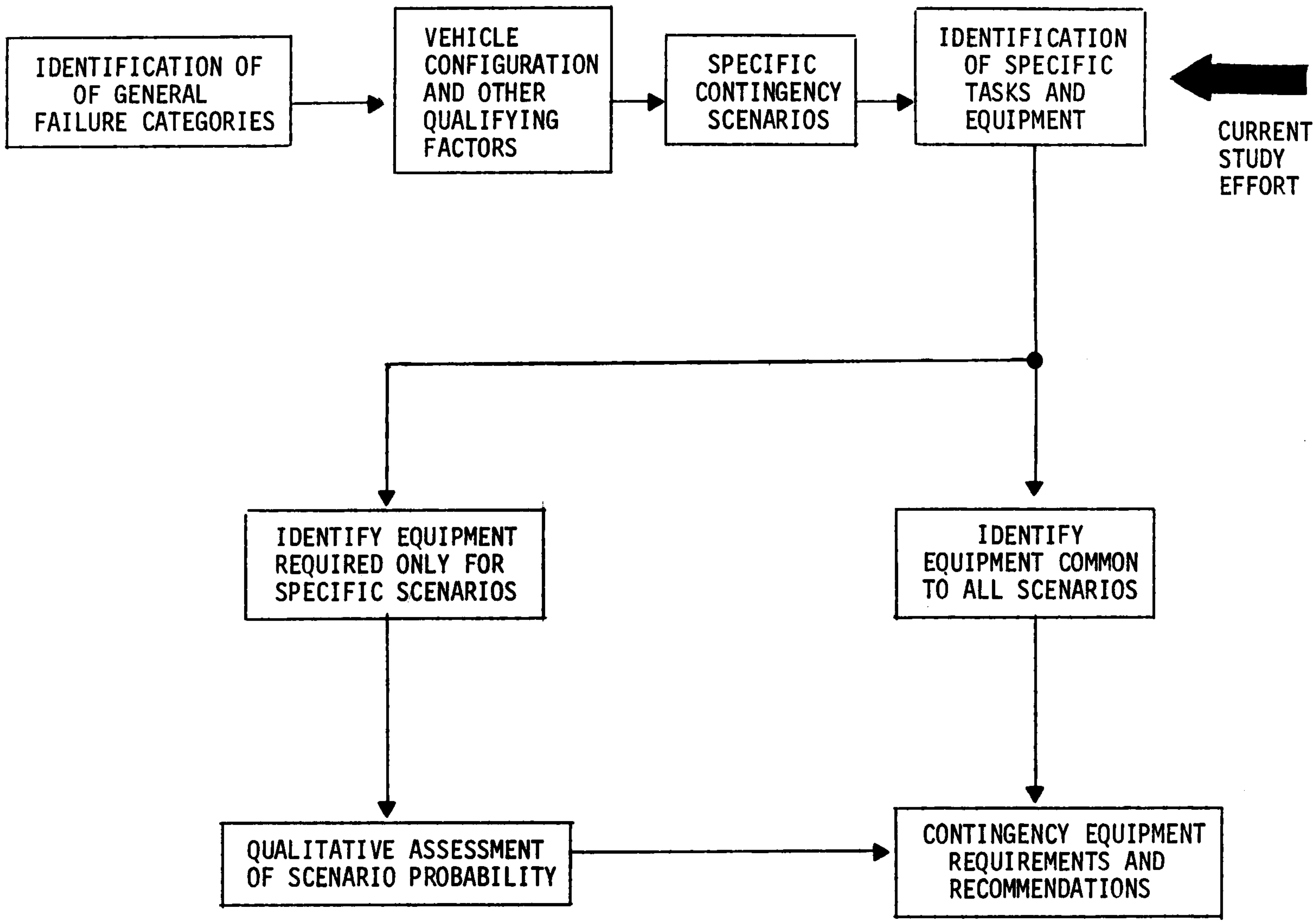
CONTINGENCY

EVA/IVA

CONTINGENCY EQUIPMENT SELECTION LOGIC

General categories of credible failures that can occur during shuttle and related operations have been identified by previous studies. Notably the recently completed safety in earth orbit study by North American. These categories have been further divided by VMSC to allow the identification of specific scenarios requiring EVA/IVA equipment or action.

Following the identification of the contingency tasks and equipment for each scenario, the equipment that is common to all scenarios can be identified. The equipment required only for a particular scenario will be included in the final contingency recommendations if an assessment of that scenario's probability of occurrence indicates that particular contingency is likely to occur.


IDENTIFICATION OF
OF GENERAL
FAILURE CATEGORIES
VEHICLE
CONFIGURATION
AND OTHER
QUALIFYING
FACTORS
SPECIFIC
CONTINGENCY
SCENARIOS
IDENTIFICATION
OF SPECIFIC
TASKS AND
EQUIPMENT
CURRENT
STUDY
EFFORT
IDENTIFY EQUIPMENT
REQUIRED ONLY FOR
SPECIFIC SCENARIOS
IDENTIFY
EQUIPMENT COMMON
TO ALL SCENARIOS
QUALITATIVE ASSESSMENT
OF SCENARIO PROBABILITY
CONTINGENCY EQUIPMENT
REQUIREMENTS AND
RECOMMENDATIONS

CONTINGENCY EVA/IVA CATEGORIES

Eight categories of related contingency situations with a potential requirement for EVA/IVA equipment or action have been identified. Each category is further divided into scenarios so that specific tasks, actions, and related equipment can be identified.

CONTINGENCY EVA/IVA CATEGORIES

CLASS I	DAMAGE CONTROL OF FIRE OR RELEASE OF TOXIC SUBSTANCES
CLASS II	DAMAGE CONTROL FOLLOWING 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

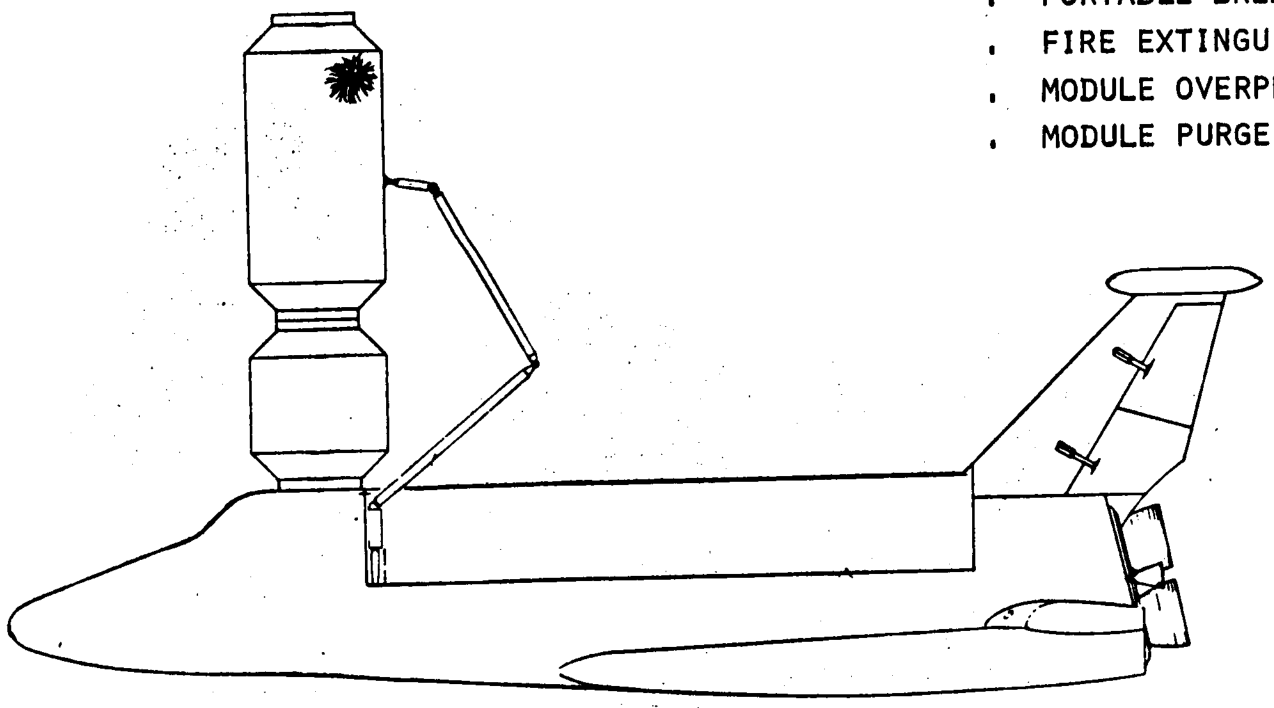
CLASS I - DAMAGE CONTROL OF FIRE OR RELEASE OF TOXIC SUBSTANCES

A fire or release of toxic substances could occur in the orbiter cabin or in a manned experiment module. Fires could be caused by a variety of sources such as electrical discharge or short circuits, chemical reactions, open flames, etc. Most fires would produce toxic byproducts but other sources of toxic material include cryogen spills, propellant leakage, and experimental chemicals. The scenario chosen for illustration is the case of a fire in a manned experiment module. The tasks and equipment required for the other scenarios are also being identified during this study.

Following the detection of a fire all crewmen not essential for fire fighting should evacuate the module and close the hatch. The remaining crewmen will don portable breathing apparatus stored in the module and extinguish the fire with portable fire extinguishers. The module will then be purged of toxic products before opening the hatch. An alternative procedure is to have all crewman evacuate the module and then extinguish the fire by depressurization.

GENERAL EQUIPMENT REQUIREMENTS

- PORTABLE BREATHING APPARATUS
- FIRE EXTINGUISHERS
- MODULE OVERPRESSURE RELIEF VALVES
- MODULE PURGE VALVES

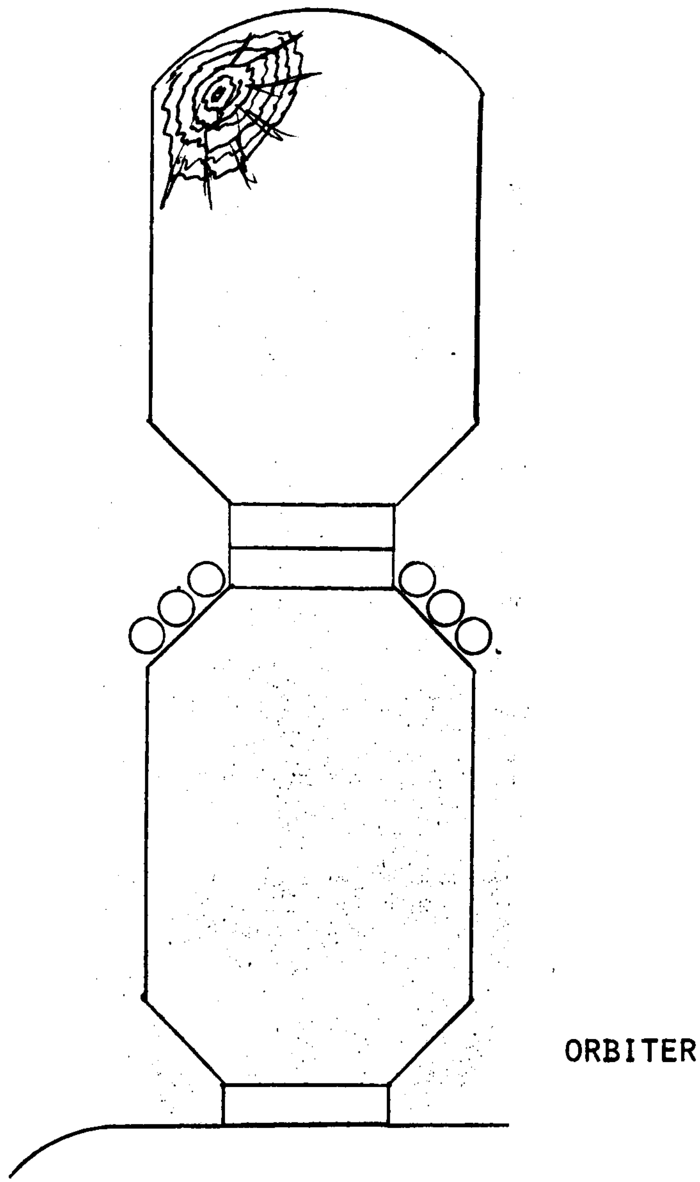


CLASS I EXAMPLE - FIRE IN MANNED EXPERIMENT MODULE

CLASS II - DAMAGE CONTROL FOLLOWING EXPLOSION

An explosion could occur in many locations in the shuttle orbiter. However, the most likely locations are in the cargo bay 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.

The first tasks required following an explosion are to remove injured crewmen from the area and determine the cabin pressure integrity. The subsequent emergency action and equipment will be designed to deal with the secondary damage and fires caused by the explosion. These are described in other scenarios.



GENERAL EQUIPMENT REQUIREMENTS

- PORTABLE BREATHING APPARATUS
- FIRE EXTINGUISHERS
- MODULE OVERPRESSURE RELIEF VALVES
- MODULE PURGE VALVES

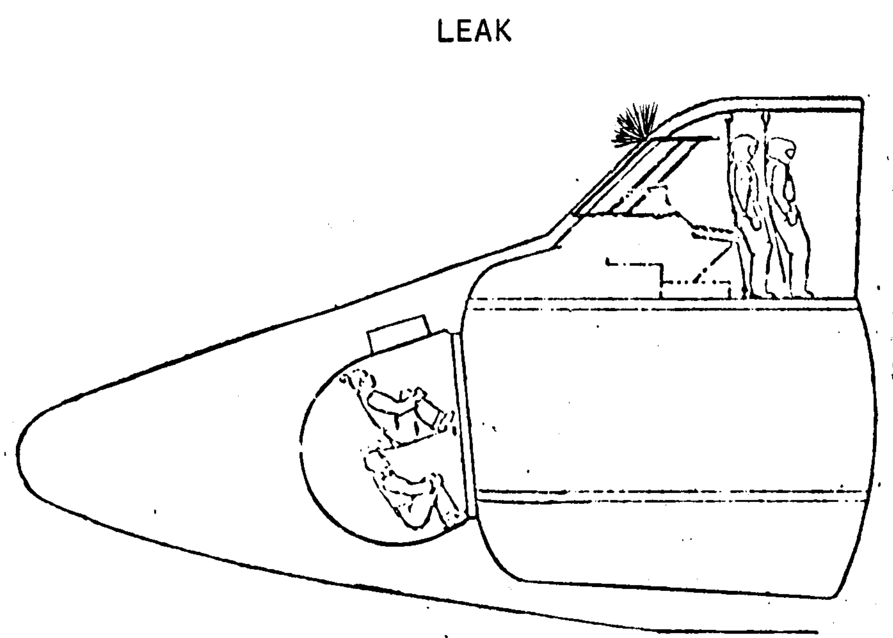
CLASS II EXAMPLE - EXPLOSION IN MANNED EXPERIMENT MODULE

CLASS III - DECOMPRESSION OF PRESSURIZED COMPARTMENT

In the case of decompression of a pressurized compartment, factors such as location and size of the leak; volume and configuration of the orbiter cabin, experiment module, and air lock; number of suits and time required for donning; and storage location of the pressure suits are all important in determining the tasks required for a particular scenario.

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. The air lock is sized for two men and has insufficient volume for the entire crew.

The first task required is recognition of the problem and determination of the leakage rate. This can be done by providing an alarm on the cabin gas make-up flow and a meter that would indicate the time available before the gas supply is exhausted. The crewmen essential for reentry must don suits and breathing equipment. The remaining crewmen can either don suits or take shelter in the air lock provided the air lock has accommodations for emergency reentry. The suited crewmen will then attempt to locate and repair the leak. If the leak can't be repaired, they will conduct an unpressurized abort.



GENERAL EQUIPMENT REQUIREMENTS

- LEAK MONITORING EQUIPMENT
- IV PRESSURE SUITS AND LIFE SUPPORT SYSTEMS
- LEAK LOCATION AND REPAIR EQUIPMENT
- REENTRY RESTRAINTS IN AIRLOCK

CLASS III EXAMPLE - DECOMPRESSION OF ORBITER CABIN

CLASS IV - INTERNAL HATCH FAILURE OR BLOCKED ACCESS PATH

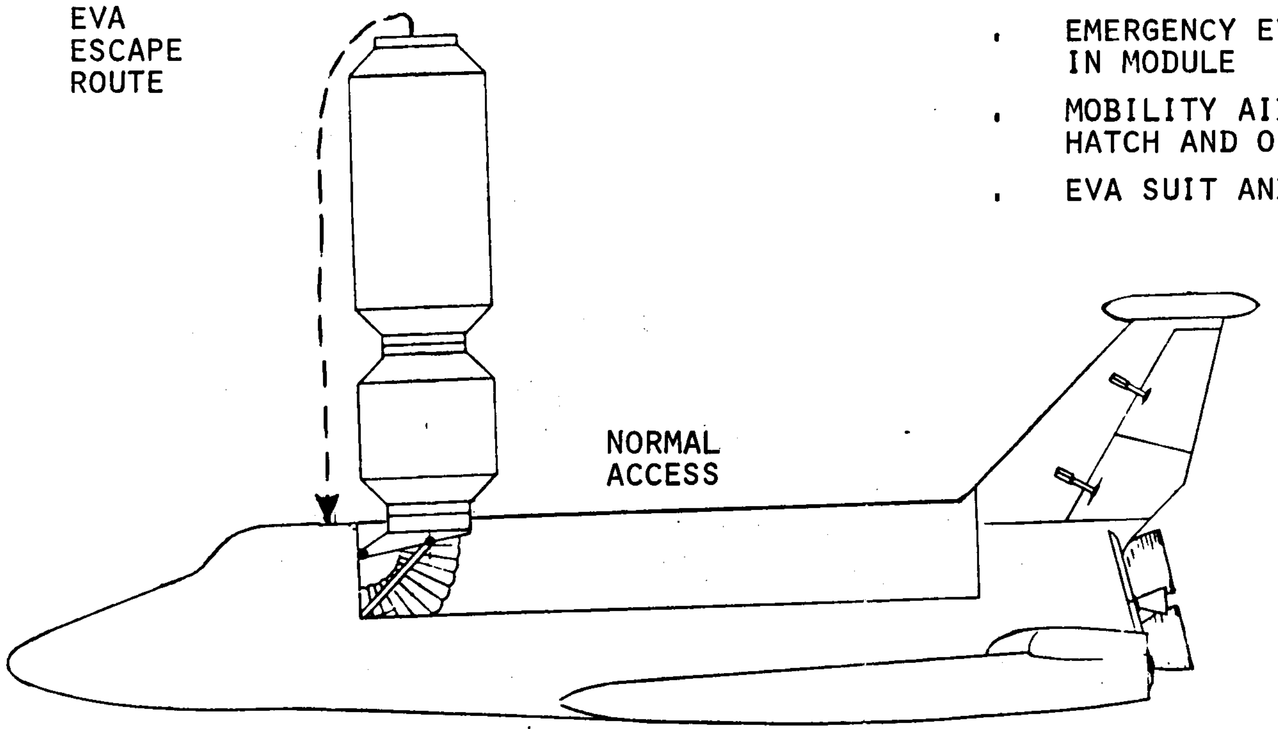
The factors that identify specific scenarios in this case are whether the hatch is failed open or closed, whether or not an alternate shirt-sleeve path is available, and whether the problem must be rectified prior to reenty.

The scenario chosen for illustration is the case of blocked access between the orbiter and a manned experiment module. It is assumed that an alternate shirt-sleeve path is not available and the module crewmen must enter the shuttle for reentry.

The module crewmen must don emergency EVA protective gear stored in the experiment module and egress the module through an emergency hatch. Orbiter crewmen, trained for EVA, can assist them in moving to an orbiter external hatch. If the module was docked to the air lock then they must enter through an alternate hatch, which may require depressurization of the orbiter cabin. In this case, suits or an alternate pressure refuge chamber must be provided for the remaining orbiter crewmen.

GENERAL EQUIPMENT REQUIREMENTS

- EMERGENCY EVA SUITS AND LSS STORED IN MODULE
- MOBILITY AIDS BETWEEN MODULE EMERGENCY HATCH AND ORBITER
- EVA SUIT AND LSS FOR ORBITER CREWMAN



CLASS IV EXAMPLE - BLOCKED ACCESS BETWEEN ORBITER AND MANNED EXPERIMENT MODULE

CLASS V - FAILURE TO DOCK/UNDOCK

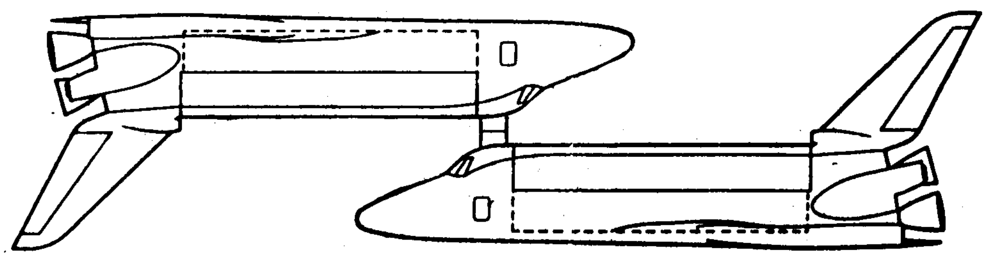
The primary qualifying factors that determine the separate scenarios in this case are whether the failure prevents docking from occurring or whether the failure prevents safe release following docking. In the case of failure to "hard" dock, further distinguishing factors are whether or not the vehicle to be docked with is manned or unmanned. Failures during the undocking procedure require different tasks and equipment depending on whether the failure occurs in a pressure seal or a hatch or it is a mechanical failure of the docking mechanism.

The scenario chosen for illustration is the case of failure to dock with a manned vehicle. This is similar to the LM contingency transfer and could occur between the shuttle and an orbiting station or between two shuttles.

The first task is for the orbiter EVA crewman to conduct an EVA to attempt to diagnose and repair the cause of the failure. If this can't be accomplished, then EVA transfer is required between the vehicles. The trained EVA crew can erect mobility aids and assist the other crew and passengers in translation. Further inspection and safing of the abandoned vehicle is then required to allow recovery on a subsequent mission.

GENERAL EQUIPMENT REQUIREMENTS

- EVA SUITS AND LSS FOR PLANNED EVA CREWMEN
- EMERGENCY EVA SUITS AND LSS FOR ALL CREWMEN ABOARD PASSIVE VEHICLE
- MOBILITY AIDS



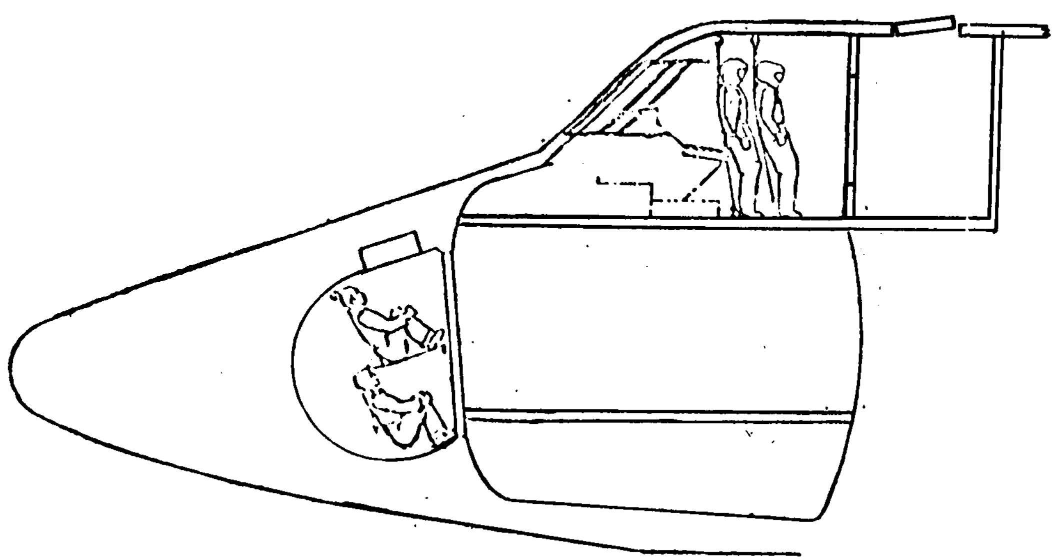
Rev.

CLASS V EXAMPLE - FAILURE TO DOCK WITH MANNED VEHCILE

CLASS VI - FAILURE OF AIR LOCK 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.

In this case the orbiter cabin must be depressurized to allow the crewman to enter the cabin. This requires pressure suits or a separate compartment for the remaining crew and passengers. The outer hatch must also be safed for reentry to prevent damage caused by reentry g loads, aerodynamic pressure, or heating. This may require special tools or materials. After safing the outer hatch, the inner hatch can be sealed and the mission can be continued if necessary.



GENERAL EQUIPMENT REQUIREMENTS

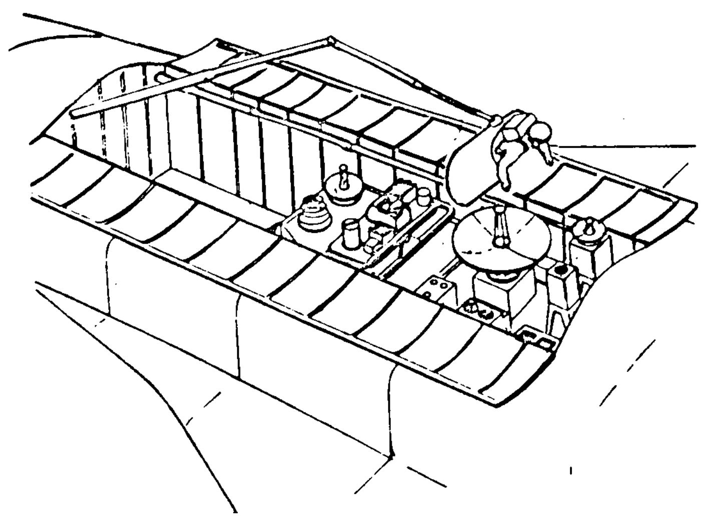
- EMERGENCY PRESSURE SUITS AND LSS FOR CREW AND PASSENGERS
- PRESSURE REFUGE CHAMBER
- TOOLS AND MATERIALS TO "SAFE" HATCH FOR REENTRY

CLASS VI EXAMPLE - OUTER HATCH FAILS TO CLOSE FOLLOWING EVA/IVA

CLASS VII - SHUTTLE EXTERNAL DAMAGE

External damage to the shuttle can result from a variety of causes during ascent or orbital operations. Among the most credible causes are collision during docking, cargo manipulator, or with meteoroids or other debris; solid rocket motor case burn-through; and explosions in or near the cargo bay. Inspection would be required following any indication of possible damage and external inspection of items such as the orbiter heat shield and controls might be desirable prior to reentry in any case.

An EVA suit and LSS would be required and fixed mobility aids or a simple hand-held maneuvering unit would be required to allow access to areas such as the lower fuselage and aerodynamic control surfaces. Simple tools and/or repair materials could allow some types of damage to be repaired without outside assistance to allow safe reentry.



GENERAL EQUIPMENT REQUIREMENTS

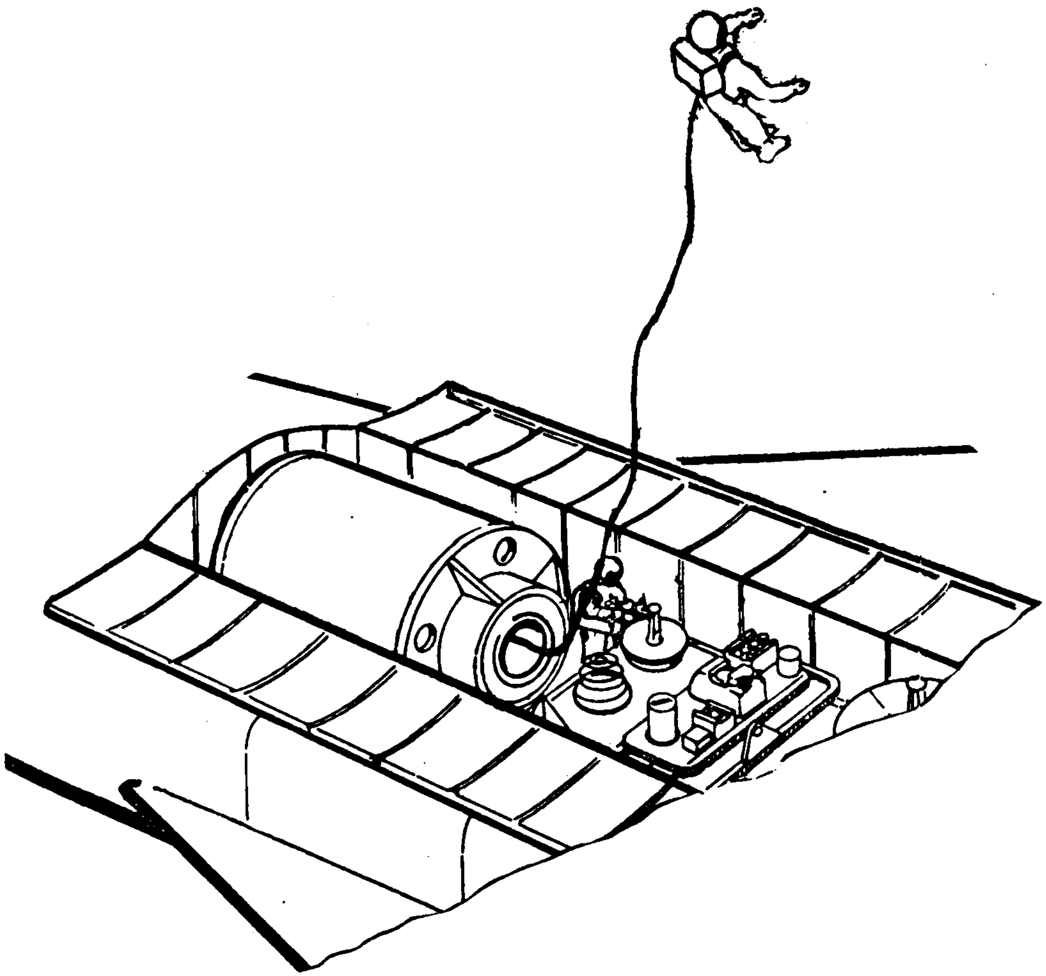
- EVA SUIT AND LSS
- MOBILITY AIDS AND/OR MANEUVERING UNIT
- HEAT SHIELD AND OTHER REPAIR TOOLS AND MATERIALS

CLASS VII EXAMPLE - SHUTTLE EXTERNAL DAMAGE

CLASS VIII - RESCUE 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 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 EVA crewman who is tethered to the orbiter but has drifted away from the surface.

A second crewman must don EVA protective gear and translate to the tether anchor. The disabled crewman can be pulled in directly provided he has no significant angular momentum relative to the shuttle (some type of momentum transfer device may be required if he has significant angular momentum). The rescue crewman then carries the disabled crewman into the air lock.



GENERAL EQUIPMENT REQUIREMENTS

- EVA EQUIPMENT FOR RESCUE CREWMAN
- AIRLOCK OPERABLE WHILE OTHER CREWMEN ARE EVA

CLASS VIII EXAMPLE - RESCUE DISABLED EVA CREWMAN

EVA/IVA EQUIPMENT FAILURES

The equipment designed for EVA/IVA must have provisions to accommodate the credible failures listed without outside assistance. An analysis of the emergency response times required shows that failures of the gas pressurization system are the most critical since consciousness will be lost in less than 15 seconds following exposure to vacuum and in several minutes following loss of gas circulation or CO_2 removal. Failures of the thermal control system are less critical for shuttle-based EVA/IVA operations than for lunar EVA's, since it is anticipated that the crewman will never be far from shelter in the orbiter. In many cases thermal storage in the crewman's body can be relied upon for the required emergency duration.

EVA/IVA EQUIPMENT FAILURES

CREDIBLE FAILURE	EMERGENCY SYSTEM REQUIREMENT
GAS CIRCULATION AND PRESSURIZATION SYSTEM	MAINTAIN SUIT PRESSURE AND PROVIDE FRESH BREATHING GAS
THERMAL CONTROL SYSTEM	MAINTAIN CREWMAN THERMAL COMFORT WITHIN ACCEPTABLE LIMITS
DEPLETED EVA EXPENDABLES	PROVIDE RESERVE CAPACITY
MANEUVERING UNIT	PROVIDE EMERGENCY RETURN CAPABILITY

GUIDELINES AND CONSTRAINTS

The guidelines presented in this section are intended to be used as general guidelines that can be violated if sufficient justification can be demonstrated. The constraints are considered to be inviolable. It is anticipated that further guidelines and constraints will be added during the remainder of the study.

GUIDELINES

AND

CONSTRAINTS

It is assumed that tethers and tether mounts will not fail since the admission of a failure might lead to a requirement on all EVAs for a maneuvering unit to allow safe return to the orbiter. If a failure did occur, the orbiter could maneuver to recover the crewman.

Recirculation of prebreathing oxygen into the cabin or pressurization of the airlock directly from the cabin could cause the orbiter cabin atmosphere to deviate outside its design envelope. These effects will be evaluated for different system concepts.

Maneuvering systems require a fail operational capability to allow a safe return to the orbiter following a failure during free-flying operations.

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 PRESSURIZED 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.

An EVA suit may not provide the same degree of radiation protection as the orbiter pressure cabin. Therefore, a dosimeter is required to be sure that an EVA crewman does not exceed the allowed radiation dose.

A requirement for continuous communications between the orbiter and the EVA/IVA crewman may lead to a requirement for a communications tether or additional antennas on the orbiter.

SHUTTLE EVA/IVA STUDY CONSTRAINTS (CONTINUED)

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.

Potential hazards resulting from tether dynamics and orbital mechanics will be calculated and evaluated if a need for a long tether and free flight operations is established.

Two men may be required to accomplish some EVA/IVA tasks or a second man may be required for rescue operations.

Potential contamination of experiments, etc. by the orbiter contaminant cloud has been discussed previously. A suited crewman also generates a cloud of contaminants, particularly in the gas of an open or semi-open loop LSS like the ALSA or if a water evaporative heat sink is used for cooling. These effects will be considered both in the selection of equipment and the tasks to be performed.

SHUTTLE EVA/IVA STUDY CONSTRAINTS (CONTINUED)

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.

Rev.

Maneuvering using the orbital maneuvering system, which can generate accelerations up to 0.5 g, should be restricted during normal EVA/IVA operations since the crewman may not be properly restrained at all times.

SHUTTLE EVA/IVA STUDY CONSTRAINTS (CONTINUED)

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:

PREBREATHING REQUIREMENTS

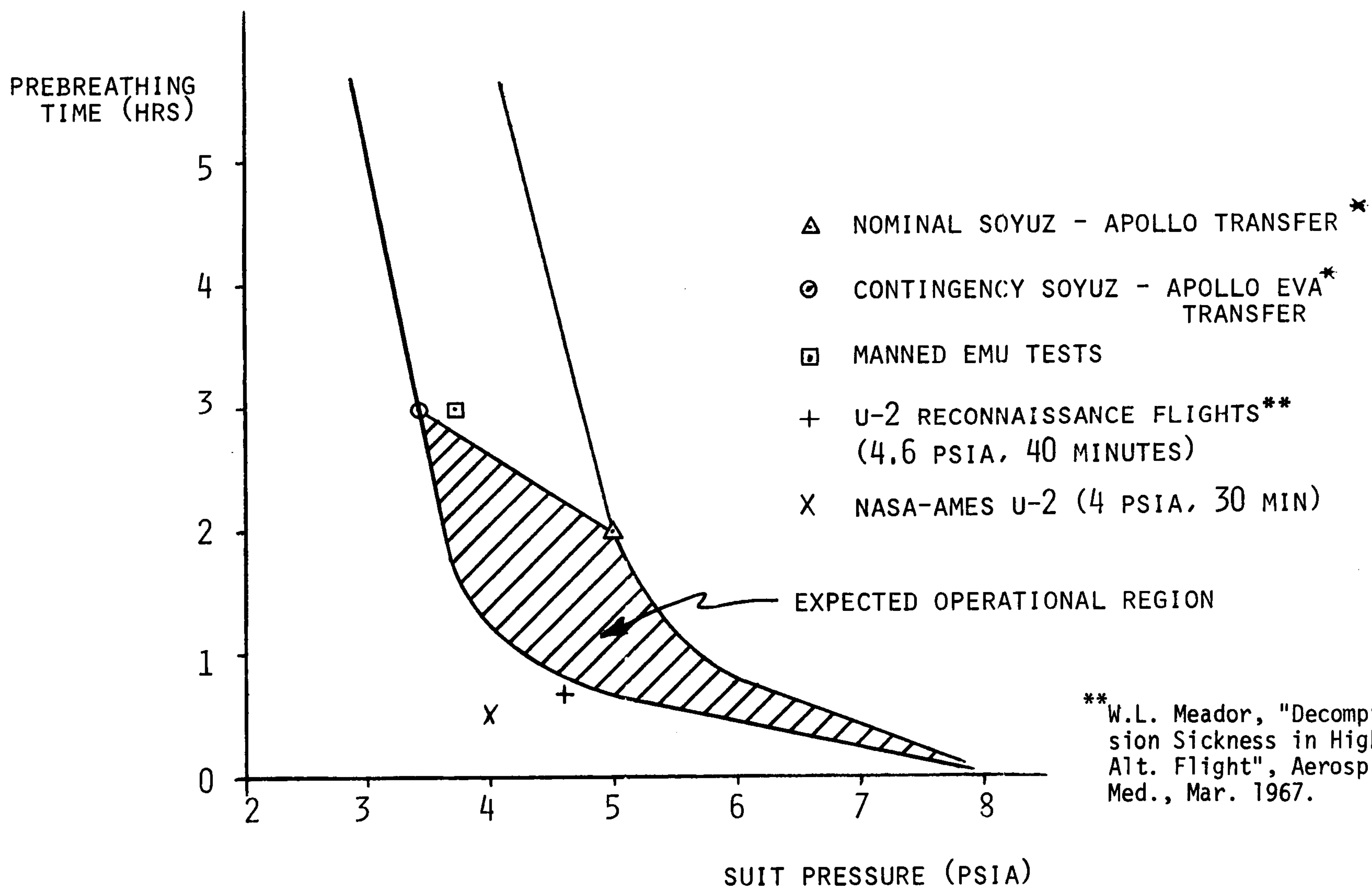
This figures presents the prebreathing time required as a function of suit pressure. The initial atmosphere is assumed to be a sea-level O_2-N_2 mixture at 14.7 psia. Several data points from manned suit tests and the planned joint US-Russian mission are included for comparison. The most interesting point on this curve is the "knee" that occurs in the range of 4-6 psia. A considerable reduction in prebreathing time is possible by operating the suit at a pressure above the "knee".

The lower curve represents approximately a 90% probability that no subjects drawn from a random population will suffer bends symptoms while the upper curve is about 99%. The effects of using each of these curves on equipment requirements will be quantitatively determined. It is possible that one curve may be used for routine EVA/IVA operations and the other for contingencies. Similarly, different curves may be used for the passengers and crew.

based on data in
Aerospace Medicine
Vol. 36, No. 5, May 1965

Rev.

PREBREATHING REQUIREMENTS



**W.L. Meador, "Decompression Sickness in High Alt. Flight", Aerosp. Med., Mar. 1967.

*Subsequent Apollo Soyuz Test Project (ASTP) changes reduced Soyuz pressure to 10 psia and eliminated prebreathing requirement.

Rev.

SHUTTLE EVA/IVA STUDY GUIDELINES

The shuttle-based EVA environment will be the normal earth orbital environment with the modification to the thermal environment caused by the orbiter and payloads. The IVA environment is distinguished by the lack of direct solar heating, but the crewman is surrounded by a structural enclosure that may provide a very hot thermal environment. Various environments will be evaluated to establish the full range of requirements.

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 ENVIRONMENTS
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.

Rev.

The heat exchangers, plumbing, and other equipment required to interface with the orbiter ECS and provide heating and cooling if required will be evaluated. Similarly, sufficient excess water is available from the shuttle fuel cells to allow an evaporative heat sink for EVA/IVA to operate with no penalty for the water expended. A penalty will be evaluated to account for any holding tanks or plumbing required. The orbiter oxygen storage tanks include sufficient excess oxygen to allow for one emergency repressurization. This gas could be available for EVA/IVA use under some conditions, but generally it will be assumed that dedicated tanks will be provided with the penalties shown.

SHUTTLE EVA/IVA STUDY GUIDELINES (CONTINUED)

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 FACTORS 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/UMBILICAL MANAGEMENT.

It may be possible to minimize the man-hour overhead required for EVA/IVA support by utilizing automatic checkout and real-time monitoring equipment. This could potentially free an orbiter crewman for other duties.

The translation velocities shown here will be used in helping to establish the time required to accomplish various tasks.

SHUTTLE EVA/IVA STUDY GUIDELINES (CONTINUED)

11. GROUND MONITORING SHOULD NOT BE REQUIRED DURING 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. VELOCITIES 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

It is assumed that the manipulator can be used both to translate an EVA crewman to different work sites and to provide restraint at these sites.

The distinction between the metabolic rate assumed for a single EVA and that assumed for all EVAs during a single mission is that a crewman may perform at a high rate for a single EVA/IVA and his supporting systems must provide sufficient expendables to account for this. However, the average rate for an entire mission will be lower since he will also perform some EVA/IVAs at a lower rate. This value is used to size the orbiter storage tanks and provisions for expendables for the entire mission. The maximum and minimum rates are required to rate limited equipment and controls.

SHUTTLE EVA/IVA STUDY GUIDELINES (CONTINUED)

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)

Rev.

Under normal conditions the EVA/IVA thermal control system will be designed to maintain the crewman in thermal equilibrium with little heat stored in his body. Up to 300 btu can be stored in contingency situations with no degradation of performance or other harmful effects.

The specifications for the CO_2 level are the same as for the orbiter cabin. The nominal value is the system design point for sizing of the CO_2 removal system. However, under some conditions, such as a high metabolic rate near the end of an EVA, the system may be incapable of maintaining this low level. 7.6 mm maximum is the design point for this condition. Under emergency conditions 15 mm Hg can be tolerated in the inlet gas stream with no performance degradation.

Crewman who may be required to do EVA/IVA can be selected and trained both in general operations procedures and for specific tasks.

It is anticipated that advantages of IVA in the cargo bay with doors closed, such as better lighting, potentially less severe environment, and greater safety when operating in an enclosure, will lead to a choice of retraction of a payload into the cargo bay for servicing whenever this is feasible.

SHUTTLE EVA/IVA STUDY GUIDELINES (CONTINUED)

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-MAXIMUM

18. THE AIRLOCK SHOULD PROVIDE EVA CAPABILITY DURING DOCKED OPERATIONS WITHOUT RESTRICTIONS 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.

Rev.

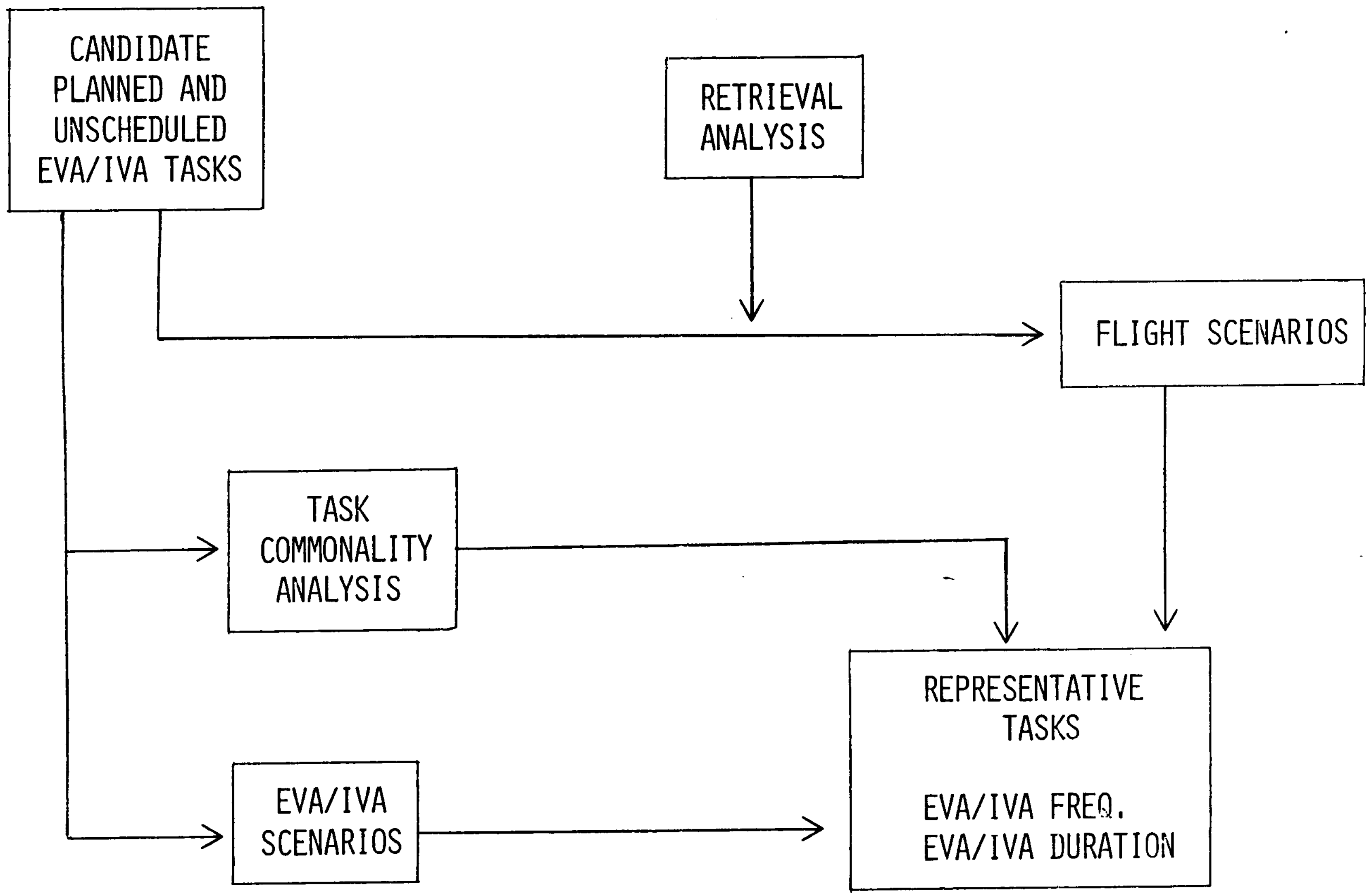
SELECTION
OF
REPRESENTATIVE
TASKS

SELECTION OF REPRESENTATIVE TASKS

This chart illustrates the procedural elements involved in defining representative tasks, frequency, and duration. A retrieval analysis was included in order to permit consideration of associated candidate EVA/IVA tasks. The elements of this flow diagram will be discussed separately in the following charts.

Only candidate planned and unscheduled EVA/IVA's were included in the analysis for representative tasks, as it was decided to retain the whole array of credible contingencies at this point in the study.

SECTION OF REPRESENTATIVE TASKS



RETRIEVAL ANALYSIS

As of March 31, 1972, there are 2764 objects currently orbiting the earth. Of these, 260 have orbital characteristics potentially within rendezvous capability of the shuttle (with up to 3 OMS sets). Several of these payloads are of considerable scientific interest. In the case of others, their removal from orbit would be desirable. In addition, 29 of the NASA traffic model satellites are potentially within reach of the shuttle. Analysis of the NASA traffic model shuttle flights shows that 185 have 10,000 lb excess capacity, which is sufficient for rendezvous and retrieval of objects in nearby orbits.

There are 319 shuttle-launched high-altitude satellites of less than 3050 lb in the NASA traffic model. 74 tug flights have geosynchronous deliveries of less than this mass, and thus can also accomplish a retrieval of a satellite of 3050 lb or less from high orbit.

With a total of 579 objects within reach and 259 shuttle/tug potential retrieval flights, a retrieval capture of 50% was assumed for purposes of including associated EVA/IVA activities in the present study.

RETRIEVAL ANALYSIS

SHUTTLE RETRIEVAL

260 CURRENTLY ORBITING OBJECTS WITHIN SHUTTLE RETRIEVAL CAPABILITY

29 ADDITIONAL SATELLITES IN TRAFFIC MODEL ARE RETRIEVABLE

185 SHUTTLE FLIGHTS HAVE SUFFICIENT EXCESS CAPACITY FOR RETRIEVAL

SHUTTLE PLUS TUG RETRIEVAL

319 HIGH ALTITUDE SATELLITES WITHIN TUG RETRIEVAL CAPABILITY

74 TUG FLIGHTS HAVE SUFFICIENT EXCESS CAPACITY FOR RETRIEVAL

TOTAL RETRIEVALS

579 OBJECTS WITHIN REACH

259 SHUTTLE/TUG FLIGHTS WITH RETRIEVAL CAPACITY

FLIGHT SCENARIOS

From a consideration of the classes of candidate planned EVA/IVA's, the 407 NASA shuttle flights in the traffic model were subdivided into groups of generically similar flights relative to EVA/IVA requirements, such as "Servicing one Large Observatory". Not all groupings have candidate planned EVA/IVA's. The two groupings involving retrieval and servicing of small satellites were added to the mission model from the retrieval analysis. The distribution of the groupings according to the traffic model was then determined.

Each grouping was examined, and two representative flight scenarios were chosen from each, one with maximum EVA/IVA requirements and one with minimum EVA/IVA requirements. The maximum/minimum requirements for EVA/IVA also depend on payload design philosophy (i.e. automated or austere), and these considerations were included in order to bracket EVA/IVA requirements.

A crude EVA/IVA timeline for each flight scenario was constructed. This led to a definition of maximum and minimum EVA/IVA frequency in terms of numbers of airlock openings. Allowance for one unscheduled/contingency EVA/IVA was included in each flight scenario.

FLIGHT SCENARIOS

NASA TRAFFIC MODEL PARTITIONED INTO EIGHT GROUPINGS RELATIVE TO EVA/IVA

- SERVICING ONE LARGE OBSERVATORY PER FLIGHT
- SERVICING TWO LARGE OBSERVATORIES PER FLIGHT
- SERVICING SMALL LOW ALTITUDE SATELLITE*
- DELIVERY ONLY, PAYLOADS WITH KICK STAGES
- MODULAR SPACE STATION BUILDUP AND RESUPPLY
- FREE FLYING OPERATIONS
- SORTIE EXPERIMENTS
- RETRIEVAL OF SATELLITES BY SHUTTLE OR TUG*

DEFINITION OF MAX/MIN FLIGHT SCENARIOS

DEFINITION OF MAX/MIN NUMBER OF AIRLOCK OPENINGS

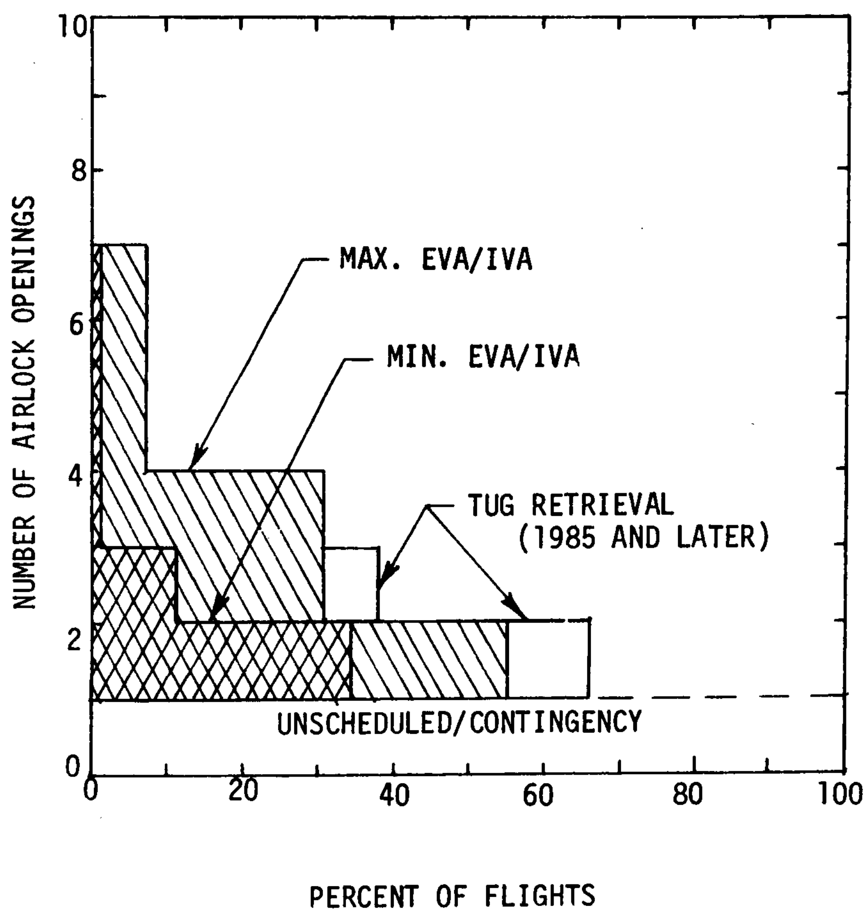
* ADDED BY RETRIEVAL ANALYSIS

EVA/IVA FREQUENCY

The distribution of EVA/IVA frequency is the result of the combined distribution of flight scenarios and the range in numbers of airlock openings per scenario. The graph illustrates the minimum expected number of EVA/IVAs by the double cross-hatched area, and the maximum number by the single cross-hatched area. The probable actual frequency would lie between, and will depend on the shuttle/experiment module/payload design philosophy.

The maximum contribution to potential EVA/IVA of 7 airlock openings is due mainly to servicing of large observatories. The second major area, involving 4 potential airlock openings per flight, is in support of sortie missions. The small unshaded area is due to the opportunity of Tug retrievals commencing in 1985. On all flights an allowance for one unscheduled or contingency EVA/IVA is provided.

EVA/IVA FREQUENCY

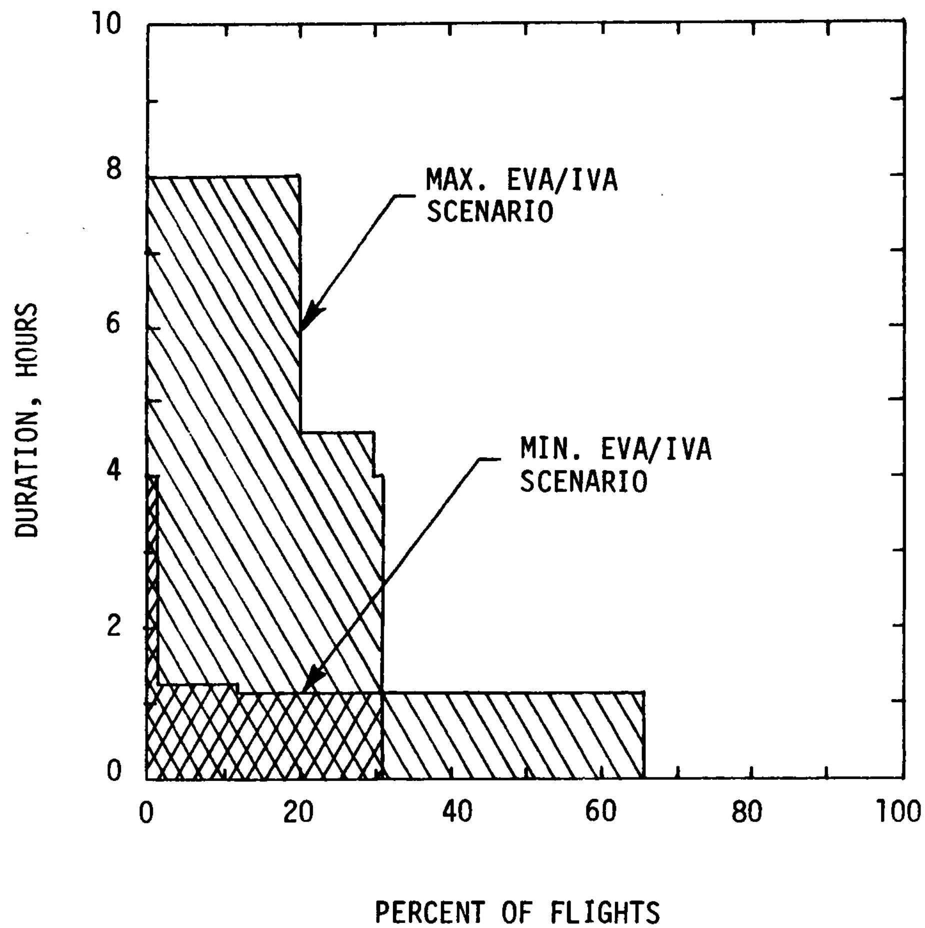


EVA/IVA DURATION

Representative maximum and minimum EVA/IVA scenarios were constructed for each of the classes of planned EVA/IVA, timelines were laid out, and durations were estimated. The distribution of durations was obtained by associating the EVA/IVA scenarios with the flight scenarios.

The expected durations of the planned EVA/IVA's range from a minimum of about 1 hour to a maximum of 8 hours on about 20% of the flights, and up to about 4.5 hours on an additional 10% of the flights. About 35% of the flights are expected to have maximum EVA/IVA durations of about 1 hour. The potential 8 hour EVA/IVA's are associated with austere sortie missions, and the 4.5 hour EVA/IVA's with the servicing of observatories. Unscheduled or contingency EVA/IVA's are not included, but would be expected to be of similar durations for similar tasks.

EVA/IVA DURATION



TASK COMMONALITY ANALYSIS

By analyzing candidate planned and unscheduled EVA/IVA tasks for commonality of functions and other considerations having a major driving influence on equipment requirements, it was possible to reduce the large number of candidate tasks to a manageable number of representative tasks. This was accomplished by first examining each class for tasks representative within that class, then comparing all classes. Additional considerations given to the tasks during the screening process included the state of definition of representative payloads and their priority/frequency relative to the traffic model and shuttle program.

TASK COMMONALITY ANALYSIS

DRIVERS FOR EQUIPMENT REQUIREMENTS

- TRANSLATION

  DISTANCE
  PATH

- CARGO HANDLING

  SMALL
  MEDIUM
  LARGE

- WORK CATEGORIES

  MONITOR/INSPECT
  REMOVE/REPLACE
  DEPLOY/RETRACT
  DATA ACQUISITION
  REPAIR/REFURBISH/DISASSEMBLY
  MATING

- MODE

  PRIMARY EVA
  MANIPULATOR AID
  FREE FLYING

- HAZARDS
- CONTAM. SENSITIVITY
- SPECIAL TOOLS
- TASK LOCATION

SCREEN FOR COMMONALITY OF TASK REQUIREMENTS

REPRESENTATIVE TASK SCENARIOS

Task scenarios, rather than a single representative task, were chosen because, in some instances, more than one EVA or IVA may be required to complete all the operations necessary to make it truly representative. For instance, support of an austere earth observation sortie may involve IVA preparatory work in the cargo bay, EVA experiment support with the cargo bay doors open, and then IVA de-orbit readiness. In general, it is expected that IVA into the cargo bay will always be preferable to EVA because of the meteoroid/radiation protection by the doors, more uniform lighting, and complete containment.

The six selected task scenarios are expected to be truly representative relative to all the equipment requirement drivers, and involve interfaces with all major equipment/payloads of the mission model.

REPRESENTATIVE TASK SCENARIOS:

1. PRESSURIZED LST CONCEPT MAINTENANCE/SERVICING (EVA)
2. AUSTERE EARTH OBSERVATION SORTIE SUPPORT (EVA & IVA)
3. DE-ORBIT READINESS OF RETRIEVED SATELLITE AND TUG (EVA & IVA)
4. INSPECTION OF SHUTTLE EXTERIOR (EVA)
5. MANUAL DEPLOYMENT OF PLASMA WAKE EXPERIMENTS (EVA)
6. UNPRESSURIZED IVA MAINTENANCE OF ASTRONOMY OBSERVATORY

APPENDIX A

REPRESENTATIVE TASK SCENARIOS

APPENDIX A

REPRESENTATIVE TASK SCENARIOS

The following seven scenarios were chosen as representative and prepared for use in identifying concepts and deriving requirements for EVA and IVA equipment for use on the Shuttle Orbiter vehicle.

The representative Orbiter vehicle configuration used in the scenarios has a 15 ft. x 60 ft. payload bay compartment. For the purposes of examining IVA in the payload bay, it is assumed the doors may be closed while the radiators are left deployed. As a worst case situation, it is assumed that the location of the airlock is aft of the windscreen area, with the outside opening on the upper surface of the shuttle.

The exterior aerodynamic surfaces of the Orbiter vehicle, with the exception of the forward body and wing and fin leading edges, will be covered with rigidized silica or mullite (aluminum silicate with silica fiber) material. The forward body and wing and fin leading edges will be covered with reinforced carbon/carbon (RCC) material. This thermal protection material will have a moisture sealing layer and an outgas prevention layer over it. The coated material is susceptible to damage and therefore, care must be taken to prevent its being bumped with sharp objects, etc.

1.0 EXAMPLE SCENARIO FOR EVA MAINTENANCE OF A LARGE SPACE TELESCOPE (LST)

The following representative LST components are to be replaced during revisits by the Orbiter vehicle:

a. The secondary mirror module
(29 in dia. x 20 in long - 120 lb)

b. One RCS module - Figure 1
(21 in x 27 in x 15 in - 120 dry, 170 lb wet)

c. One assy containing two dual rollout solar cell panels
(10 in dia x 11 ft long - 90 lb)

d. 6-Contamination monitoring gages in the area of the secondary mirror - Figure 2
(1.3 in dia x 3.5 in long - .5 lb)

e. 2-Mass spectrometer end instruments in the area of the secondary mirror - Figure 3
(4 in dia x 6 in long - 2 lb)

f. 4-Contamination monitoring gages inside telescope tube, two in the area of the primary mirror and two in the area of the secondary mirror - Figure 2
(1.3 in dia. x 3.5 in long - .5 lb)

In conjunction with replacing contamination gages inside the telescope tube, the primary and secondary mirror surfaces would be cleaned. Figure 4 shows an active cleaning device.

Any single EVA will not include all items listed, therefore the following lists are provided for representative LST EVA.

A. Aperture End

1. Replace the secondary mirror module

2. Replace the 6 contamination monitoring gages in the area of the secondary mirror

3. Replace the 2 mass spectrometer end instruments in the area of the secondary mirror

B. Inside the Telescope Tube

1. Replace the 4 contamination monitoring gages

2. Clean primary and secondary mirror surfaces

C. Replace 2 RCS modules on opposite sides of the LST

D. Replace one assy containing two dual rollout solar cell panels

The Orbiter vehicle will be docked with the LST, as shown in Figure 5, in a 28.5° orbit at 300-400 nautical miles. A support module, such as the illustrated sortie can, will be used to pressurize the LST for servicing operations. The light shield, at the aperture end of the LST, is retracted, the environment protection doors are closed, and all deployable components, such as the solar cell panels and antennas, are retracted.

Figure 6 shows the LST as it would appear in orbit with all components deployed. The optical telescope assembly and the scientific instrumentation package of the LST are mounted on an experiment-peculiar bulkhead. The pressure bulkhead is attached to a pressurizable compartment. The pressurizable compartment subsystems and experiment electronics are located within the compartment, allowing shirtsleeve access to all of the instrumentation packages and the compartment subsystems when docked with the Orbiter vehicle.

Figure 7 is a scale drawing of the LST. The secondary mirror module is outside the pressurizable compartment, at the aperture of the optical telescope assembly. The dual solar cell panel assemblies are mounted on the outside surface of the pressurizable compartment and the 4 RCS modules are in line with the dual solar cell panel assembly supports. Six of the contamination monitoring gages are located outside the telescope tube in the vicinity of the secondary mirror and four inside the telescope tube, two in the vicinity of the primary mirror and two in the vicinity of the secondary mirror. Access to all these components is to be gained by EVA. It is assumed that access into the telescope tube will be through an opening in the aperture end.

The following is a listing of events (not necessarily in sequence) for replacing the LST components.

1. Unstow EVA equipment
2. Don and checkout EVA equipment and prepare for EVA
3. Exit Orbiter vehicle through airlock
4. Translate across Orbiter vehicle surface to sortie can
5. Unstow spare component
6. Translate across sortie can and LST to worksite
7. Prepare worksite for removal of component
8. Gain access to component
9. Remove component
10. Transport removed component to Orbiter vehicle and stow
11. Transport spare component to worksite
12. Install spare component
13. Replace parts removed to gain access
14. Prepare to return to Orbiter vehicle
15. Repeat 5 through 14 for other components
16. Translate across LST and sortie can to Orbiter vehicle
17. Translate across Orbiter vehicle to airlock opening
18. Re-enter Orbiter vehicle through airlock
19. Doff EVA equipment and stow

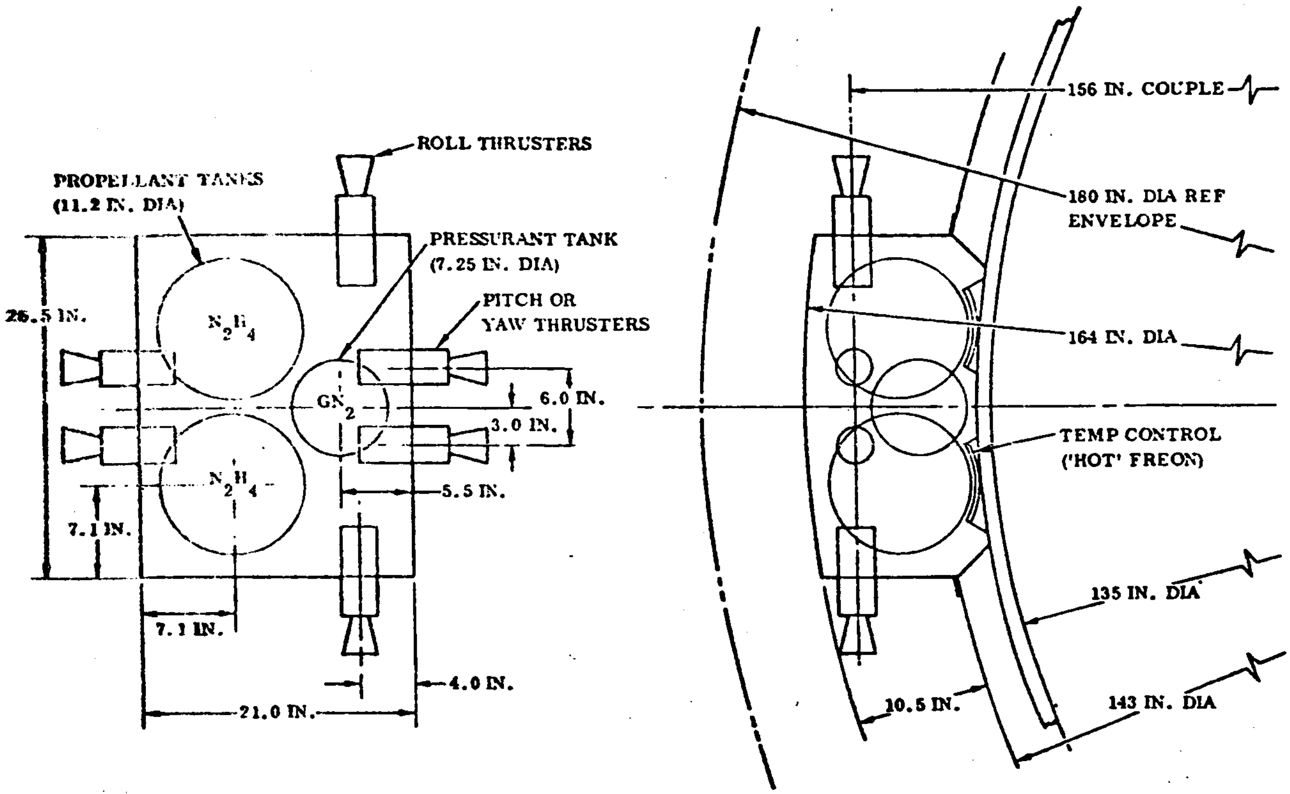


FIGURE 1 LARGE SPACE TELESCOPE RCS MODULE

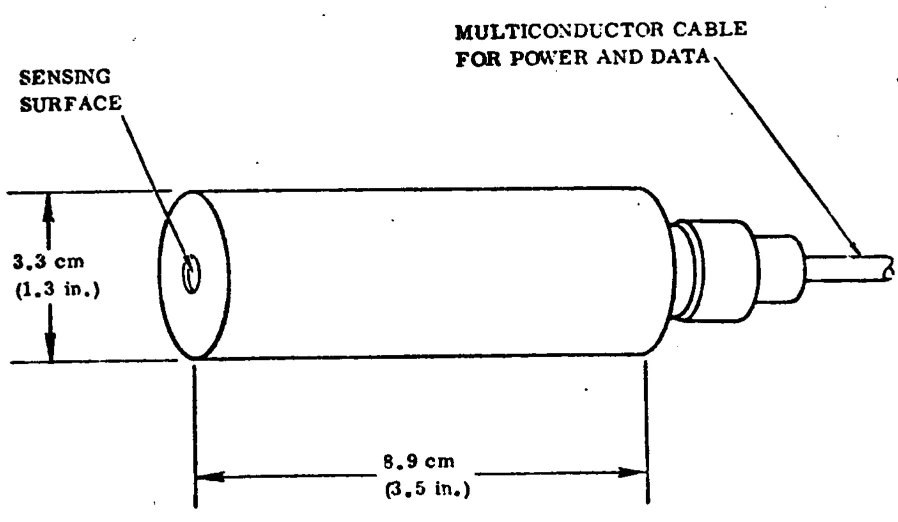


FIGURE 2 CONTAMINATION MONITORING GAGE

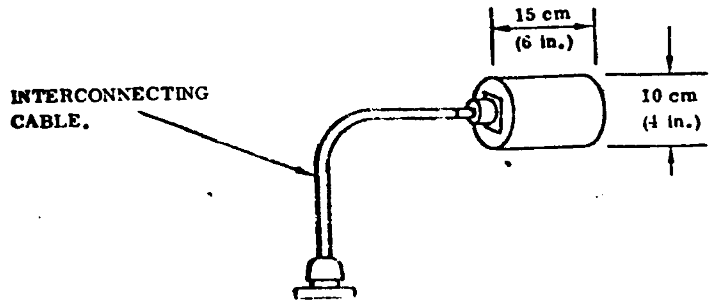


FIGURE 3 MASS SPECTROMETER END INSTRUMENT

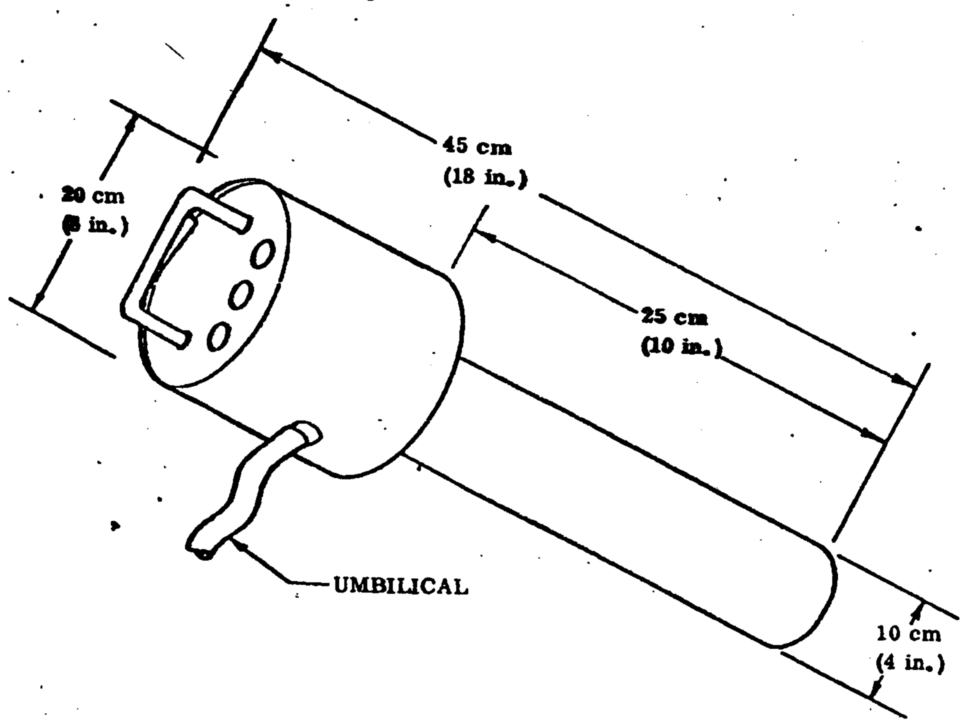


Figure 4 Active Cleaning Device

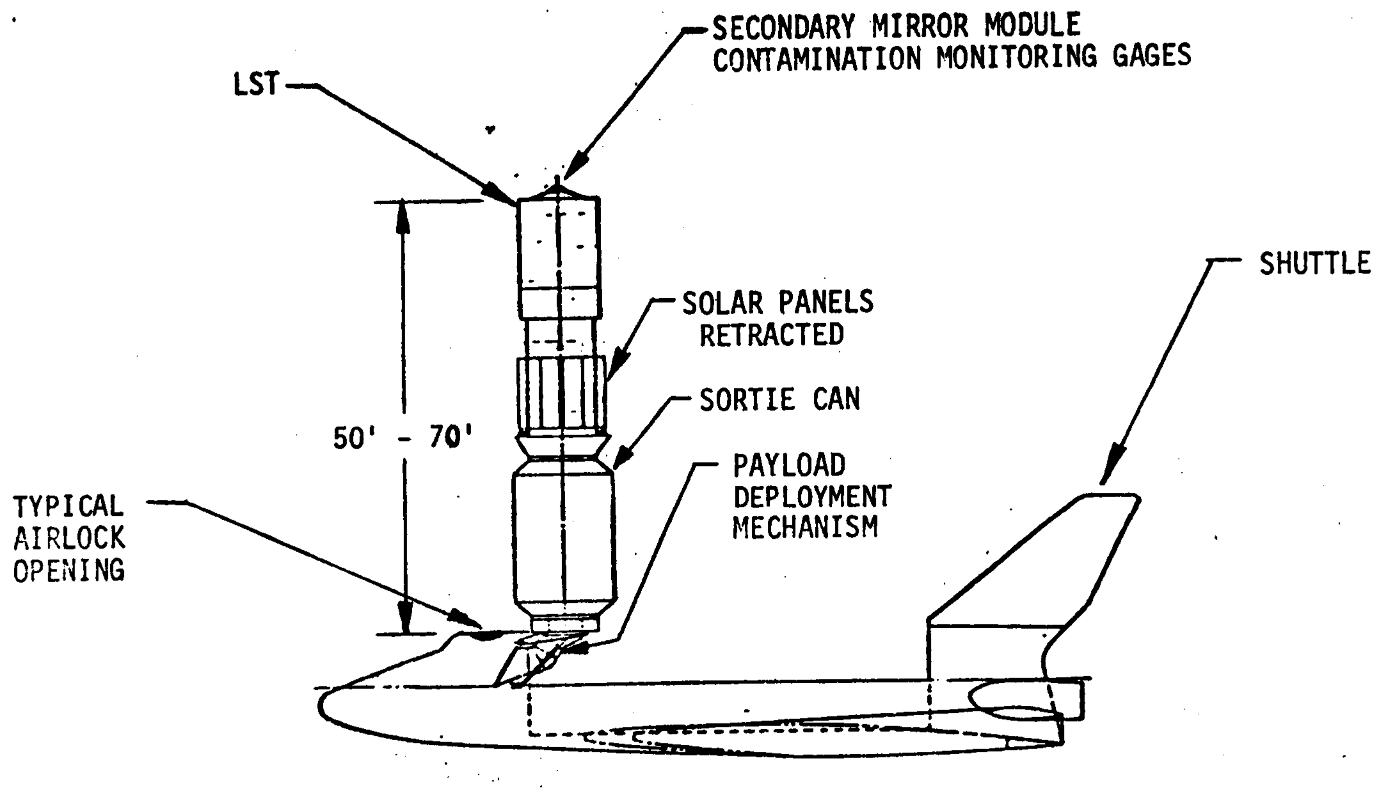


FIGURE 5 SHUTTLE DOCKED WITH LST

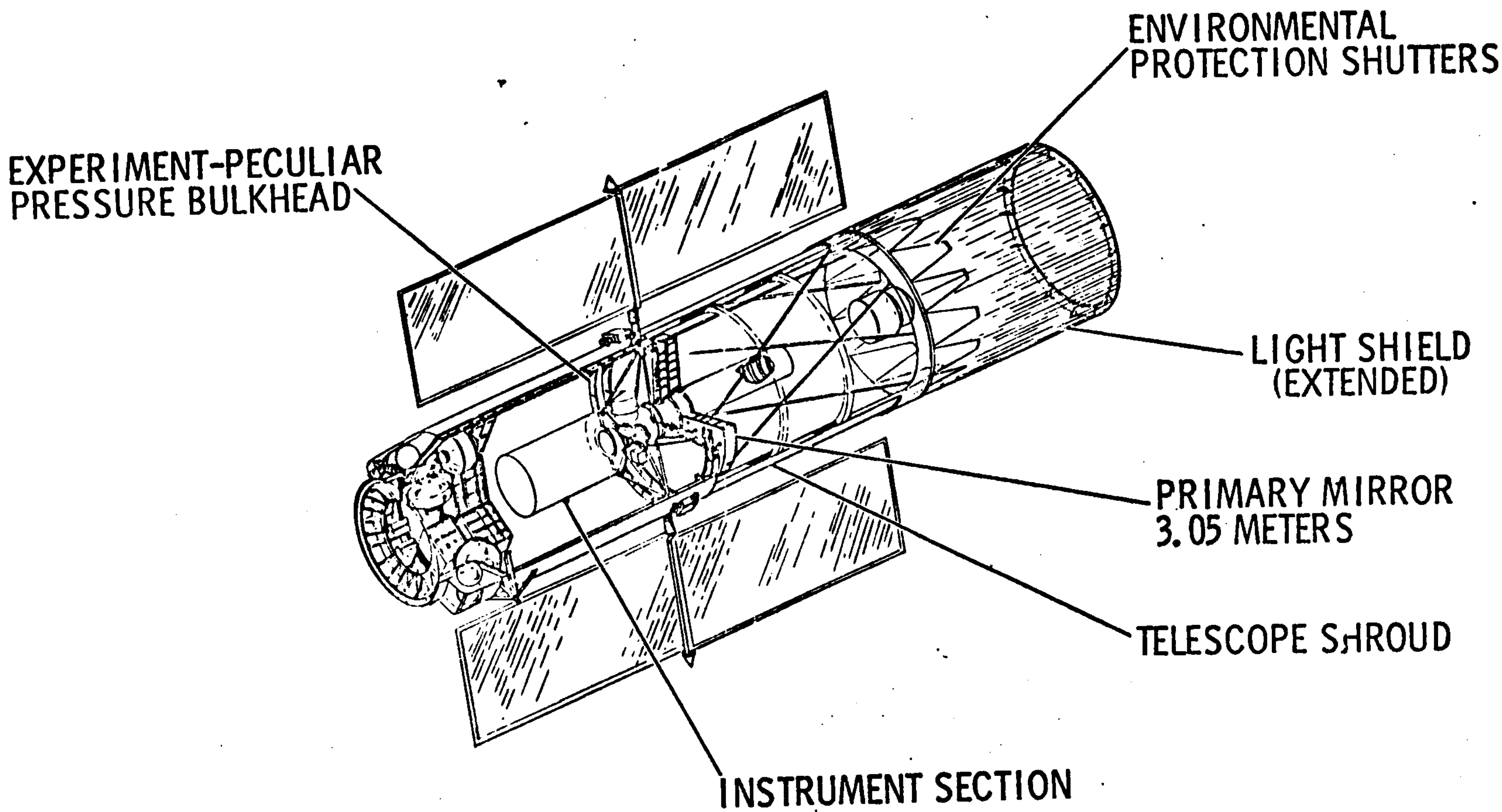
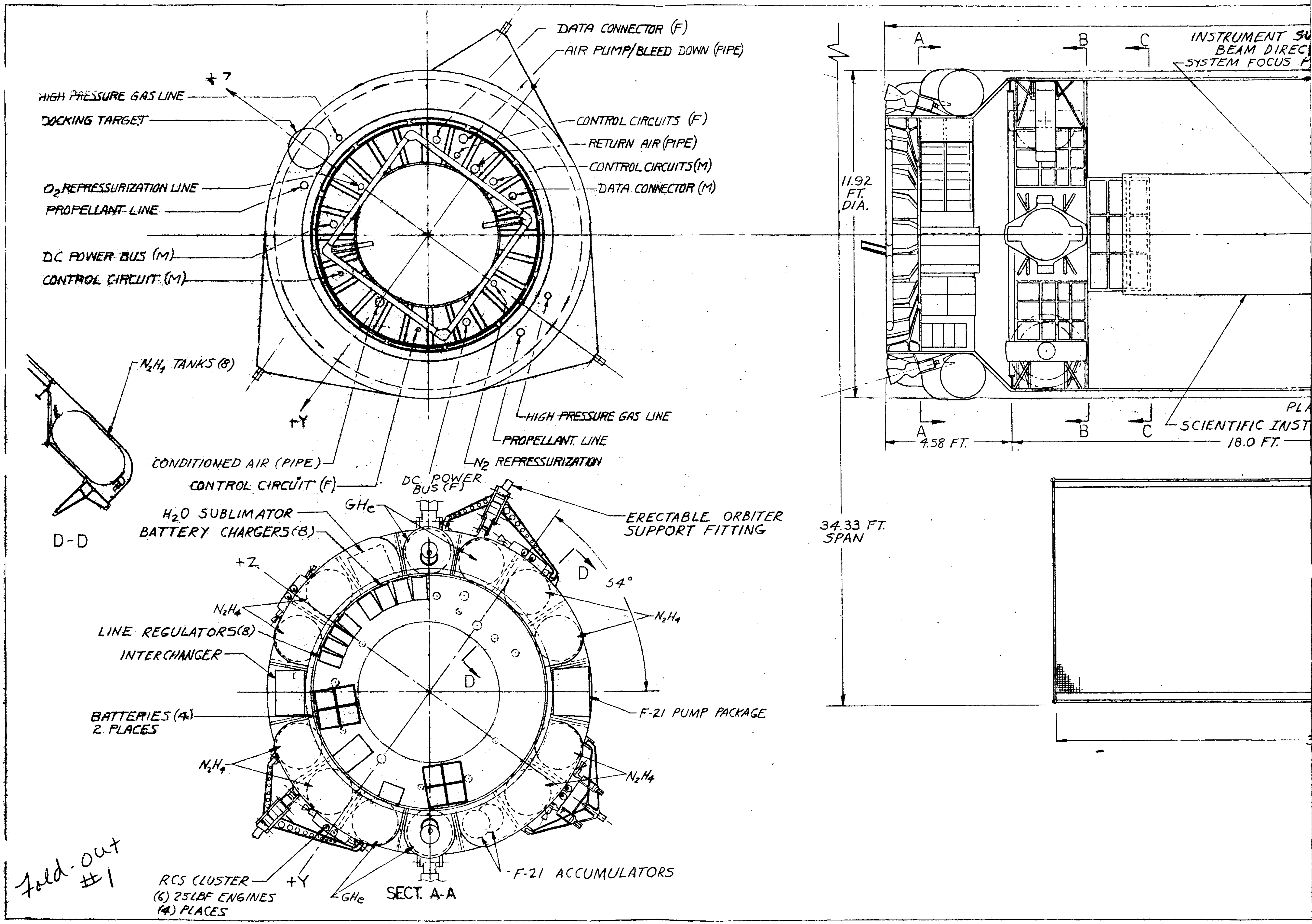
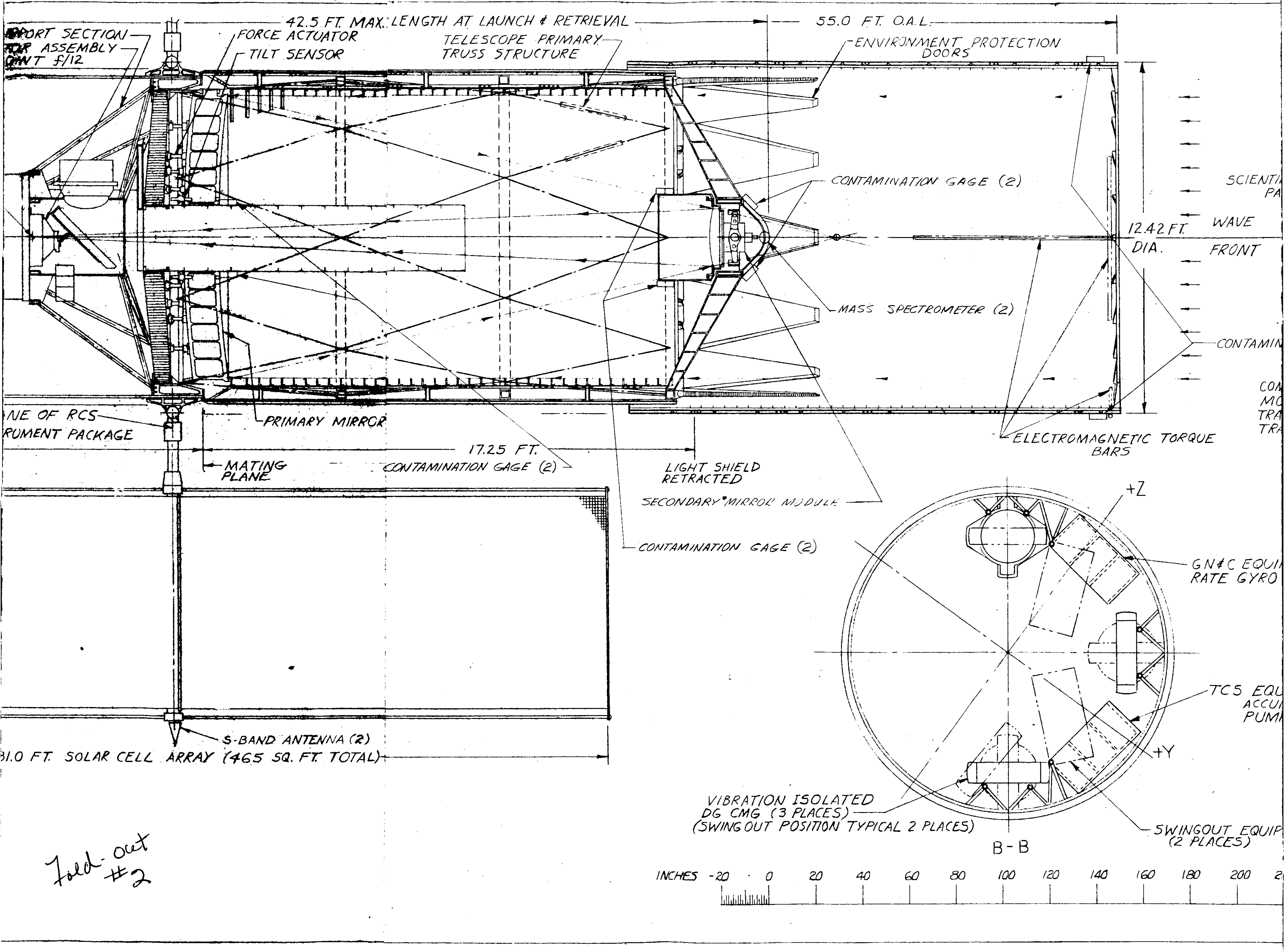


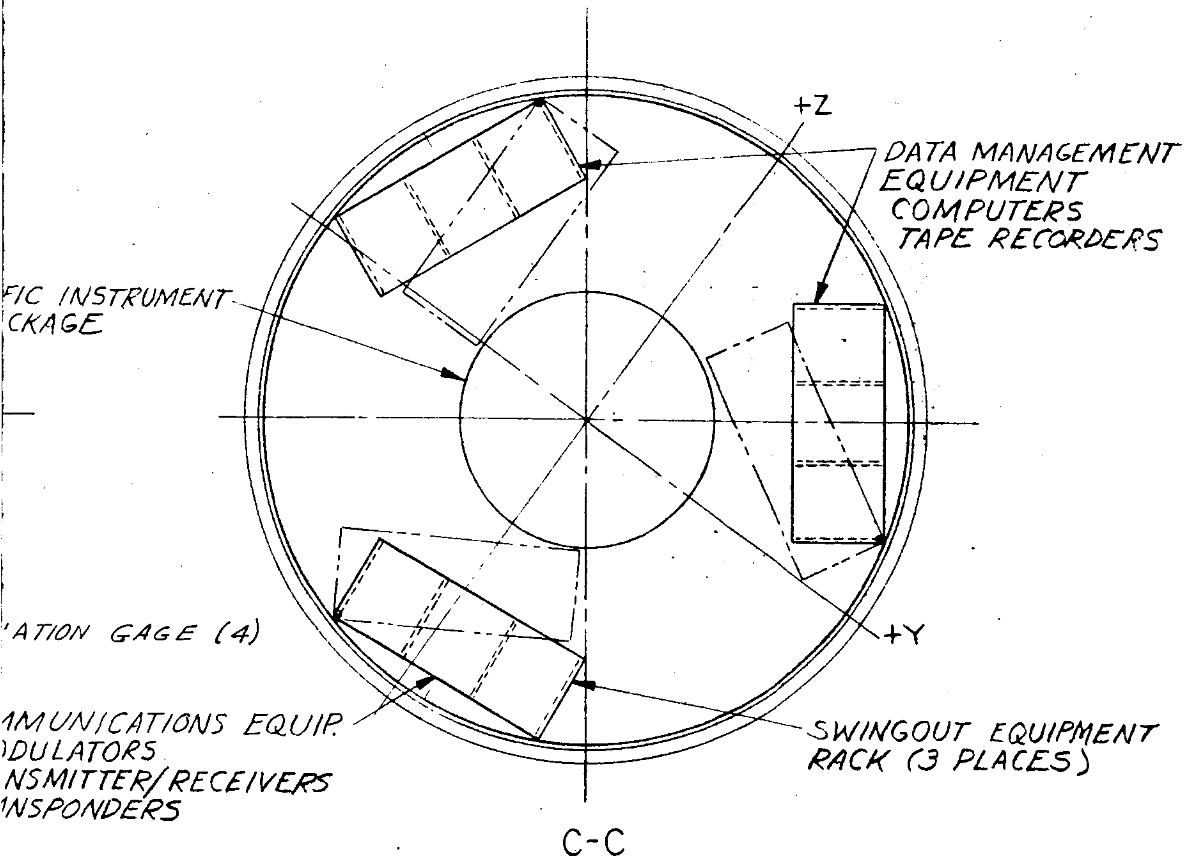
FIGURE 6 LST WITH COMPONENTS DEPLOYED


DATA CONNECTOR (F)
AIR PUMP/BLEED DOWN (PIPE)
HIGH PRESSURE GAS LINE
DOCKING TARGET
O_2 REPRESSURIZATION LINE
PROPELLANT LINE
DC POWER BUS (M)
CONTROL CIRCUIT (M)
CONTROL CIRCUITS (F)
RETURN AIR (PIPE)
CONTROL CIRCUITS (M)
DATA CONNECTOR (M)
+Z
+Y
N_2H_4 TANKS (8)
HIGH PRESSURE GAS LINE
PROPELLANT LINE
N_2 REPRESSURIZATION
CONDITIONED AIR (PIPE)
CONTROL CIRCUIT (F)
D-D
DC POWER BUS (F)
GHe
H_2O SUBLIMATOR
BATTERY CHARGERS (8)
ERECTABLE ORBITER SUPPORT FITTING
54°
N_2H_4
LINE REGULATORS (8)
INTERCHANGER
BATTERIES (4) 2 PLACES
F-21 PUMP PACKAGE
F-21 ACCUMULATORS
RCS CLUSTER (6) 25LBF ENGINES (4) PLACES
GHe
SECT. A-A
Fold-out #1
INSTRUMENT SU BEAM DIREC SYSTEM FOCUS
11.92 FT. DIA.
4.58 FT.
SCIENTIFIC INST
18.0 FT.
34.33 FT. SPAN



42.5 FT. MAX. LENGTH AT LAUNCH & RETRIEVAL
55.0 FT. O.A.L.
FORCE ACTUATOR
TILT SENSOR
TELESCOPE PRIMARY TRUSS STRUCTURE
ENVIRONMENT PROTECTION DOORS
CONTAMINATION GAGE (2)
12.42 FT. DIA.
WAVE
FRONT
MASS SPECTROMETER (2)
PRIMARY MIRROR
17.25 FT.
MATING PLANE
CONTAMINATION GAGE (2)
LIGHT SHIELD RETRACTED
SECONDARY MIRROR MODULE
CONTAMINATION GAGE (2)
ELECTROMAGNETIC TORQUE BARS
S-BAND ANTENNA (2)
SOLAR CELL ARRAY (465 SQ. FT. TOTAL)
+Z
+Y
GN&C EQUI
RATE GYRO
TCS EQU
VIBRATION ISOLATED
DG CMG (3 PLACES)
(SWING OUT POSITION TYPICAL 2 PLACES)
SWINGOUT EQUIP
(2 PLACES)
B - B
INCHES -20 0 20 40 60 80 100 120 140 160 180 200

Fold-out #2



PMENT
PACKAGE

IPMENT
ULATORS
S

Foldout #3

FIGURE 7.

MENT RACK

0 240 260 280 300

CHECK		CONVAIR AEROSPACE DIVISION OF GENERAL DYNAMICS SAN DIEGO, CALIFORNIA
STRESS		
GR ENGR		INBOARD PROFILE - LARGE SPACE TELESCOPE
DESIGN Hunter	6/20/72	
DRAWN		
CONTRACT NO.		SIZE / CODE IDENT 14170 / DRAWING NO. 71X1068
		SCALE / RELEASED / SHEET 1 OF 1

2.0 EXAMPLE SCENARIO FOR EVA/IVA SUPPORT OF AN EARTH OBSERVATION SORTIE

The following are representative activities associated with an Earth Observation Sortie mission.

A. Preparation of Sortie EVA in Open Payload Bay

1. Install 4 small film magazines
2. Install 1 large film magazine
3. Assemble and erect the large dish antenna

B. Support EVA In Open Payload Bay

1. Replace 4 small film magazines
2. Replace 1 large film magazine

C. Stowage of Antenna EVA in Open Payload Bay

1. Disassemble and stow the large dist antenna

D. Stowage IVA In Closed Unpressurized Payload Bay

1. Remove 4 small film magazines
2. Remove 1 large film magazine

E. Unscheduled IVA in Unpressurized Sortie Facility

1. Operate the observation telescope and control data taking equipment

Small film magazine, 6 in. x 9 in. x 6 in. - 5 lb.

Large film magazine, 15 in. x 50 in. x 20 in. - 45 lb.

Assembled dish antenna -30 ft. dia. x 3 ft. thick - 276 lb.

It is assumed that the dish antenna is broken down into 10 pieces (9.5 ft. x 15 ft. x 1.5 ft. - 20 lb) which are stowed in the payload bay. These pieces are to be fitted together and attached to a drive mechanism mounted in the payload bay.

The Shuttle will be in a polar orbit at 270 nautical miles with a Land Use Mapping experiment in the cargo bay. Figure 8 shows a representative configuration for earth observation sorties. A pressurizable sortie experiment facility will be available for installing equipment such that access for maintenance or servicing is available from inside. This facility is shown rotated upward, out of the Orbiter vehicle payload bay with the experiment equipment pointed toward earth. The 30 ft. dia. antenna is shown in place pointed toward the earth. Several cameras are mounted on the pallet because they are too large or there are more than can be accommodated by the experiment facility.

The antenna segments would be stowed in the payload bay aft of the experiment facility until the Orbiter vehicle is in position on orbit. Replacement film magazines would be stored inside the Shuttle or sortie experiment facility.

The following is a listing of events (not necessarily in sequence) for performing the tasks, EVA or IVA.

1. Unstow EVA or IVA equipment and equipment to be carried to the worksite
2. Don and checkout EVA or IVA equipment and prepare for exiting Orbiter vehicle cabin or sortie experiment facility
3. Exit Orbiter vehicle through airlock
4. Translate to payload bay worksite
5. Prepare work site for tasks
6. Accomplish assigned tasks
7. Prepare for return to Orbiter vehicle
8. Translate from worksite to airlock opening
9. Re-enter Orbiter vehicle through airlock
10. Doff EVA or IVA equipment and stow

Should the pressurization system in the experiment facility fail while in orbit, assume that the mission will be continued unpressurized by IVA. Since several of the Land Use Mapping experiments are aimed at specific objects on the earth with the optical telescope, an IV astronaut wearing a pressure suit helmet will view the earth through an eyepiece and control telescope orientation and operation.

Figure 9 shows a representative sortie experiment facility with the Land Use Mapping experiment equipment mounted in it.

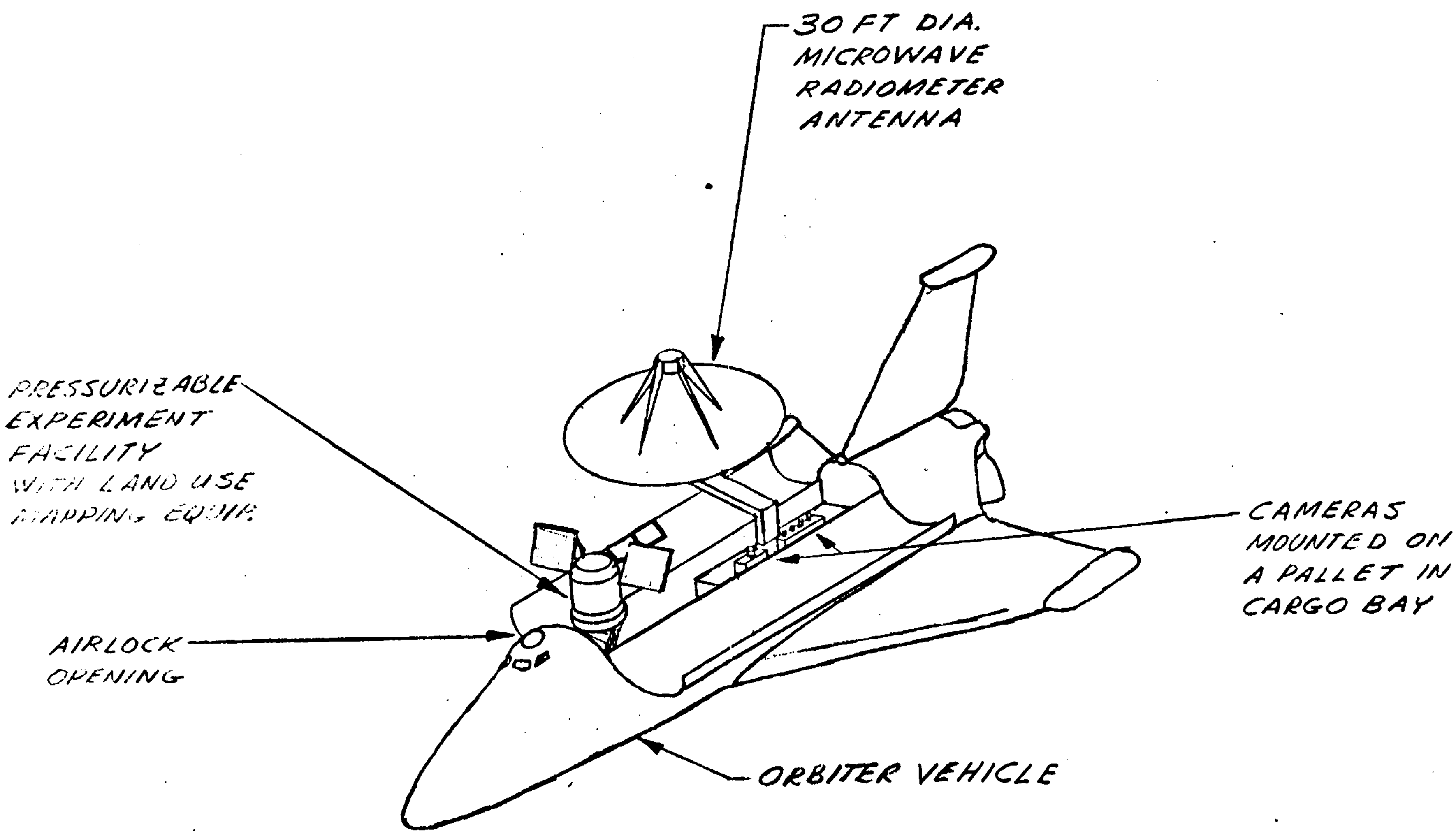


FIGURE 8 - EARTH OBSERVATION SORTIE

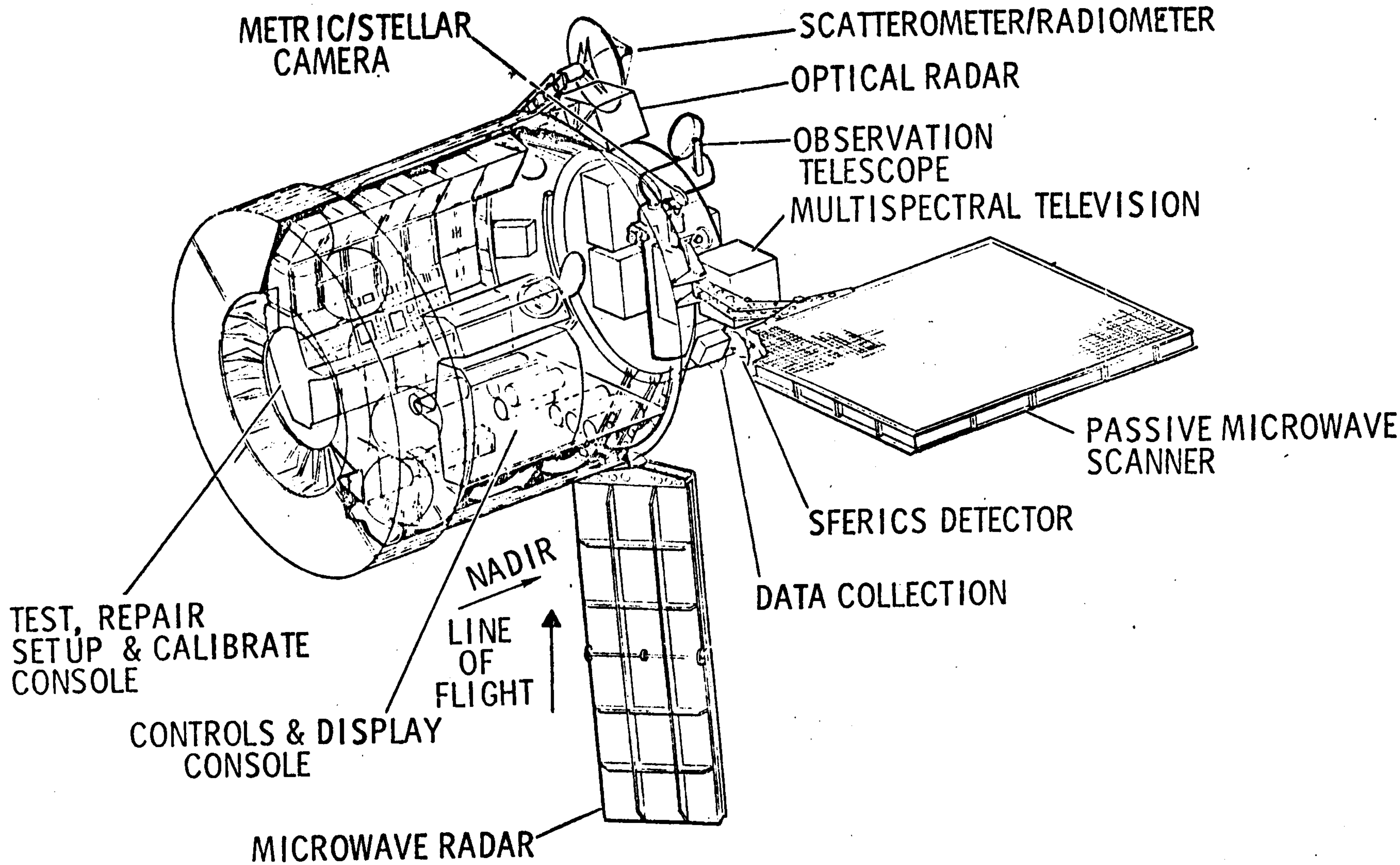


FIGURE 9 REPRESENTATIVE SORTIE EXPERIMENT FACILITY

3.0 EXAMPLE SCENARIO FOR EVA/IVA DE-ORBIT READINESS OF RETRIEVED SATELLITE AND TUG

The following are representative tasks which could be accomplished by EVA or IVA (with the payload bay doors closed) to prepare a Tug and satellite for deorbit and landing.

a. Connect umbilical connections to Tug and satellite

b. Install covers on delicate instruments and lenses

c. Purge Tug and satellite systems which contain harmful materials

d. Perform safety and health checks on the Tug and satellite

e. Aid in tying down the Tug and satellite to the payload bay structure

f. Fold or reposition antennas, solar cell arrays and sensors which have been deployed and erected.

The Orbiter vehicle is in an equitorial orbit at 100 nautical miles. A reusable Space Tug has been deployed and has returned a Synchronous Equatorial Earth Resources Observatory (SEO) from geosynchronus orbit and has docked with the Orbiter vehicle as shown in Figure 10. The Space Tug is the third stage of Shuttle Orbiter vehicle and is configured to be delivered to low earth orbit in the payload bay. It will either deploy or retrieve earth orbiting payloads. A scale drawing of the Space Tug is shown in Figure 11. The main engine is gimbaled by electromechanical actuators. The thrust structure consists of fiber glass tubes and boron-epoxy layups. The aluminum shell inner barrier is the primary load carrying structure, the outer barrier, rubber impregnated beta cloth, serves as a meteoroid shield. The aluminum LOX and hydrogen tanks are covered with double goldized Kapton multi-layer insulation to minimize heat inputs into the tanks. Four reaction control system (RCS) modules, with four thrustors each, are located at the conical section of outer shell close to the vehicle cg. The RCS conditioning equipment is located in the intersection between the two main tanks. The propellant tanks that supply propellants for the RCS, the electrical power system, and the main engine for idle mode operation and for feedline conditioning are located inside the main tanks. The majority of the avionics elements are located in the forward skirt and are passively cooled, with the exception of the fuel cell. Some avionics components, and data collection and transmission are located throughout the vehicle. The active element of the payload docking structure is located at the forward end of the vehicle and consists of a square docking frame with shock absorbers to negate the closure energy. Guidearms, which are the passive element of the Tug to Orbiter vehicle docking interface, are located at the aft end of the vehicle and engage in a similar square frame with shock attenuation devices located in the Orbiter vehicle.

The Synchronous Equatorial Earth Resources Observatory (SEO) is an unmanned satellite designed to gather scientific data concerning earth resources from synchronous equatorial earth orbit. Photographic data will be obtained by means of photographic subsystem consisting of a frame type camera, a processor-dryer, and a scanner. Both the photographic data and the television data will be transmitted to ground receiving stations by means of a communications link in a time-sharing mode. The configuration of the SEO is shown in Figure 12. In the stowed condition, the solar paddles are rotated into a fore-aft plane (perpendicular to the plane of the docking ring).

The following is a listing of events (not necessarily in sequence) for performing the de-orbit readiness tasks by EVA and IVA.

1. Unstow EVA equipment and equipment to be carried to the work site
2. Don and checkout EVA equipment and prepare to exit the Orbiter vehicle cabin
3. Exit Orbiter vehicle thru airlock
4. Translate to Space Tug work site area
5. Prepare work site for tasks
6. Accomplish Tug tasks
7. Prepare work site for departure
8. Translate to satellite work site area
9. Prepare work site for tasks
10. Accomplish satellite tasks
11. Prepare work site for departure
12. Translate to safety site clear of payload bay
13. Remain at safety site until Space Tug and Satellite are lowered into payload bay
14. Translate to payload bay Space Tug work site
15. Prepare work site for tasks
16. Accomplish Tug tasks
17. Prepare work site for departure
18. Translate to Satellite work site
19. Prepare work site for tasks
20. Accomplish Satellite tasks
21. Prepare work site for departure
22. Translate from payload bay to airlock opening
23. Re-enter Orbiter vehicle through airlock
24. Doff EVA equipment and stow

Should the payload bay doors be closed after the Tug and satellite are lowered into the payload bay, event 15 through 21 will be accomplished as unpressurized IVA.

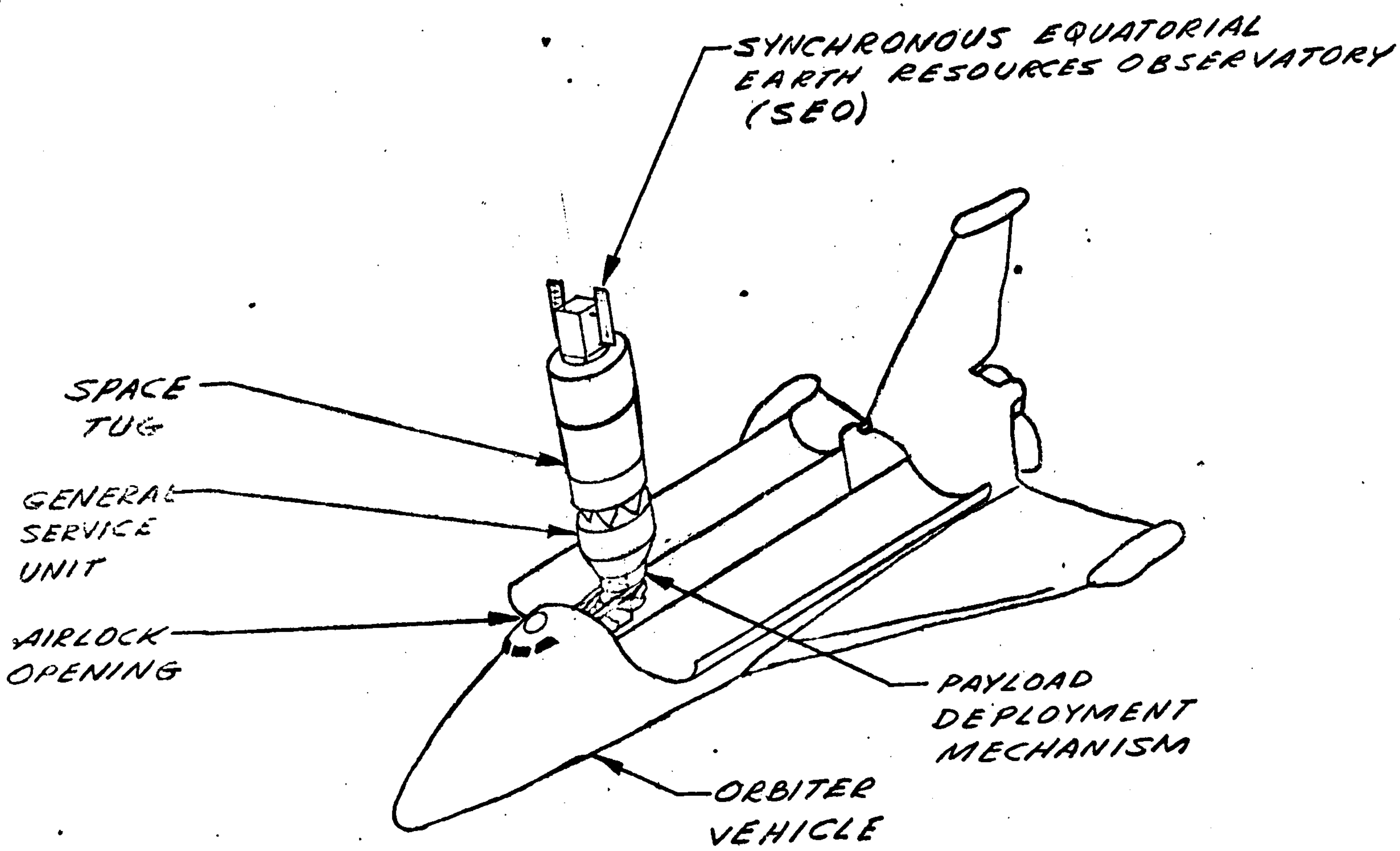


FIGURE 10- SHUTTLE RETRIEVING SPACE TUG AND SATELLITE

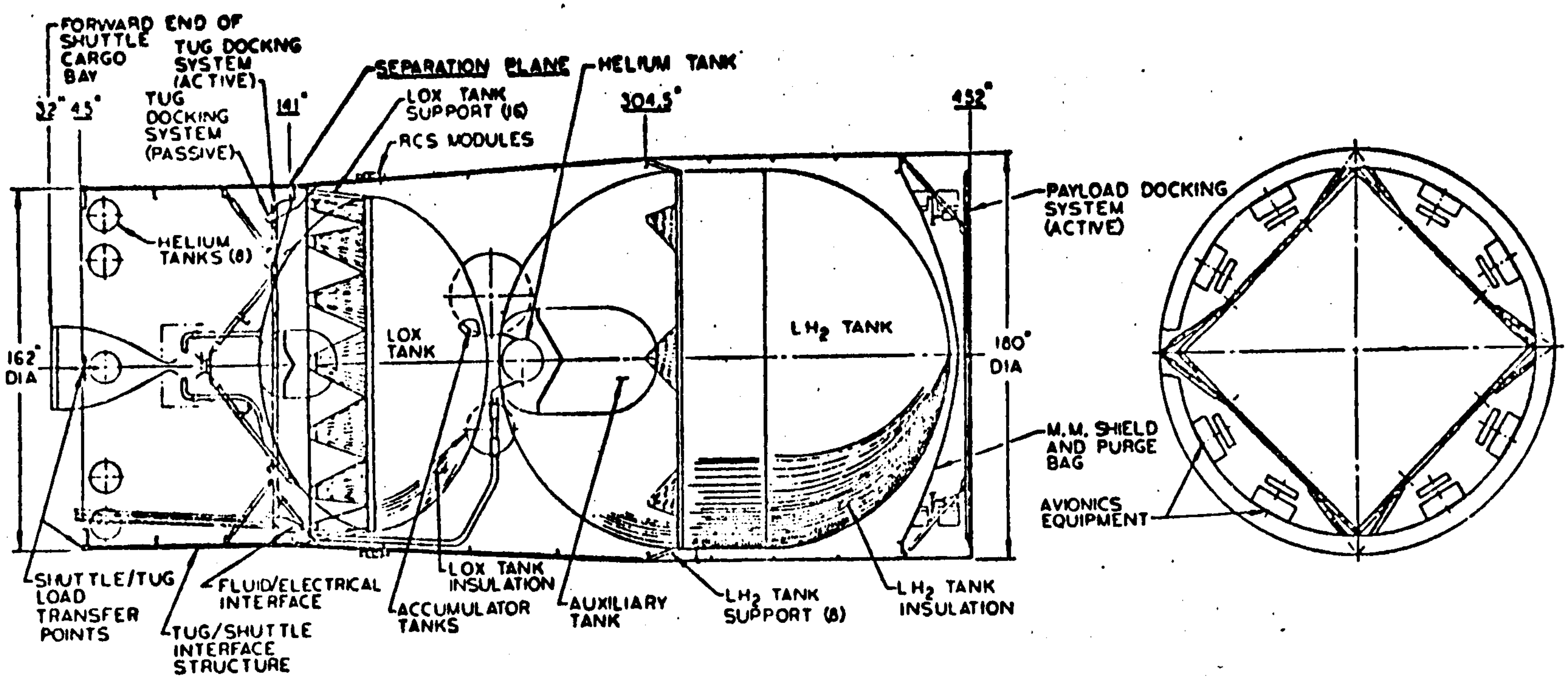


FIGURE 11 REUSABLE SPACE TUG

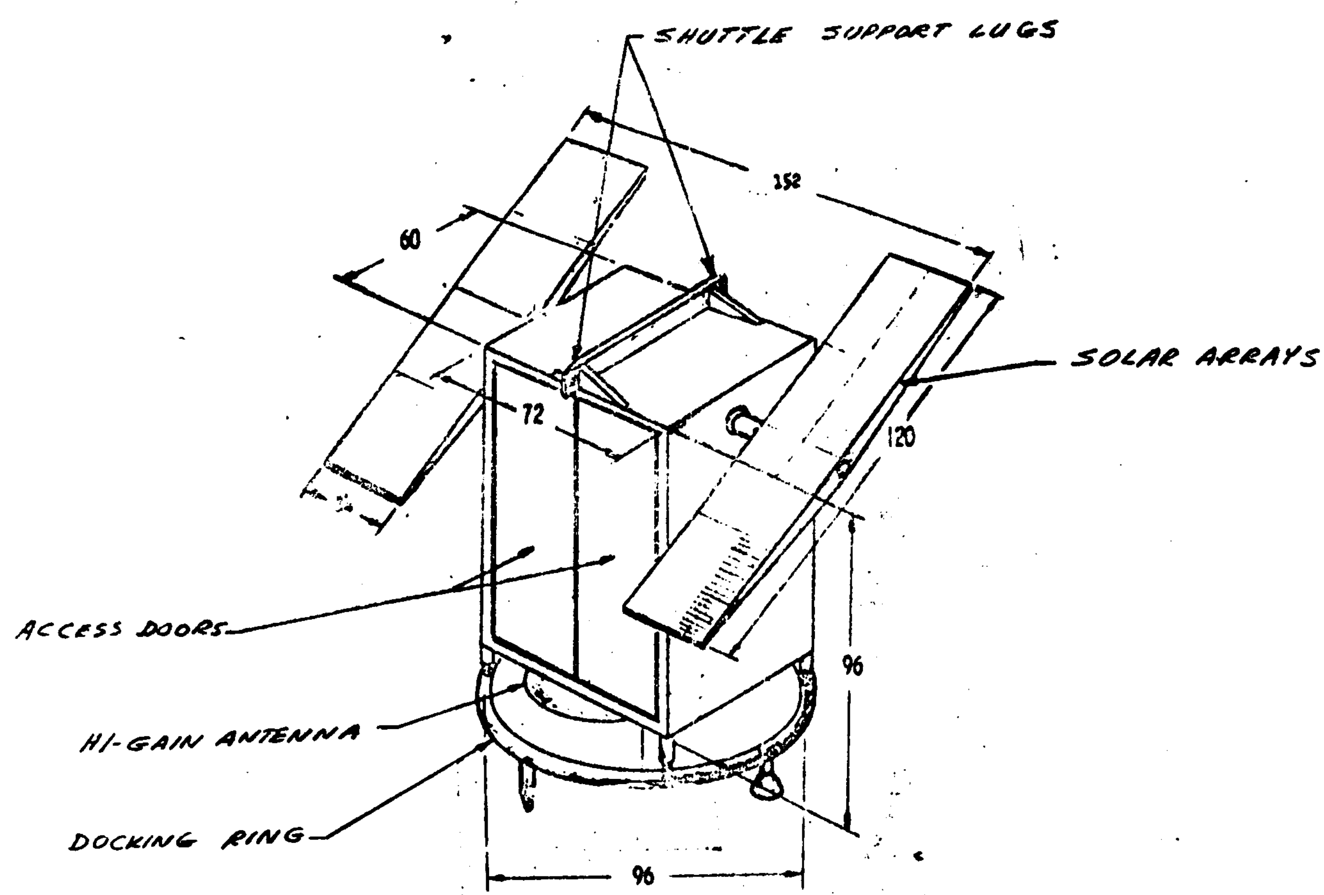


FIGURE 12 SEO GENERAL CONFIGURATION

4.0 EXAMPLE SCENARIO FOR EVA INSPECTION AND REPAIR OF THE ORBITER VEHICLE EXTERIOR

The following are representative Orbiter vehicle components to be inspected for proper condition and repaired,if necessary, by EVA in preparation for de-orbit. These are also candidate Free Flyer tasks.

a. Thermal Protection System (TPS) over the exterior surface

b. Structural supports, fluid connections and electrical connections for the External Tank Subsystem

c. All doors and mechanisms operated after launch

d. Payload bay equipment prior to closing payload bay doors

e. Sensors and sensor ports such as pitot-static tubes, air data transducer ports, horizon sensors and star trackers

f. Antennas

g. Aerodynamic control surfaces

h. Exhaust ports such as APU and evaporative heat sink

i. Windows

j. Emergency egress doors

k. Abort rocket structural supports and electrical connections

The Orbiter vehicle is in any obtainable orbit, (Ref. MSC-06746) preparing to deorbit and land.

Figure 13 is a sketch of the Orbiter vehicle showing the overall dimensions and the general locations for some of the components to be inspected and repaired.

The TPS is made up of two basic types of materials: 1) the entire exterior aerodynamic surface,with the exception of the Orbiter forward body and leading edges of the wings and fins, will be covered with rigidized silica or mullite (aluminum silicate with silica fiber) material herein called rigidized silica insulation (RSI).

There are two classes of RSI. RSI Class I is a ceramic material covered by a ceramic moisture resistant coating extending from the forward body of the Orbiter to within 2-4 feet aft of the cockpit. It can withstand 15-25 psi compression over a flat area or a 4 in-lb impact without damage. RSI Class II is a sponge elastomer material coated with a silicone paint. It can withstand "reasonable" (undefined) contact pressure; 2) the Orbiter forward body and leading edges of the wings and fin will be covered with Reinforced Carbon/Carbon (RCC) material. The RCC material will have an oxidation-inhibiting coating over it. The RCC material is installed along the wing and fin leading edges in segments approximately 30 inches long and in segments of varying sizes on the forward body. The RCC material thickness is over 1/8 inch. The RCC material is rigid with a hard brittle coating, rugged and capable of withstanding moderate impacts without damage.

No on-orbit repair technique has been defined for either the surface material or the RCC material. However, replacement of segments will certainly be a candidate repair technique for some areas and a repair technique for filling damage holes with a temporary "get down" material will be a candidate for other areas.

The following is a listing of events (not necessarily in sequence) for performing the inspection task:

1. Unstow EVA equipment and equipment to be carried during the inspection
2. Don and checkout EVA equipment and prepare to exit the Orbiter vehicle cabin

3. Exit Orbiter vehicle through the airlock
4. Translate to open payload bay
5. Perform inspection task
6. Translate to safety site clear of payload bay
7. Remain at safety site until payload bay doors are closed
8. Translate over the Orbiter vehicle surface making a visual inspection
9. Return to area of airlock opening
10. Re-enter Orbiter vehicle through airlock
11. Doff EVA equipment and stow

The following is a listing of events (not necessarily in sequence) for performing repair tasks:

1. Unstow EVA equipment and repair tools and equipment
2. Don and checkout EVA equipment and prepare to exit the Orbiter vehicle cabin
3. Exit Orbiter vehicle through the airlock
4. Translate to repair worksite
5. Prepare worksite for tasks
6. Perform repair
7. Prepare worksite for departure
8. Translate to area of airlock opening
9. Re-enter Orbiter vehicle through airlock
10. Doff EVA equipment and stow

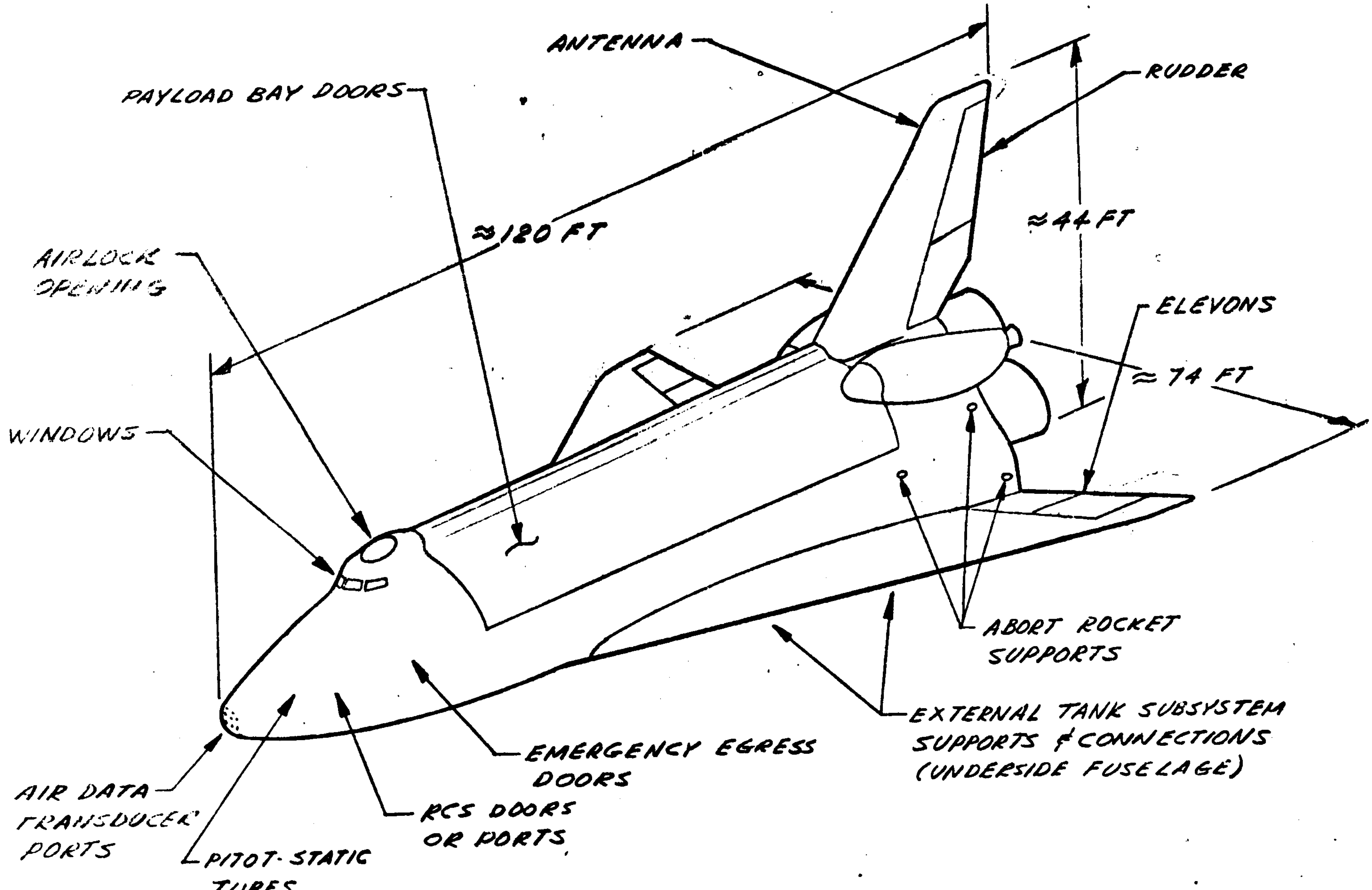


FIGURE 13 - SHUTTLE ORBITER VEHICLE

5.0 EXAMPLE DEPLOYMENT AND RETRACTION OF PLASMA WAKE EXPERIMENTS

The following are representative activities to be accomplished by EVA or IVA:

A. Replace 6 sensors on the end of a 160 ft. boom by EVA without retracting the boom

Sensor Sizes and Weights:

1. 8 in. x 10 in. x 11 in. - 15 lbs
2. 6 in. x 6 in. x 6 in. - 5 lbs
3. 2.5 ft^3 - 30 lbs
4. 9 in. x 9 in. x 12 in. - 20 lbs
5. 6 in. dia. x 1 in. - 3 lbs
6. 5.6 in. dia. x 1 in. - 5.5 lbs

B. Manually retract a boom by unpressurized IVA inside the experiment compartment.

C. Manually retract a boom by EVA outside the experiment compartment.

D. Manually rotate the sortie lab into position for conducting experiments.

E. Manually rotate the sortie lab into the stowed position following the completion of the experiments.

The Orbiter Vehicle is in a polar orbit at 100 nautical miles on a sortie mission with a plasma wake measurements experiment. The experiment equipment is shown in Figures 14 and 15. Figure 14 shows the pressurized experiment compartment for displays and controls. Instruments and sensors are deployed on booms by means of the three airlocks on one end of the pressurized compartment. Figure 15 (a) shows a typical sensor deployment for the plasma wake measurements. Figure 15 (c) shows typical boom mounted antennae for other physics experiments, and Figure 15 (b) shows a typical boom package. With the equipment deployed as shown in Figure 15 (a) the 160 ft. boom has failed to retract by the normal powered method for changing the boom mounted equipment and re-deployment.

It is desirable to change the boom mounted equipment by EVA and complete the mission and then retract the boom manually before de-orbit.

The following is a listing of events (not necessarily in sequence) for changing the boom mounted equipment by EVA:

1. Unstow EVA equipment and equipment to be taken to the worksite.
2. Don and checkout EVA equipment and prepare to exit the Orbiter through the airlock.
3. Exit Orbiter vehicle through the airlock
4. Translate to worksite at end of extended 160 ft. boom
5. Prepare worksite for equipment change
6. Accomplish equipment change
7. Prepare worksite for departure
8. Translate to area of airlock opening
9. Re-enter Orbiter vehicle through airlock
10. Doff EVA equipment and stow

The following is a listing of events (not necessarily in sequence) for retracting the boom manually by IVA within the pressurized experiment compartment.

1. Unstow IVA equipment
2. Don and checkout IVA equipment

3. Enter pressurized experiment compartment
4. Depressurize pressurized compartment
5. Open boom inner airlock door
6. Install crank in retraction mechanism and crank in boom
7. Close outer airlock door
8. Pressurize the compartment
9. Re-enter Orbiter vehicle cabin
10. Doff IVA equipment and stow

The following is a listing of events (not necessarily in sequence) for retracting the boom manually by EVA.

1. Unstow EVA equipment and equipment to be carried to the worksite
2. Don and checkout EVA equipment and prepare to exit the Orbiter vehicle cabin
3. Exit Orbiter vehicle through the airlock
4. Translate to area of boom housing
5. Prepare worksite for manual retraction task
6. Retract boom by turning the boom forcing the links into the housing one by one
7. Assist in closing airlock outer door
8. Prepare worksite for departure
9. Translate to area of airlock opening
10. Re-enter Orbiter vehicle through airlock
11. Doff EVA equipment and stow

The following is a listing of events (not necessarily in sequence) for rotating the sortie lab to change its position.

1. Unstow EVA equipment

2. Don and checkout EVA equipment and prepare to exit the Orbiter vehicle cabin
3. Exit Orbiter vehicle through the airlock
4. Translate to area of sortie lab
5. Prepare for rotation operation
6. Manually rotate sortie lab into desired position
7. Prepare for departure from work area
8. Translate to area of airlock opening
9. Re-enter Orbiter vehicle through airlock
10. Doff EVA equipment and stow

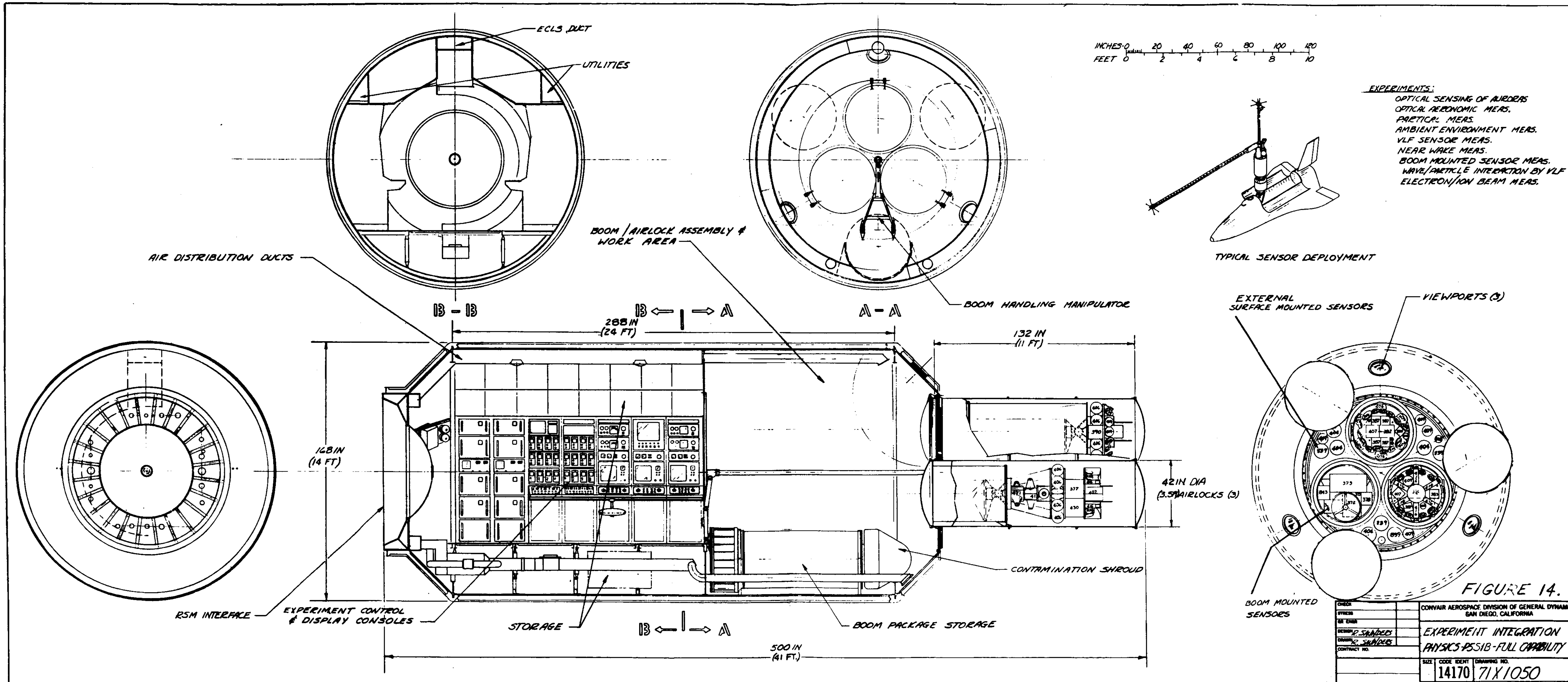
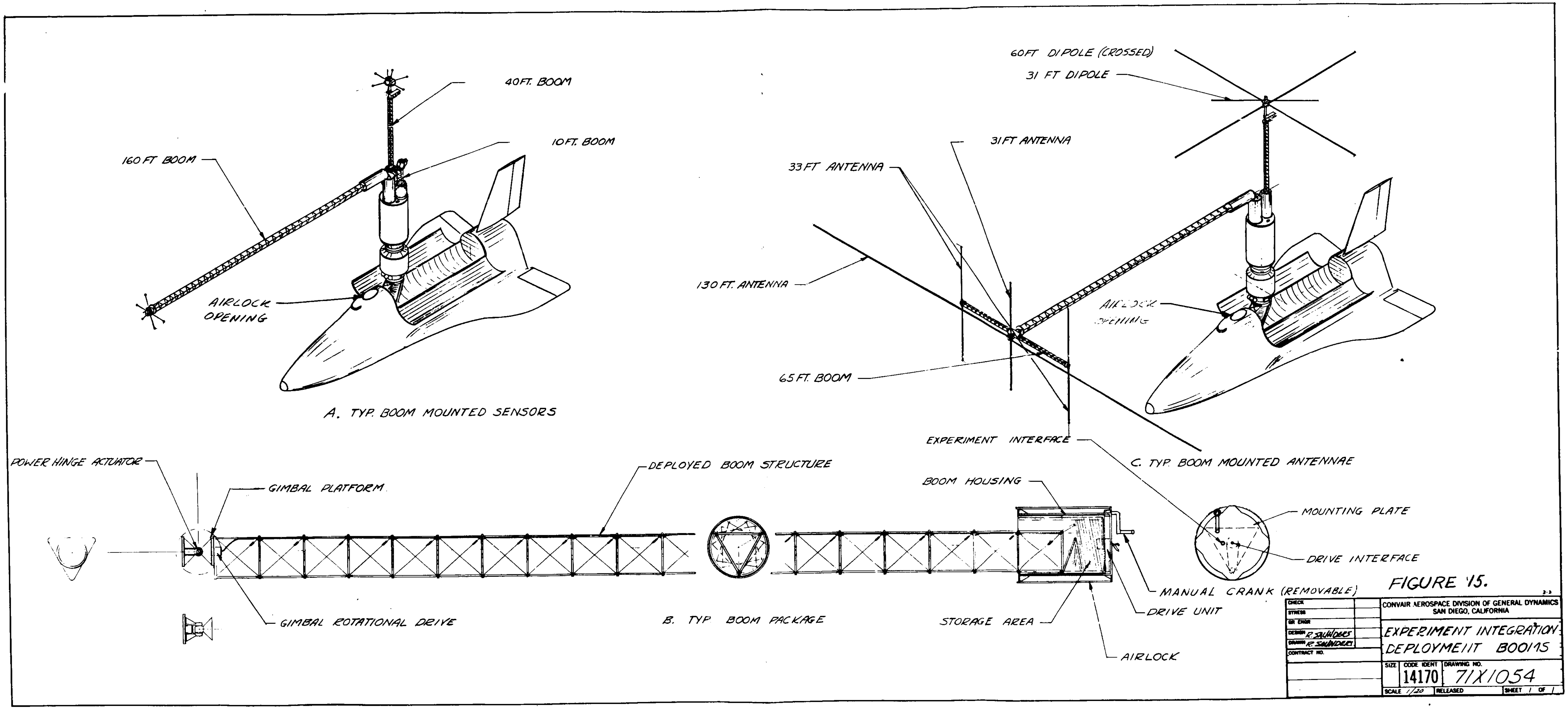


FIGURE 14.

CHECK	CONVAIR AEROSPACE DIVISION OF GENERAL DYNAMICS SAN DIEGO, CALIFORNIA
DESIGN R. SANDERS	EXPERIMENT INTEGRATION
DRAWN R. SANDERS	PHYSICS-PS51B-FULL CAPABILITY
CODE IDENT 14170	DRAWING NO. 71X1050
SCALE 1/20	SHEET 1 OF 1


40FT. BOOM
10FT. BOOM
160 FT BOOM
AIRLOCK OPENING
A. TYP. BOOM MOUNTED SENSORS
60FT DIPOLE (CROSSED)
31 FT DIPOLE
31FT ANTENNA
33FT ANTENNA
130 FT. ANTENNA
65 FT. BOOM
EXPERIMENT INTERFACE
C. TYP. BOOM MOUNTED ANTENNAE
POWER HINGE ACTUATOR
GIMBAL PLATFORM
DEPLOYED BOOM STRUCTURE
GIMBAL ROTATIONAL DRIVE
B. TYP BOOM PACKAGE
BOOM HOUSING
STORAGE AREA
AIRLOCK
MANUAL CRANK (REMOVABLE)
DRIVE UNIT
MOUNTING PLATE
DRIVE INTERFACE
CHECK
STRESS
GR ENGR
DESIGN R. SAUNDERS
DRAWN R. SAUNDERS
CONTRACT NO.
CONVAIR AEROSPACE DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA
EXPERIMENT INTEGRATION DEPLOYMENT BOOMS
SIZE
CODE IDENT 14170
DRAWING NO. 71X1054
SCALE 1/20
RELEASED
SHEET 1 OF 1
FIGURE 15.

6.0 EXAMPLE SCENARIO FOR IVA MAINTENANCE OF AN X-RAY ASTRONOMY OBSERVATORY

The following are representative X-Ray Astronomy Observatory activities during a revisit by the Orbiter vehicle.

A. Replace the proportional counter array (15 in x 26 in x 66 in - 166 lb)

B. Replace the scintellation counter (20 in x 30 in x 27 in - 286 lb)

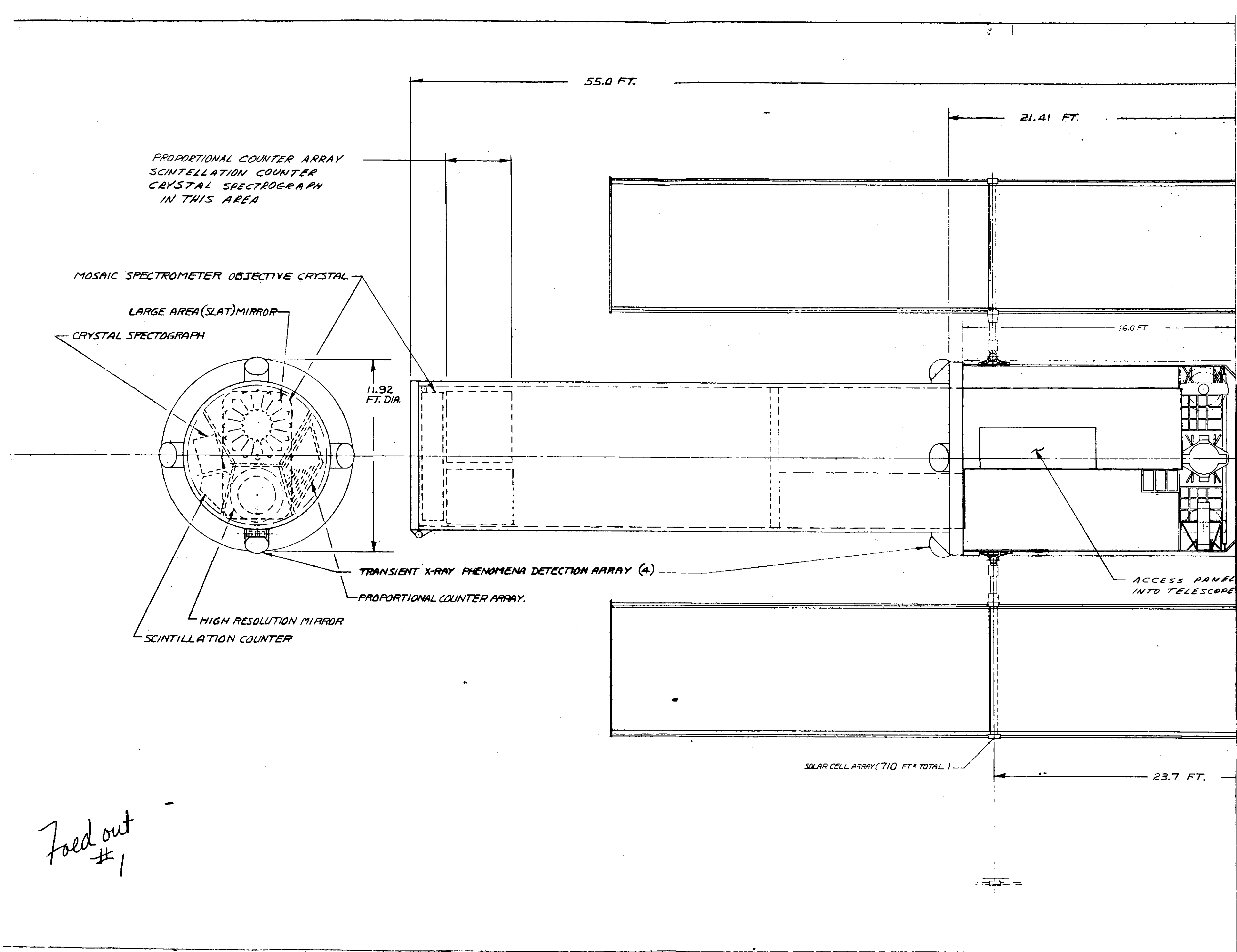
C. Replace the crystal spectrograph (29 in x 64 in x 28 in - 117 lb)

The X-Ray Astronomy Observatory is in a 40° orbit at 300 nautical miles. The orbiter vehicle will be docked with the X-Ray Observatory as it is shown docked with the LST in Figure 5. A support module will be used to pressurize the X-Ray Observatory for servicing operations. The three components to be replaced, however, are outside the pressurized area as shown in Figure 16. Access to the sensors is through the unpressurized telescope tube from inside the pressurizable compartment.

The following is a listing of events (not necessarily in sequence) for replacing each component by unpressurized IVA.

1. Unstow IVA equipment, replacement component and other equipment to be carried to the work site
2. Don and checkout IVA equipment
3. Enter the X-Ray Observatory pressurizable compartment
4. Depressurize X-Ray compartment
5. Gain access into the telescope tube
6. Translate through the telescope tube to the work site area with replacement component and required equipment

7. Prepare the work site area
8. Gain access to the component to be replaced
9. Accomplish component replacement
10. Replace any parts removed to gain access
11. Prepare work site for departure
12. Translate from work site to area of access opening between telescope tube and the pressurizable compartment with replaced component and other equipment
13. Exit the telescope tube with component and other equipment
14. Close access opening between the telescope tube and the pressurizable compartment
15. Repressurize the compartment
16. Doff IVA equipment and stow all equipment


55.0 FT.
21.41 FT.
PROPORTIONAL COUNTER ARRAY
SCINTELLATION COUNTER
CRYSTAL SPECTROGRAPH
IN THIS AREA
MOSAIC SPECTROMETER OBJECTIVE CRYSTAL
LARGE AREA (SLAT) MIRROR
CRYSTAL SPECTOGRAPH
11.92 FT. DIA.
16.0 FT
TRANSIENT X-RAY PHENOMENA DETECTION ARRAY (4)
PROPORTIONAL COUNTER ARRAY.
HIGH RESOLUTION MIRROR
SCINTILLATION COUNTER
ACCESS PANEL INTO TELESCOPE
SOLAR CELL ARRAY (710 FT² TOTAL)
23.7 FT.

Fold out #1

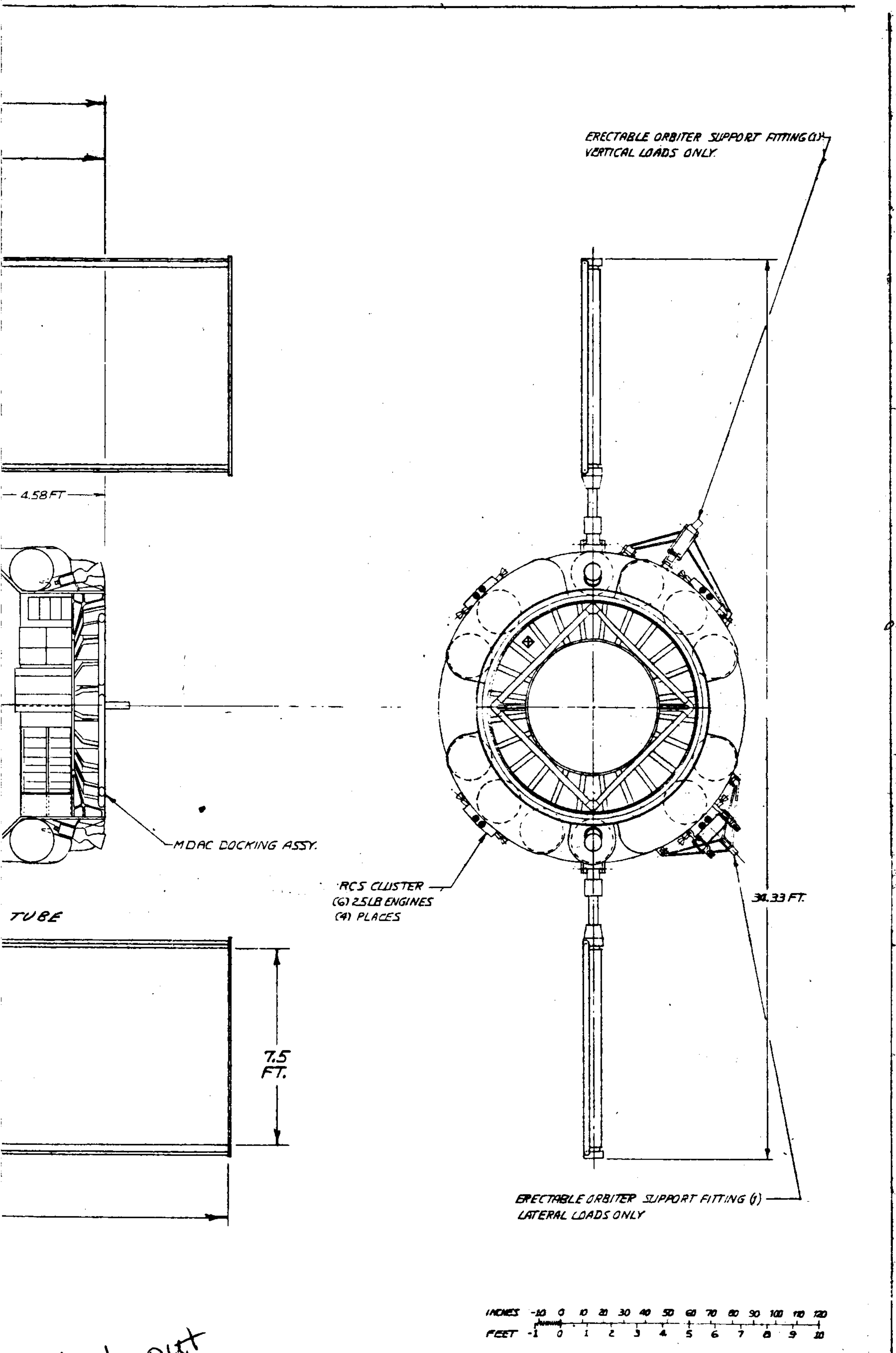


FIGURE 16.

PRELIMINARY DESIGN DRAWING

X-RAY STELLAR ASTRONOMY OBSERVATORY
PAYLOAD A103B
(PRELIMINARY)

TRUSSELL | APPROVED | SCALE | DATE 71 NOV 29

CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

Fold-out #2

7.0 EXAMPLE SCENARIO FOR EVA MAINTENANCE AND SERVICING OF A ASTRONOMY EXPLORER (A) SATELLITE

Service and maintenance of an Astronomy Explorer A Satellite was selected as representative of all free flying task scenarios. It represents such things as survey of the contaminant cloud, shuttle orbiter exterior inspection/repair, military applications (such as close-up inspection/retrieval of satellites, de-arming, etc.), and work on contamination sensitive satellites which are not desired to be exposed to the near-proximity contamination field of the shuttle.

The following are representative tasks to be accomplished during a service and maintenance visit to an Astronomy Explorer (A) Satellite.

A. Repressurize gaseous nitrogen RCS tanks - 6 lbs

B. Replace worn thruster - 0.02 lb thruster

C. Replace deteriorating TV camera

D. Replace damaged or deteriorating Solar cell panel 10 in. x 40 in. x .10 in

The Orbiter vehicle will be in the same orbit as the Astronomy Explorer, 28.5° at 270 nautical miles, stationed approximately one nautical mile away. The Orbiter will station-keep in this position during the maintenance and servicing.

Figure 17 shows the Astronomy Explorer Satellite. The mission objectives of the Astronomy Explorer program are independent investigations of solar and stellar behavior in the UV, X-Ray and radio spectral regions. The Satellite weights will be approximately 860 lbs. The types of sensors to be carried are optical and radio sensors, cosmic ray and VanAllen belt detectors, IR, Laser, TV camera, and radio frequency detectors. Subsystems consist of gaseous nitrogen propulsion for stationkeeping; momentum wheels and gravity gradient attitude control; telemetry, tracking and command for real time data, playback data and command data; and solar cell plus battery electrical power.

The following is a listing of events (not necessarily in sequence) for Astronomy Explorer Satellite maintenance and servicing.

1. Unstow EVA equipment and spare components
2. Don and checkout EVA equipment and prepare for EVA
3. Exit Orbiter vehicle through airlock
4. Translate to area of free flying maneuvering unit in the payload bay
5. Unstow, prepare for use and checkout the free flying maneuvering unit
6. Translate from Orbiter to the Satellite
7. Dock with Satellite at worksite
8. Prepare worksite for maintenance and servicing
9. Perform maintenance and servicing
10. Prepare to return to Orbiter
11. Translate from Satellite to Orbiter
12. Dock with Orbiter in area of Payload bay
13. Shut down and stow the free flying maneuvering unit
14. Translate to airlock opening
15. Re-enter Orbiter through airlock
16. Doff EVA equipment and stow

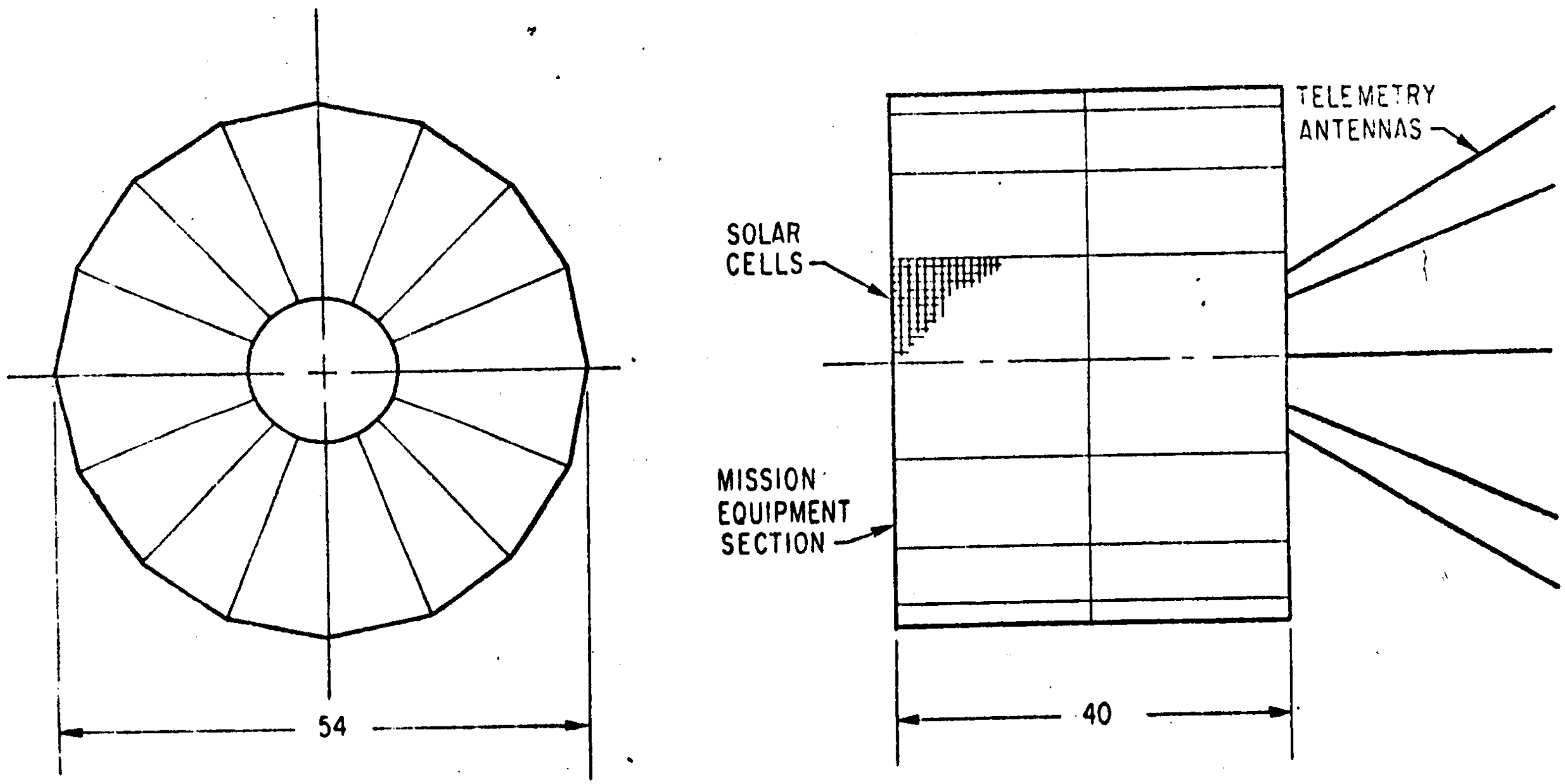


FIGURE 17 ASTRONOMY EXPLORER SATELLITE

APPENDIX B

REVISED SHUTTLE TRAFFIC MODEL

DESIGN INFORMATION ~~REQUEST~~ - RELEASE

DEL. (S) AND EFF. Study of Space Shuttle EVA/IVA Support Requirements	DIR. NO. T-192-DIR-07	REV.
SYSTEM Revised Shuttle Traffic Model	DATE	PAGE 1 OF 3
	REF. S. O. NUMBER	

Fill in block below for Information Request

TO ______ GROUP ______

REQ. BY ______ GROUP ______

REASON ______

TV ONLY ☐ BWR ☐ BUWEPS ☐ ☒ NASA

Fill in block below for Information Release

IN REPLY TO DIR. NUMBER ______

REL. TO R. L. Cox GROUP ______

PREPARED BY	DATE	CHECKED BY	DATE
P. W. Wood PW	12-7-72	—	
GROUP APP.	DATE	PROJ OFFICE	DATE
Bird	1-11-73	R L Cox	1-18-73

CC

J. M. Bird, C. R. King - 2-51750, R. J. Copeland, R. J. French

DESIGN INFORMATION:

Ref. 1 - Updated NASA Mission Model dtd 6 June 1972 (Wernher von Braun to Deputy Associate Adm.

Ref. 2 - NASA/DOD Earth Orbit Shuttle Traffic Model in Support of the March 1972 RFP-MSC-06746 dtd 21 March 1972. (MSC Internal Note 72-FM-71)

Ref. 3 - NASA Payload Data Book - 31 July 1972 - The Aerospace Corporation ATR-72(7312)-1, Vol. II

Ref. 4 - Anon. Integrated Operations/Payloads/Fleet Analysis, Phase II Second Interim Report Volume II: NASA Payload Data - ATR-71(7231)-11, Aerospace Corp., 31 March 1971.

Ref. 5 - Research and Applications Modules (RAM) Phase B Study, Technical Data Document, GDCA-DDA72-003B, General Dynamics, 12 May 1972.

Ref. 6 - Shuttle Orbital Applications and Requirements (SOAR) Final Report - Technical Volume 1 - Candidate Payload Identification, MDCG2355 Rev. A, McDonnell Douglas Astronautics Company, December 1971.

Reference 2 was revised to reflect the requirements of Ref. 1. Table I is the revised payloads and schedule replacing Table I in Ref. 2. Those payloads which were in Ref. 2 but are not in Ref. 1 have been eliminated, and those payloads in Ref. 1 which were not in Ref. 2 have been added as new numbered payloads starting with No. 82. The orbital characteristics are taken from Ref. 3.

Table II is the revised payload combinations and flights, replacing Table II in Ref. 2. Those payloads which were eliminated in revising Table I have been replaced by new payloads of approximately the same weight and requiring the same orbit where possible. Where no replacement was possible, the payload was eliminated. The new payloads were used in the same year they are called for in Table I except in a few cases where they are off by one or two years. Some flights were eliminated due to an overall decrease in payloads in Ref. 1. No effort was made to coordinate the old payload numbers from Ref. 2 with the new schedule in Table I. The combinations shown are, however, considered representative and are to be used for mission analysis in determining EVA/IVA equipment requirements.

Table III is the revised Traffic Model Summary replacing Table III in Ref. 2. The NASA payload and flight totals and total payload and flight totals have been revised to reflect the revised tables I & II.

Table IV gives available payload references and is organized by payload class rather than payload reference number.

TABLE I - PAYLOAD CHARACTERISTICS AND SCHEDULE

MSC 06746 TRAFFIC MODEL PAYLOAD NO.	PAYLOAD TITLE	ART-72(7312)-1 ORBIT (i - ^{o}XH - N.M.)	ART-72(7312)-1 WEIGHT (LB.)	SCHEDULE 1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
1a	EXPLORER - LEO (AST) (SAS-C SAT.)	28.5 x 550	373	1	2	1	1	1	2	1	1	1	2	1	2
1b	EXPLORER - SYNC (AST) (SAS-C SAT.)	28.5 x 19,323	373												
3	EXPLORER - UPPER ATMOSPHERE (SPACE PHY)	90 ± 20 x 100-180	1,160												
4	EXPLORER - MED. ALTITUDE (SPACE PHY)	0-90 x 1000-20,000	570	2	1	2	1	2	1	2	1	2	1	2	1
5	EXPLORER - HIGH ALTITUDE (SPACE PHY)	1 A.U. ECLIPTIC	640												
7	GRAVITY AND RELATIVITY SATELLITES - LEO	90 x 500	1,020	1			1				1				1
8	GRAVITY AND RELATIVITY SATELLITES - SOLAR	3/1.0 A.U. x ECLIPTIC	770												
13	HIGH ENERGY ASTRONOMY OBSERVATORY (HEAO-C)	28.5 x 250 ± 50	18,264	UP				DN,UP	UP				DN	UP,DN	
14	HEAO-C REVISIT	28.5 x 250 ± 50	3,500		1	1	1		1	2	2	2	1		1
15	LARGE SPACE TELESCOPE (LST)	28.5 x 330	18,581	UP				DN,UP					UP,DN		
16	LST REVISIT	28.5 x 300	3,500		1	1	1		1	1	1	1		1	1
17	LARGE SOLAR OBSERVATORY (LSO)	28.5 - 90 x 500 ± 102	32,282								UP				
18	LSO REVISIT		3,500									1	1	1	1
19	RADIO ASTRONOMY OBSERVATORY (RAO)	28.5 ± 28.5 x 38,646 ± 20	2,385												UP
21	EARTH OBSERVATION SATELLITE	98 x 500 ± 50 - 926 ± 93	2,400	1	1	1		1		1		1		1	
22	SYNCHRONOUS EARTH OBSERVATORY SAT.(SEOS)	0 ± 30 x 19,323	2,500		1		1			1		1			1
24	SYNCHRONOUS METEOROLOGICAL SATELLITE	0 ± 3 x 19,323	535			1	1								
25	TIROS-O	103 x 906	1,380			1									
26	EARTH RESOURCES SATELLITE (PROTO)	98 x 500 ± 50	1,800	2	2				1	1					2
27	SYNC. EARTH OBSERV. SATELLITE (PROTO)	0 ± 3 x 19,323	2,640												1
28	APPLICATIONS TECHNOLOGY SATELLITE	0 ± 3 x 19,323	3,000	1			1	1		1		1		1	
29	SMALL APPLICATIONS TECH. SAT. SYNC.	0 ± 3 x 19,323	300	1	1	1	1	1	1	1	1	1	1	1	1
30	SMALL APPLICATIONS TECH. SAT. POLAR	90 x 300-3000 +100 -20	300	1	1	1	1	1	1	1	1	1	1	1	1
35	SYSTEMS TEST SATELLITES	0 ± 3 x 19,323	2,860		1	1	1	1	1	1		1	1		
36	TRACKING & DATA RELAY SATELLITE (TDRS)	0 ± 3 x 19,323	1,760					3						3	

TABLE I - PAYLOAD CHARACTERISTICS AND SCHEDULE
(continued)

MSC 06746 TRAFFIC MODEL PAYLOAD NO.	PAYLOAD TITLE	ART-72(7312)-1 ORBIT (i - °XH - N.M.)	ART-72(7312)-1 WEIGHT (LB.)	SCHEDULE 1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
38	ASTRONOMY/PHYSICS OBSERVATIONS - SORTIE	55 x 270	23,569	1	1	1	1	2	2	2	2	2	2	2	2
42	EARTH OBSERVATION LABORATORY - SORTIE	$90^{+20}_{-35} \times 100^{+170}_{-0}$	25,581		1	1	1	1	1	1	1	1	1	1	1
43	BIO RESEARCH MODULE	$28.5^{+10}_{-0} \times 300$	370	2											
46	TELEOPERATOR	$28.5^{+10}_{-0} \times 300$	960	1											
50	MARS VIKING	M-NA x 17,838 - 811	7,491	2											
51	MARS ROVER	SUR. TRAV.-90-270 NM	5,548								1				
52	VENUS PIONEER	-	878		1										
53	VENUS RADAR MAPPER	V-POLAR x 270	2,087						2						
54	VENUS LARGE LANDER	-	1,169											2	
55	PIONEER - JUPITER ORBITER	-	1,948	1											
56	GRAND TOUR (JUN)	-	1,540	2											
57	MARINER - JUPITER ORBITER	-	2,500								1	1			
58	URANUS PROBE/NEPTUNE FLYBY	-	4,990								2				
59	ASTEROID RENDEZVOUS	-	3,640											2	
60	ENCKE RENDEZVOUS	-	3,193						2						
60-1	ENCKE SLOW FLYBY	-	3,159	1											
60-3	MARINER - SATURN ORBITER	-	2,368											1	1
62	SPACE STATION MODULES	55 x 270	20,000							3					2
64	PHYSICS LAB - SPACE STATION RAM	55 x 270	22,811									UP		DN, UP	
66	SPACE STATION - LIFE SCIENCES LAB	55 x 270	28,984									UP			
68	SPACE STATION - (RAM) COMM./NAV. LAB	55 x 270	36,500								UP, DN		UP, DN		
70	COMSAT	0 x 19,323	1,490	2	1	1		2	1	1			2	1	
71	U. S. DOMESTIC COMM. (ORBITS AND WEIGHTS FROM MSC 06746)	0 x 19,323	3,545	1	2	1	1	2	2	2	2	2	2	2	2
72	FOREIGN DOMESTIC COMM.	0 x 19,323	1,030		2	6	2	2			4	5	2	1	2
73	NAV. & TRAFFIC CONTROL	28.5 x 30,000-16,000	725	3	1	2		1		1		1		1	

TABLE I - PAYLOAD CHARACTERISTICS AND SCHEDULE
(continued)

MSC 06746 TRAFFIC MODEL PAYLOAD NO.	PAYLOAD TITLE	ATR-72(7312)-1 ORBIT (i - ^{o}XH - N.M.)	ART-72(7312)-1 WEIGHT (LB.)	SCHEDULE 1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
74	NAV. & TRAFFIC CONTROL	5 x 19,300	725	1		1		1		1		1		1	
75	TOS METEOROLOGICAL	100.7 x 700	1,030	1	1	1	1	1	1	1	1	1	1	1	1
76	SYNC. METEOROLOGICAL	0 x 19,323	1,035	1	1	1	1	1	1	1	1	1	1	1	1
77	POLAR EARTH RESOURCES ORBITS AND WEIGHTS FROM MSC 06746	99.15 x 500	2,590	4		4		4		4				6	
78	SYNC. EARTH RESOURCES	0 x 19,323	1,030							4			4		
79	COMM. SATELLITES GENERAL	0 x 19,323	850	4	4	4	4	4	4	4	4	4	4	4	4
80	BROADCAST SATELLITES	0 x 19,323	2,500	2	2	2	2	2	2	2	2	2	2	2	2
81	BROADCAST SATELLITES	0 x 19,323	1,000	2	2	2	2	2	2	2	2	2	2	2	2
82	SORTIE - COMM./NAV. EXPERIMENTS	28^{+27}_{-0} x 200 $^{+400}_{-100-0}$	17,910	1	1			1	1			1			1
83	SORTIE - COMM./NAV. LABORATORY	28^{+27}_{-0} x 200 $^{+400}_{-100-0}$	17,510			1	1			1				1	
84	DISASTER WARNING SATELLITE	0 $\pm$ 3 x 19,323	1,860	1											
85	GEOPAUSE	90 x 270	710	1	1										
86	PIONEER SATURN PROBE	-	850						2						
87	PIONEER - JUPITER PROBE	-	794				2								
88	MERCURY ORBITER	M - 27 x 270	5,166									2			
89A	ENVIRONMENT PERTURBATION SAT-MISSION A	55 $^{+}_{-}$30 x 6900$^{+}_{-}$500	4,350			1			1			1			1
89B	ENVIRONMENT PERTURBATION SAT-MISSION B	55 $^{+35}_{-0}$ x 6900 $\pm$ 500	8,700												
90	HELIOCENTRIC & INTERSTELLAR SPACECRAFT	ESCAPE	616										1		
91	LARGE HIGH ENERGY TELESCOPE (X-RAY)	28.5 $^{+70}_{-0}$ x 400	15,781											UP	
92	X-RAY TELESCOPE REVISIT	28.5 $^{+70}_{-0}$ x 400	3,500												1
93	SORTIE - MINI 7-DAY MODULE	0 x 463	14,041		1	1	1								
94	SORTIE - MINI 30-DAY MODULE	0 x 463	18,891					1	1						
95	SPACE STATION - MINI 30-DAY MODULE	55 x 270	26,576							UP,DN	UP,DN				
96	METEOROID & EXPOSURE MODULE	28.5 x 500	10,000		UP,DN			UP,DN							
97	MATERIAL SCIENCE EXPERIMENTS - SORTIE	ANY	2,720	1	1	1	1	1	2						
98	SORTIE - ADVANCED TECHNOLOGY EXPERIMENTS	28.5 $^{+60}_{-0}$ x 250	13,781	1		1		1							
99	SPACE STATION - RAM TECH. & MAT. SCI. LAB	55 x 270	19,113							UP					
100	SPACE STATION - CREW/OPS LOGISTICS MODULE	55 x 270	20,000							5	6	6	6	6	6

TABLE II

PAYLOAD COMBINATIONS FOR ORBITER FLIGHTS

1979 Orbiter Flight No.	1979 Payload Numbers	1980 Orbiter Flight No.	1980 Payload Numbers
1	1a, 43	1	85, 3, 4
2	1a, 13	2	85, 73, 5
3	3, 73, 5	3	97, 26
4	80, 73	4	97, 14
5	28, 4, 73	5	82, 14
6	98	6	46
7	50	7	93
8	56	8	60-1
9	56	9	52
10	79, 81	10	1b, 84, 80
11	70	11	79, 1b, 70
12	79, 36, 81	12	80, 36, 22
13	79, 80, 29	13	36, 81, 79
14	74, 79	14	81, 79, 29
15	71	15	89, 76, 79
16	70, 76	16	71, 72
17	21, 77	17	71, 72
18	30	18	21, 75
19	77, 75	19	85, 30
20	77	20	42 (A)
21	77		

TABLE II
(Continued)

1981 Orbiter Flight No.	1981 Payload Numbers	1982 Orbiter Flight No.	1982 Payload Numbers
1	73, 5	1	3, 4, 5
2	13, 1a	2	16, 83
3	- *	3	93, 14, 1a
4	73, 8	4	14, 16, 1a
5	15	5	53
6	14, 82	6	55
7	14, 83	7	55
8	93	8	60
9	50	9	22, 27
10	27, 81, 79	10	35, 79, 29
11	28, 72, 1b	11	24, 27, 81
12	80, 72, 79	12	81, 80, 79
13	80, 81, 29	13	76, 80, 79
14	35, 72, 79	14	35, 72, 79
15	35, 72, 79	15	71, 72
16	36, 72, 76	16	38
17	74, 70	17	38
18	71, 72	18	38
19	38	19	97
20	38	20	96
21	97	21	42 (A)
22	98	22	85, 30
23	3, 30	23	42
24	85, 4	24	42
25	42 (A)	25	21, 75
26	21, 77		
27	77, 25		
28	77, 75		
29	77		

* No corresponding NASA payload identified from Ref. (1), orbiter flight eliminated.

TABLE II

(Continued)

1983		1984	
Orbiter Flight No.	Payload Numbers	Orbiter Flight No.	Payload Numbers
1	14, 98	1	- *
2	1a, 73, 5	2	14, 1a, 5
3	14, 16, 1a	3	14, 16
4	15U, 13D	4	16, 18
5	16, 97	5	18
6	17	6	59
7	87	7	28, 22, 16
8	24, 74	8	36, 81, 79
9	36, 81, 79	9	71, 79
10	28, 27, 79	10	80, 76, 79
11	36, 81, 79	11	35, 79, 29
12	80, 29, 79	12	71
13	80, 76	13	80, 81
14	35, 70	14	35, 70
15	35, 70	15	38
16	71, 72	16	38
17	71, 72	17	38
18	38	18	38
19	38	19	97
20	38	20	97
21	38	21	94
22	94	22	82
23	96	23	42
24	3, 4	24	42
25	85, 30	25	3, 4
26	21, 77	26	7, 30
27	77, 75	27	21, 75
28	77		
29	77		

* No corresponding NASA payload identified from Ref. (1), orbiter flight eliminated.

TABLE II
(Continued)

1985

Orbiter Flight No.	Payload Numbers
1	5, 4, 86
2	3, 86, 73
3	13U, 15D
4	14, 16
5	14, 18
6	17
7	18, 19
8	54
9	57
10	60
11	78, 1b, 81
12	79, 1b, 78
13	29, 80
14	35, 79
15	35, 79
16	71
17	71
18	70
19	79, 76, 78
20	80, 78
21	74, 81
22	99
23	62
24	62
25	62
26	62
27	- *
28	66
29	95
30	38
31	38
32	38
33	82
34	83
35	42
36	100
37	100
38	100
39	100
40	85, 30
41	21, 75
42	77, 25
43	77
44	77
45	77
46	64
47	68

1986

Orbiter Flight No.	Payload Numbers
1	5
2	14, 18, 1a
3	16, 1a
4	14, 16
5	18
6	58
7	28
8	22, 76, 79
9	29, 81
10	35, 79
11	35, 79
12	72, 79
13	71
14	71
15	72, 80
16	72, 80
17	72, 81
18	- *
19	- *
20	- *
21	- *
22	- *
23	95
24	42
25	100
26	100
27	100
28	100
29	100
30	100
31	100
32	100
33	3, 4
34	21
35	26
36	26, 75
37	30

* No corresponding NASA payload identified from Ref. (1), orbiter flight eliminated.

TABLE II
(Continued)

1987

Orbiter Flight No.	Payload Numbers
1	8, 89
2	14, 16, 1a
3	5, 73
4	15U, 13D
5	14, 18
6	16
7	19
8	17
9	18
10	57
11	74, 36
12	29, 1b
13	72, 79
14	27, 81
15	72, 79
16	35, 79
17	35, 79
18	80, 72
19	80, 72
20	36, 76
21	81, 72
22	71
23	71
24	42
25	82
26	100
27	100
28	100
29	100
30	- *
31	- *
32	- *
33	- *
34	- *
35	- *
36	100
37	100
38	100
39	3, 4
40	30
41	26, 75
42	26
43	26
44	26
45	66
46	100
47	68
48	21

1988

Orbiter Flight No.	Payload Numbers
1	1a, 3, 88
2	1a, 14
3	5, 4, 88
4	14
5	16, 18
6	16
7	54
8	78, 79
9	78, 22
10	78, 79, 27
11	78, 79, 27
12	79, 72
13	80, 72
14	28
15	29, 80
16	35, 81
17	35, 81
18	36, 76
19	70
20	70
21	71
22	71
23	42
24	100
25	100
26	100
27	100
28	100
29	100
30	100
31	100
32	30
33	21, 75

* No corresponding NASA payload identified from Ref. (1), orbiter flight eliminated.

TABLE II
(Continued)

1989 Orbiter Flight No.	1989 Payload Numbers	1990 Orbiter Flight No.	1990 Payload Numbers
1	1a, 14, 16	1	5
2	1a	2	14, 16
3	5, 73	3	14, 18
4	- *	4	16, 92
5	13U, 15D	5	18
6	14, 18	6	51
7	16	7	51
8	17	8	79, 1b
9	18	9	72, 1b
10	19	10	29, 72
11	58	11	35, 79
12	60 - 3	12	35, 79
13	28	13	79, 80
14	29, 79	14	71
15	35, 79	15	71
16	35, 79	16	80, 81
17	79, 80	17	22, 76, 81
18	70	18	42
19	80, 81	19	82
20	71	20	100
21	72, 81	21	100
22	74, 76	22	100
23	3, 4	23	100
24	42	24	100
25	83	25	100
26	91	26	100
27	100	27	- *
28	100	28	- *
29	100	29	- *
30	100	30	- *
31	100	31	100
32	100	32	3, 4
33	- *	33	7, 30
34	- *	34	25, 75
35	- *	35	21
36	- *	36	69
37	- *	37	100
38	- *		
39	- *		
40	30		
41	35		
42	21, 75		
43	77		
44	77		
45	77		
46	77		
47	77		
48	77		
49	71		

* No corresponding NASA payload identified from Ref. (1), orbiter flight eliminated.

TABLE III- TRAFFIC MODEL SUMMARY

(a) Unlimited Traffic Model

	Year												
	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	Total
NASA payloads	47	37	32	32	42	41	47	40	48	40	52	43	511
NASA flights	21	20	28	25	29	26	46	32	42	33	41	33	376
DOD payloads	23	34	18	21	32	28	25	23	25	25	25	26	305
DOD flights	20	30	16	20	26	24	24	20	23	23	21	23	270
Total payloads	70	71	50	53	74	69	72	60	73	65	77	69	816
Total flights	41	50	44	45	55	50	70	52	65	56	62	56	646

(b) More Realistic Shuttle Flight Frequency

	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	Total
NASA & DOD flights	6	15	24	32	40	60	60	60	60	60	60	60	60	597

TABLE IV - ORBITER PAYLOADS INFORMATION

MSC (1) J6746 Traffic Model Payload No.	Payload Title	Aerospace (2) ART-72(7312)-1 Orbit (i-°Xh - N.M.)	Weight (lb)	Aerospace (3) ART-71(7231)-11 Identifier	Aerospace (2) ART-72(7312)-1 Identifier	General (4) Dynamics RAM Code	MacDac (5) SOAR MDC-2355 Identifier	12 YR Total	REF From (2) ART-72(7312)-1
	EXPLORER CLASS							60	
	SCIENCE								
1a	Explorer - Leo (AST) (SAS-C-SAT.)	28.5 x 550	373	NAS-14A	NA2-1		A14	16	Ref. 3
1b	Explorer - Sync (AST) (SAS-C SAT.)	28.5 x 19,323	373	NAS-14B	NA2-2		A14		
3	Explorer - Upper Atmosphere (Space Phy)	90 +20 x 100-180	1,160	NSP-1	NP2-13		SP1	18	
4	Explorer - Medium Altitude (Space Phy)	0-90 x 1000-20,000	570	NSP-2	NP2-14		SP2		
5	Explorer - High Altitude (Space Phy)	1 A.U. Ecliptic	640	NSP-3	NP2-15		SP3		
	APPLICATIONS								
29	Small Applications Tech. Sat. Sync.	0 +3 x 19,323	300	NCN-2B	NC2-47		SA8	12	
30	Small Applications Tech. Sat. Polar	90 x 300 - 3000 +00 -20	300	NCN-2A	NC2-48		SA8	12	
	LIFE SCIENCES								
43	Bio Research Module	28.5 +10 -0 x 300	370	NSO-5	NB2-55		-	2	Ref. 28
	INTERMEDIATE CLASS							87 9	
	SCIENCE								
7	Gravity and Relativity Satellites - Leo	90 x 500	1,020	NSP-6	NP2-16		SP7	4	Ref. 11
8	Gravity and Relativity Satellites - Solar	.3/1. OAU x Ecliptic	770	NSP-7	NP2-16		SP8		
89a	Environment Perturbation Sat - Mission A	55 +30 x 6900 + 500	4,350	-	NP2-18		-	4	
89b	Environment Perturbation Sat - Mission B	55 +35 -0 x 6900 + 500	8,700	-	NP2-19		-		
90	Heliocentric & Interstellar Spacecraft	Escape	616	-	NP2-20		-	1	
	APPLICATIONS							47	
21	Earth Observation Satellite	98 x 500 +50 - 926 +93	2,400	NEO-2	NE2-38		-	7	
22	Synchronous Earth Observatory Sat. (SEOS)	0 +30 x 19,323	2,500	NEO-3	NE2-39		SA1	5	
24	Synchronous Meteorological Satellite	0 + 3 x 19,323	535	NEO-8	NE2-41		-	2	Ref. 24
25	TIROS-O	103 x 906	1,380	NEO-6	NE2-40		SA9 & SA10	1	
26	Earth Resources Satellite (PROTO)	98 x 500 +50	1,800	NEO-17	NE2-42		SA4	8	
27	Sync. Earth Observ. Satellite (PROTO)	0 +3 x 19,323	2,640	NEO-11	NE2-43		SA2	1	
28	Applications Technology Satellite	0 +3 x 19,323	3,000	NCN-1	NC2-46		SA5	6	
84	Diaster Warning Satellite	0 +3 x 19,323	1,760	--	NC2-50		-	1	
85	Geopause	90 x 270	710	--	NE2-45		-	2	
35	Systems Test Satellites	0 +3 x 19,323	2,860	NCN-13	NC2-51		SA7	8	
36	Tracking & Data Relay Satellite (TDRS)	0 +3 x 19,323	1,760	NCN-5	NC2-49		-	6	Ref. 26

(1) Ref. 2
(2) Ref. 3
(3) Ref. 4
(4) Ref. 5
(5) Ref. 6

MSC 06746 Traffic Model Payload No.	Payload Title	Aerospace ART-72(7312)-1 Orbit (i-°Xh - N.M.)	Aerospace ART-72(7312)-1 Weight (lb)	Aerospace ART-71(7231)-11 Identifier	Aerospace ART-72(7312)-1 Identifier	General Dynamics RAM Code	MacDac SOAR MDC-2355 Identifier	12 YR Total	Ref From ART-72(7312)-1
	PLANETARY							28	
50	MARS Viking	M-NA x 17,838 - 811	7,491	NPL-1	NU2-22		PL1	2	Ref. 12
51	MARS Rover	Sur. Trav. - 90-270 NM	5,548	NPL-19	NU2-23			1	Ref. 13
52	Venus Pioneer		878	NPL-5	NU2-24		PL4	1	Ref. 14
53	Venus Radar Mapper	V-Polar x 270	2,087	NPL-6	NU2-25		PL6	2	Ref. 15
54	Venus Large Lander	--	1,169	NPL-7	NU2-26		PL7	2	Ref. 16
55	Pioneer - Jupiter Orbiter	--	1,948	NPL-11	NU2-28		PL11	1	Ref. 18
56	Mariner - Jupiter/Uranus Flyby		1,540	NPL-10	NU2-29			2	
86	Pioneer - Saturn Probe		850	--	NU2-31		--	2	
87	Pioneer - Jupiter Probe		794	--	NU2-30		--	2	Ref. 19
88	Mercury Orbiter	M-27 x 270	5,166	--	NU2-27		--	2	Ref. 17
57	Mariner - Jupiter Orbiter	--	2,500	NPL-13	NU2-32		PLB	2	Ref. 20
58	Uranus Probe/Neptune Flyby	--	4,990	NPL-14	NU2-33		--	2	
59	Asteroid Rendezvous	--	3,640	NPL-15	NU2-37		PL15	2	Ref. 22
60	Encke Rendezvous	--	3,193	NPL-18	NU2-36		--	2	
60-1	Encke Slow Flyby	--	3,159		NU2-35		--	1	
60-3	Mariner - Saturn Orbiter	--	2,368	NPL-18	NU2-34		--	2	
	LIFE SCIENCES							1	
46	Teleoperator	28.5^{+10}_{-0} x 300	960	NSO-5	NB2-56	T5S2B	--	1	Ref. 29, 30
	SPACE TECHNOLOGY							2	
96	Meteoroid & Exposure Module	28.5 x 500	10,000	--	NT2-61		--	2 up 2 dn	
	LARGE OBSERVATORIES							36	
91	Large High Energy Telescope (X-Ray)	28.5^{+70}_{-0} x 400	15,781	--	NA2-9	A103B	--	1 up	Ref. 5
92	X-Ray Telescope Revisit		3,500	--	NA2-19		--	1	
13	High Energy Astronomy Observatory ((HEAO-C)	28.5 x 250 ±50	18,264	NAS-4	NA2-3	A502D	A4	4 up 3 dn	Ref. 4
14	HEAO-C Revisit	28.5 x 250 +50	3,500	NAS-6	NA2-4	A503D	A6	12	
15	Large Space Telescope (LST)	28.5 x 330	18,581	NAS-1	NA2-5	A202B	A1	3 up 2 dn	Ref. 5
16	LST Revisit	28.5 x 330	3,500	NAS-5	NA2-6	A203B	A5	9	
17	Large Solar Observatory (LSO)	28.5 - 90 x 500 + 102	32,282	NAS-2	NA2-7	A303B	A2	1 up	Ref. 6
18	LSO Revisit		3,500	NAS-5	NA2-8		A5	4	Ref. 7
19	Radio Astronomy Observatory (RAO)	28.5 ± 28.5 x 38,646 ±20	2,385	NAS-3	NA2-11		A3	1 up	

MSC 06746 Traffic Model Payload No.	Payload Title	Aerospace ART-72(7312)-1 Orbit ($i - {}^{o}X h$ - N. M.)	Weight (lb)	Aerospace ART-71(7231)-11 Identifier	Aerospace ART-72(7312)-1 Identifier	General Dynamics RAM Code	MacDac SOAR MDC-2355 Identifier	12 YR Total	Ref From ART-72(7312)-1
	SORTIES							56	
38	Astronomy/Physics Observations-Sortie	55 x 270	23,569	NSO-1	NA2-12	P5S18 P6S2A P7S1A P7S3A P8S2B A3S1B A6S1B A9S1J A8S1U, V, W, X, Z A3S1B, A6S1B A9S1J	--	20	Ref. 9 & 10
82	Sortie - Comm. /Nav. Experiments	$28^{+27}_{-0} \times 200^{+400}_{-100.0}$	17,910	--	NC2-52	C1S2C C1S1E	--	6	Ref. 25, 27
83	Sortie - Comm. /Nav. Laboratory	$28^{+27}_{-0} \times 200^{+400}_{-100.0}$	17,510	--	NC2-53	C1S1F	--	4	Ref. 25, 27
93	Sortie - Mini 7-Day Module	0 x 463	14,04?	--	NB2-57		--	3	Ref. 7
94	Sortie - Mini 30-Day Module	0 x 463	18,891	--	NB2-58	L8S1B L8S2B	--	2	Ref. 7
97	Material Science Experiments - Sortie	Any	2,720	--	NT2-62	M1S1E, F, G, M152B T1S3A T2S1A T202F T2S2E T4S1A T3S2B T4A1A T401A T3S1A	--	7	Ref. 29
42	Earth Observation Laboratory - Sortie	90^{+20}_{-35}	25,581	NSO-5	NE2-44	E1S1N, O, P, Q, R, S	--	11	Ref. 9, 10, 25

MSC 06746 Traffic Model Payload No.	Payload Title	Aerospace ART-72(7312)-1 Orbit (i-°Xh - N.M.)	Weight (lb)	Aerospace ART-71(7231)-11 Identifier	Aerospace ART-72(7312)-1 Identifier	General Dynamics RAM Code	MacDac SOAR MDC-2355 Identifier	12 YR Total	Ref From ART-72(7312)-1
	SPACE STATION							48	
62	Space Station Modules		20,000	NSS-2B	NS2-65, 66, 67		--	5	Ref. 31
100	Space Station - Crew/Ops Logistics Module		20,000	--	NS2-68		--	35	Ref. 31
64	Physics Lab - Space Station RAM		22,811	NSS-7A	NP2-21	P6A3A P3A3A-1, -2	--	2 up 1 dn	Ref. 9 & 10
68	Space Station - (RAM) Comm. /Nav. Lab		36,500	NSS-7C	NC2-54	C1A2B C1A3B	--	2 up 2 dn	Ref. 25 & 27
95	Space Station - Mini 30-Day Module	55 x 270	26,576	--	NB2-39			2 up 2 dn	Ref. 7
66	Space Station - Life Sciences Lab.		28,984	NSS-5A	NB2-60	L8A1B-1, -2 L8A2B-1, -2	--	1 up	Ref. 7
99	Space Station - RAM Tech. & Mat. Sci. Lab		19,113	--	NT2-64	M1A3B, T1A3A, T4A1A	--	1 up	
	NON-NASA PAYLOADS							224	
70	COMSAT	0 x 19,323	1,490	NCN-7			--	11	
71	U.S. Domestic Comm.	0 x 19,323	3,545	NCN-8			--	21	
72	Foreign Domestic Comm.	0 x 19,323	1,030	NCN-9			NO4	26	
73	Nav. & Traffic Control	28.5 x 30,000-16,000	725	NCN-10A			NO5	10	
74	Nav. & Traffic Control	5 x 19,300	725	NCN-10B			NO6	6	
75	TOS Meteorological	100.7 x 700	1,030	NEO-7			--	12	
76	Sync. Meteorological	0 x 19,323	1,035	NEO-15			--	12	
77	Polar Earth Resources	99.75 x 500	2,590	NEO-16			--	22	
78	Sync. Earth Resources	0 x 19,323	1,030	NEO-11			NO1	8	
79	Comm. Satellites General	0 x 19,323	850	--			--	48	
80	Broadcast Satellites	0 x 19,323	2,500	--			--	24	
81	Broadcast Satellites	0 x 19,373	1,000	--			--	24	

ORBITS & WEIGHTS FROM MSC 06746

APPENDIX C

TIMELINE AND MISSION ANALYSIS

DESIGN INFORMATION REQUEST – RELEASE

MODEL (S) AND EFF. Study of Space Shuttle EVA/IVA Support Requirements	DIR. NO. T-192-DIR-08 — REV.
SYSTEM Timeline and Mission Analyses	DATE — PAGE 1 OF 12
	REF. G. O. NUMBER 3356-AA-1160

Fill in block below for Information Request	Fill in block below for Information Release
TO ____ GROUP ____	IN REPLY TO DIR. NUMBER ____
REQ. BY ____ GROUP ____	REL. TO R. L. Cox GROUP ____
REASON ____	PREPARED BY P.W. Wood PW — DATE 12-7-72 — CHECKED BY R L Cox — DATE 1-20-73
LTV ONLY ☐ BWR ☐ BUWEPS ☐ ☒ NASA	GROUP APP. J Bird — DATE 1-11-73 — PROJ OFFICE R L Cox — DATE 1-20-73

CC

C. R. King 2-51753, R. J. Copeland, R. J. French

DESIGN INFORMATION:

Timeline analyses were conducted and timeline diagrams prepared for each EVA and IVA identified in the scenarios contained in Appendix A of Tasks, Guidelines and Constraints Briefing Report. The detailed timeline analyses are contained in Attachment 1.

Mission analyses were then conducted, utilizing the timeline analysis results, to determine (1) umbilical lengths required, (2) EVA & IVA equipment operating times required per EVA/IVA and per orbiter flight, (3) payload sensitivity to contamination, (4) EVA's and IVA's associated with contamination sensitive payloads, (5) maximum number of EVA/IVA required per orbiter flight, and (6) maximum EVA/IVA time required per orbiter flight. The detailed mission analyses are contained in Attachment 2.

Figures 1 thru 7 and Table I present the results of these analyses. This data is released for use in selecting EVA and IVA equipment requirements.

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 or unscheduled EVA or IVA could be applicable. EVA's and IVA's on DOD payloads were estimated based on their similarity to NASA payloads.

Figure 1 shows the potential number of representative EVA's and IVA's compared to the number of times payloads are handled (delivered to orbit, retrieved or revisited) by the

0-52042 R1

Orbiter vehicle. The quantities of potential EVA's and IVA's in this plot were derived without consideration of payload combinations on Orbiter flights; only payload type vs representative EVA/IVA was considered.

Figure 2 shows these potential EVA's and IVA's from Figure 1 related to umbilical length. It can be seen that an umbilical length of about 70 ft will accommodate a large percentage of the potential 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. Potential EVA's and IVA's affecting contamination sensitive payloads and water vapor sensitive payloads are shown separately to illustrate the possible magnitude of the water vapor sensitivity problem. The potential EVA's and IVA's are those which could be accomplished on payloads containing contamination sensitive optics or sensors, ignoring the possible use of remotely operated contamination covers.

Table I summarizes the time required off an umbilical, if a 70' umbilical were provided. Only 4 representative EVA's would require off-umbilical operation. As in Table I of Attachment 1, the timeline estimates are doubled to allow for equipment unknowns and to obtain the total time estimates.

TABLE I - ESTIMATED REQUIRED TIME OFF A 70' UMBILICAL

EVA/IVA	EST. NO. OF WATER SENSITIVE EVA/IVA	OPERATING TIME OFF A 70' UMBILICAL TIME LINE (MIN)	TOTAL EST. (MIN)
1A - Aperture End of LST-EVA	7	52	104
1B - LST Telescope Tube EVA	2	135	270
4 - Inspection of Orbiter Exterior - EVA	0	36	72
5 - Replace Boom Mounted Sensors - EVA	3	160	320

Figure 3 illustrates when an umbilical is undesirable. An analysis of the representative EVA's and IVA's and the routes to be covered if utilizing handrails indicates that for about 80% of the potential 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.

The potential water vapor sensitive EVA's and IVA's where it is undesirable to use an umbilical are shown in Figure 3 relative to the total potential water vapor sensitive EVA's and IVA's since the use of an umbilical is one means of avoiding water vapor expulsion from the life support system. The large percentage where an umbilical is undesirable indicates another method of avoiding water vapor expulsion should be used. The "other" EVA's and IVA's shown in Figure 3 are those which are not water vapor sensitive but the use of an umbilical is undesirable.

Figure 4 shows the number of potential planned and unscheduled EVA's or IVA's per flight plotted against the percent of NASA orbiter flights; DOD flights are not included.

The "Payload Combination for Orbiter Flights" in the Shuttle Traffic Model, MSC-06746, March 12, 1972 was updated to reflect the payloads in the NASA Mission Model dated 6 June 1972. The EVA's and IVA's previously selected for the payloads were related to the orbiter flights, avoiding unlikely EVA and IVA duplications. Figure 4 shows the number of EVA's and IVA's per flight resulting from this analysis. The plot shows a maximum of 6 potential planned EVA/IVA's and a maximum of 9 planned plus potential unscheduled EVA/IVA's. By providing for 3 EVA/IVA's, over 80 percent of the total potential and over 90 percent of the potential planned EVA/IVA's would be accommodated.

Figure 5 shows the potential EVA's and IVA's in Figure 1 related to the time required to accomplish them. It is a summary of the timeline analyses conducted on representative EVA's and IVA's related to 713 of the 788 potential EVA's and IVA's identified in the payload analysis. (Scenario #7, Maintenance and Servicing of An Astronomy Explorer Satellite is omitted.) 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.

Figure 6 shows the total potential EVA and IVA time per flight plotted against the percent of NASA flights. This plot is for the potential EVA's and IVA's shown in Figure 4 using the timeline analyses results for the EVA/IVA durations. Potential planned EVA and IVA time is shown separately plus the times for both 1 man and 2 man EVA's and IVA's. The times as used here are the operating times of EVA and IVA equipment or the amount of time EVA and IVA expendables are being used. If one man EVA/IVA is used the total required time to cover all orbiter flights is 1237 minutes (approximately 21 hours). The total required time for 2 man EVA/IVA, is shown twice as long, approximately 42 hours. The second man was considered to be a safety monitor and umbilical manager. A reduction in this time could possibly be made by having the two crewmen work together on the tasks.

The figure shows that a large percentage of two men EVA/IVA's and almost all one man EVA/IVA's could be accommodated by providing for approximately 14 hours of equipment operation time for planned and unscheduled tasks.

Figure 7 shows the percentage of NASA orbiter flights which could require non-venting EVA/IVA. The plot shows the potential planned and unscheduled non-venting EVA/IVA of those in Figure 4, being required on orbiter flights, year by year. 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 malfunctioned covers on all types of payloads. The incidence of such malfunctions has been rather high.

It seems reasonable 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% to the 43.6% 12 year average 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 also create a need for non-venting EVA/IVA. In almost all cases, some areas of the spacecraft or payload will be at a very cold temperature during shuttle orbital operations. Water vapor, in vented, will condense on these surfaces, and 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. 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%, or 4 to 10 flights per year, illustrated on the plot.

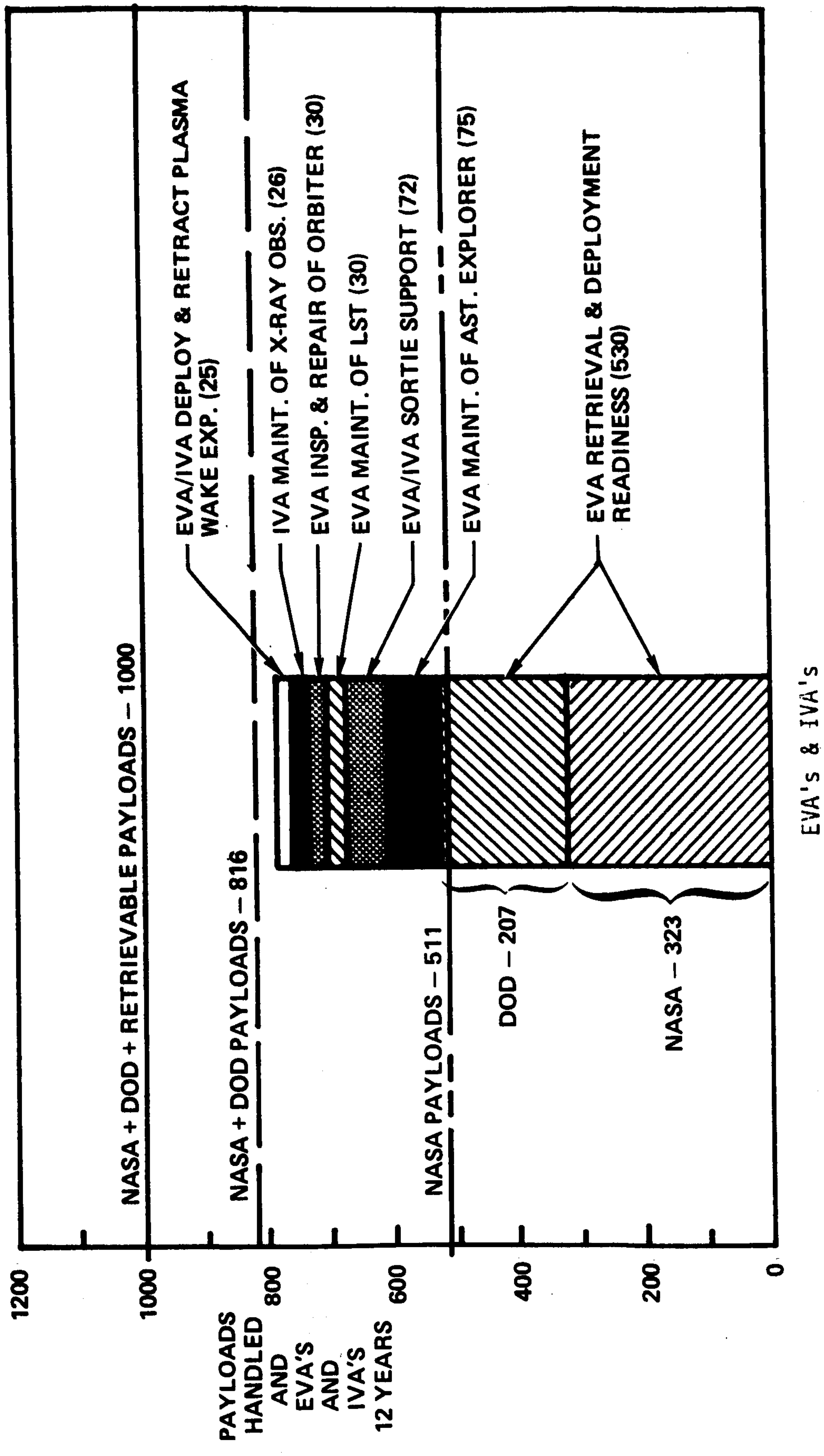


FIGURE 1. RESPRESENTATIVE EVA's AND IVA's COMPARED WITH PAYLOADS HANDLED BY THE ORBITER

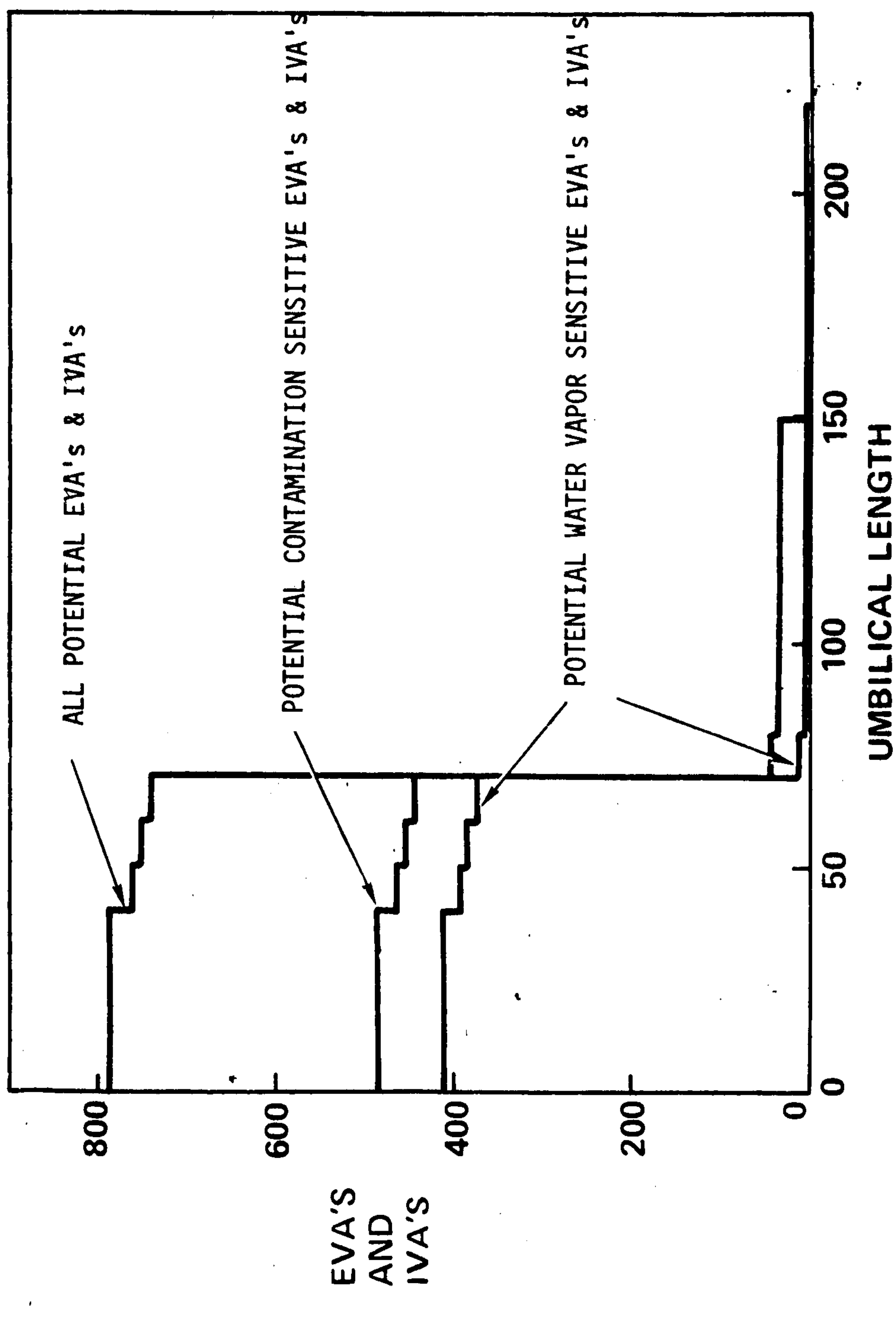


FIGURE 2. EVA's AND IVA's VS UMBILICAL LENGTH

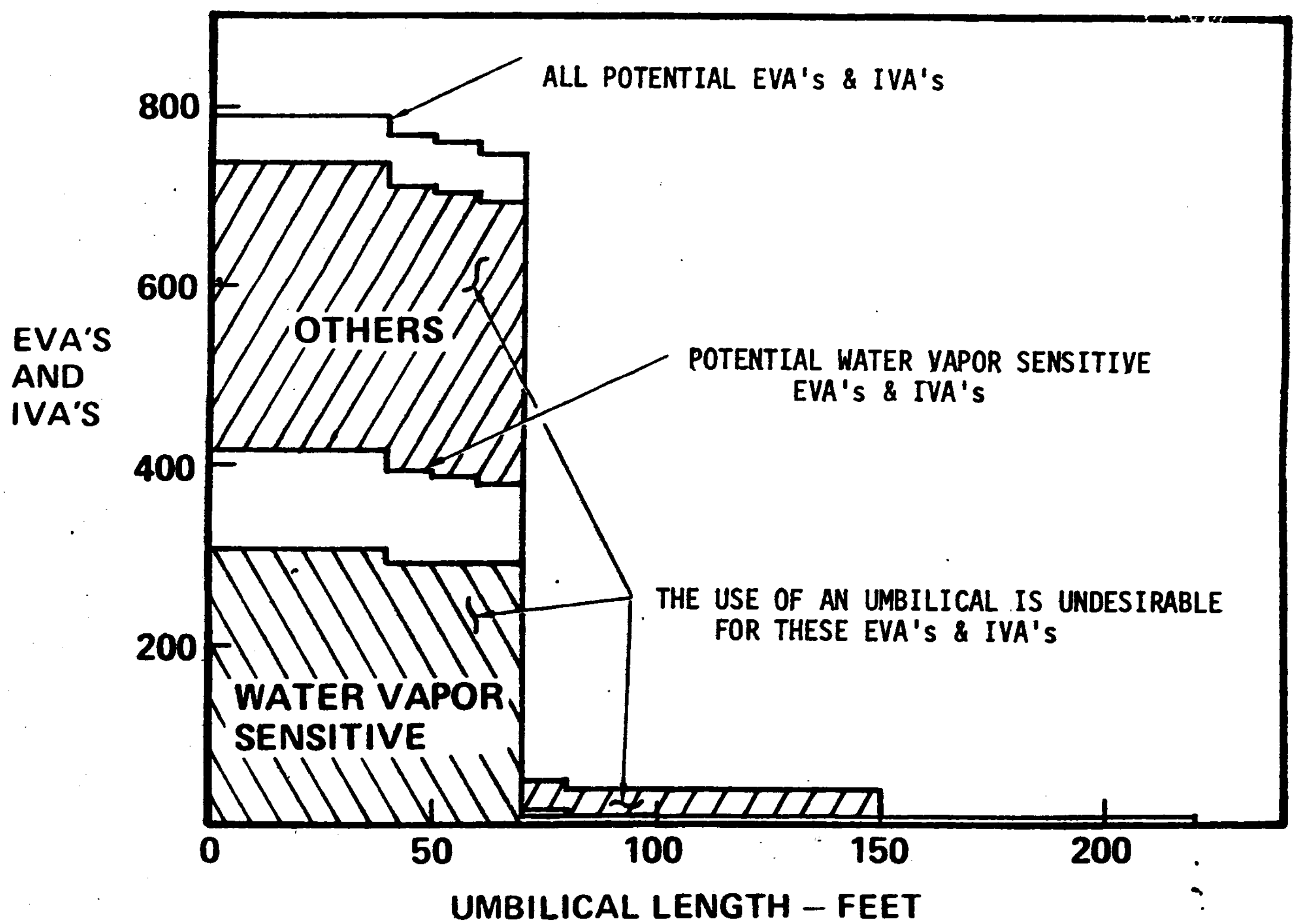
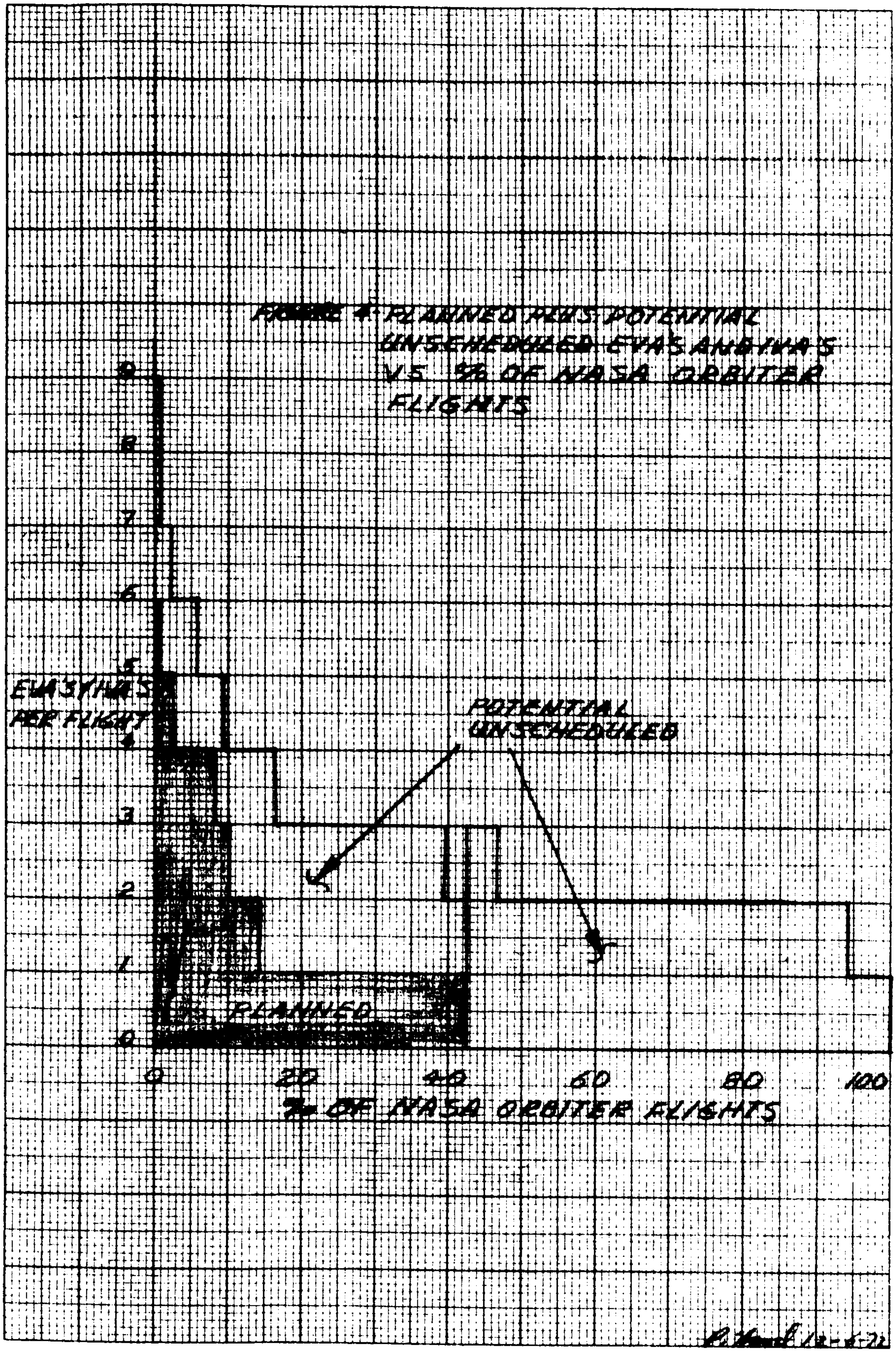


FIGURE 3. EVA's AND IVA's WHERE AN UMBILICAL IS UNDESIRABLE


4: PLANNED PLUS POTENTIAL
UNSCHEDULED EVA'S AND IVA'S
VS % OF NASA ORBITER
FLIGHTS
POTENTIAL
UNSCHEDULED
EVA'S/IVA'S
PER FLIGHT
PLANNED
0
1
2
3
4
5
6
7
8
9
0
20
40
60
80
100
% OF NASA ORBITER FLIGHTS

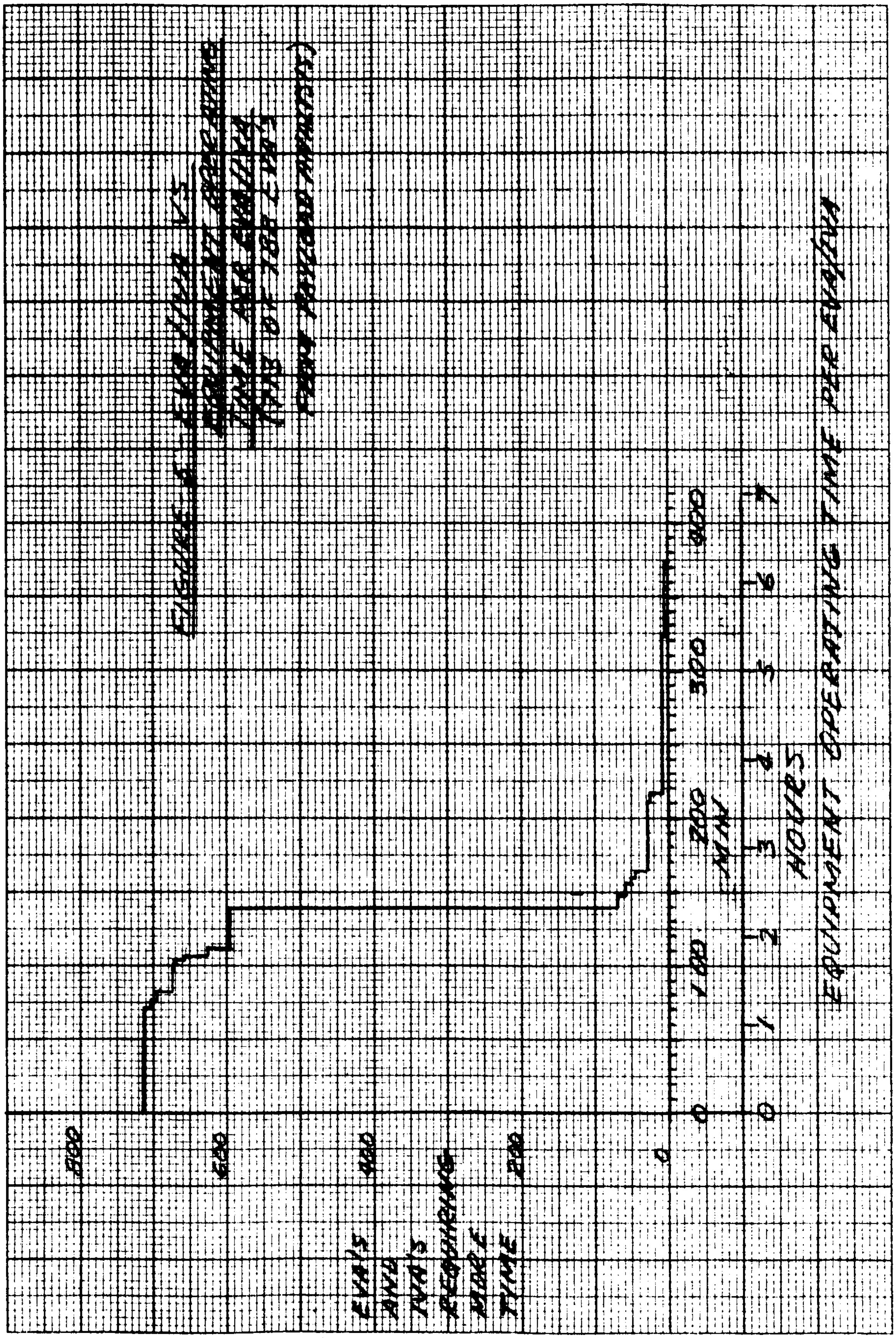


FIGURE 5 - EVA/IVA VS
EVA'S AND IVA'S REQUIRING MORE TIME
800
600
400
200
0
0
100
200
300
400
MIN
0
1
2
3
4
5
6
7
HOURS
EQUIPMENT OPERATING TIME PER EVA/IVA

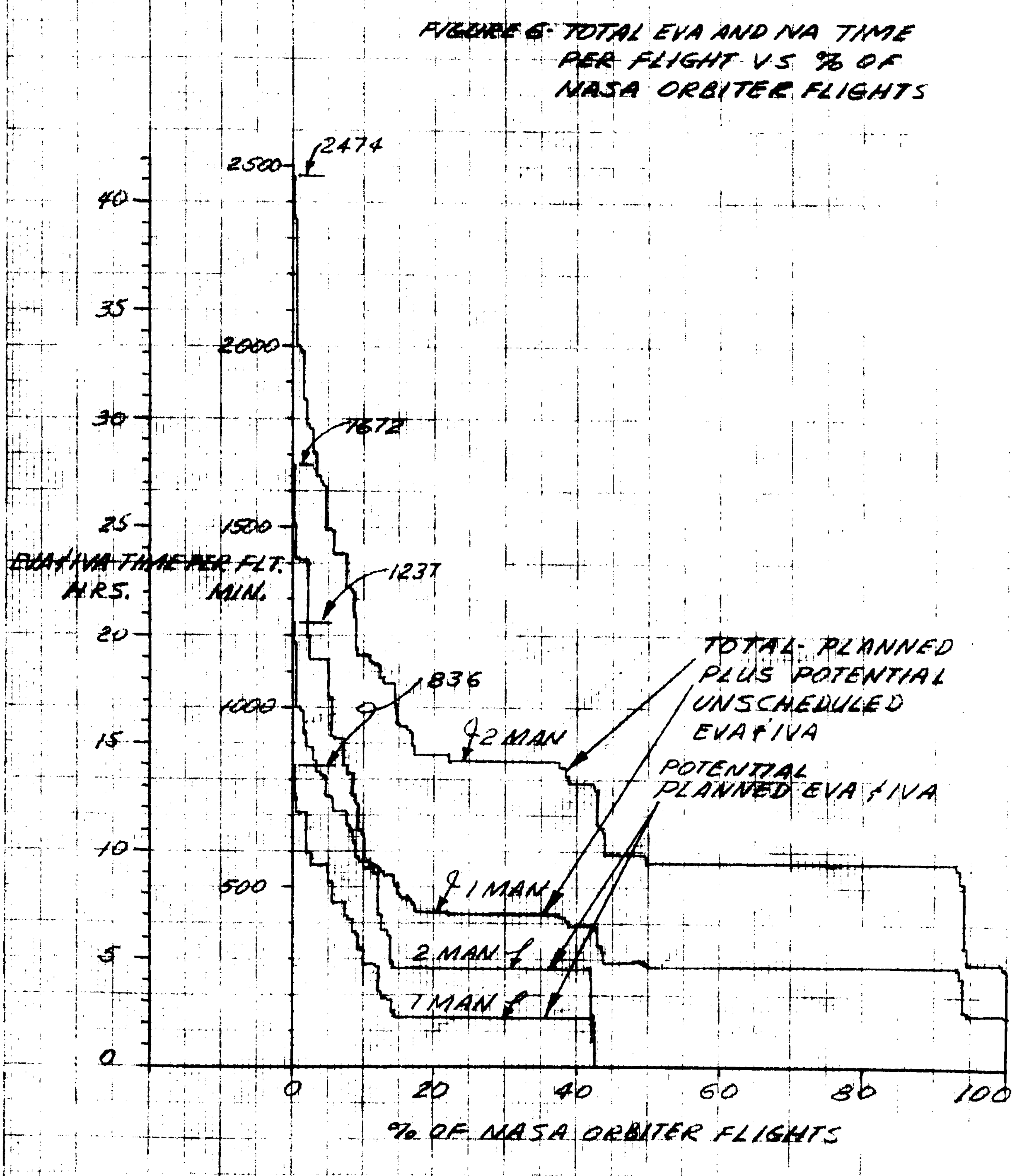


FIGURE 6- TOTAL EVA AND IVA TIME PER FLIGHT VS % OF NASA ORBITER FLIGHTS
2474
1672
1237
836
2 MAN
1 MAN
2 MAN
1 MAN
TOTAL- PLANNED PLUS POTENTIAL UNSCHEDULED EVA & IVA
POTENTIAL PLANNED EVA & IVA
EVA/IVA TIME PER FLT.
HRS.
MIN.
40
35
30
25
20
15
10
5
0
2500
2000
1500
1000
500
0
20
40
60
80
100
% OF NASA ORBITER FLIGHTS

12-6-72

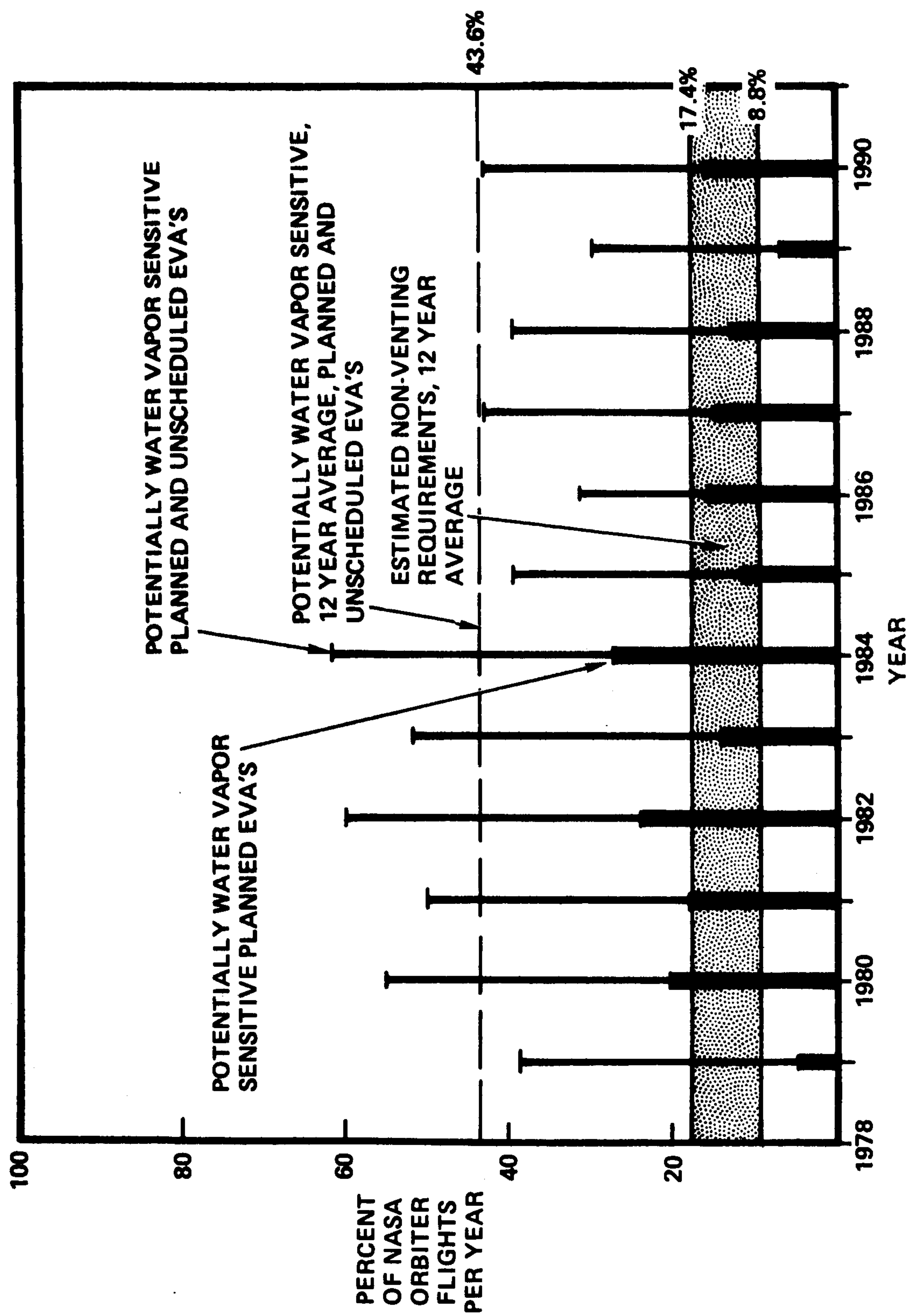


FIGURE 7 NASA ORBITER FLIGHTS WHICH COULD REQUIRE NON-VENTING EVA/IVA

ORBITER EVA AND IVA

TIMELINE ANALYSES

Timeline analyses were conducted and timeline diagrams prepared for each EVA and IVA in Ref. 1 except No. 7 - Maintenance and Servicing of an Astronomy Explorer (A) Satellite. VSD was verbally directed by the Contract Monitor after the midterm review to pursue this Scenario no further since it involved the use of a free-flying maneuvering unit.

The following assumptions were made during the timeline analyses.

1. Assume manual translation by the crewman using handrails.
2. Use a translation rate of .5 ft/sec (Ref. 1, Guideline 14, Nominal)
3. Assume cargo transfer is manual, no aids.
4. Assume the crewman can transfer one large package or several small packages of cargo in one trip.
5. Assume the cargo packages for planned EVA's are stored along the path, and for unscheduled EVA's the crewman will have these when he exits the airlock. (As much as 2-1/2 min. more time could be required to retrieve parts stowed in the payload bay)
6. Assume 5 min. removal and replacement time for each item for planned EVA and prepared worksites with foot restraint (Ref. 2).
7. Assume 20 min. max. and 10 min. minimum removal and replacement time for each item, for unscheduled EVA and unprepared worksite without foot restraints. (Ref. 2)
8. Assume time to enter and prepare worksite or prepare and evaluate worksite to be 30 sec to 2 min., according to estimated complexity of task.

Figures 1 through 16 are the timeline diagrams for the EVA's and IVA's for the time from "read to move away from the airlock opening" to "ready to re-enter the airlock". If the required umbilical length exceeded 70 ft. for the EVA and "off-umbilical time" is also shown on the diagram. The tasks required to accomplish each EVA or IVA were postulated and are listed on the diagram. The time to accomplish each task and additional assumptions are on a sheet following each diagram.

Table I is a summary of the times estimated for each EVA and IVA. Since timeline analyses accomplished at this early time in the development of shuttle hardware are only best guesses, the timeline estimates are multiplied by two in order to allow for the unknowns. An estimated time of 25 minutes for EVA equipment operating time required during egress/ingress of the airlock is added to obtain the total estimated EVA and IVA times shown.

REFERENCES

Ref. 1 Tasks, Guidelines, and Constraints Briefing, June 15, 1972, LTV Aerospace.

Ref. 2 Maintainability Design Criteria for Packaging of Spacecraft Replaceable Electronic Equipment, AIAA Paper No. 72-235, March 27-28, 1972, John R. Kappler, Grumman Aerospace Corp. and Anne B. Folsom, NASA-MSFC.

TABLE I - TIMELINE SUMMARY

EVA/IVA	TIMES-MINUTES		
	TIMELINE	TIMELINE X2	TOTAL EST.
1A	66	132	157
1B	149	298	323
1C	23	46	71
1D	26	52	77
2A	96	192	217
2B	39	78	103
2C	69	138	163
2D	27	58	83
2E	93	186	211
3	57	114	139
4	41	82	107
5A	174	348	373
5B	38	76	101
5C	67	134	159
5D	61	122	147
5E	61	122	147
6A	44	88	113
6B	44	88	113
6C	44	88	113
7	—	—	—

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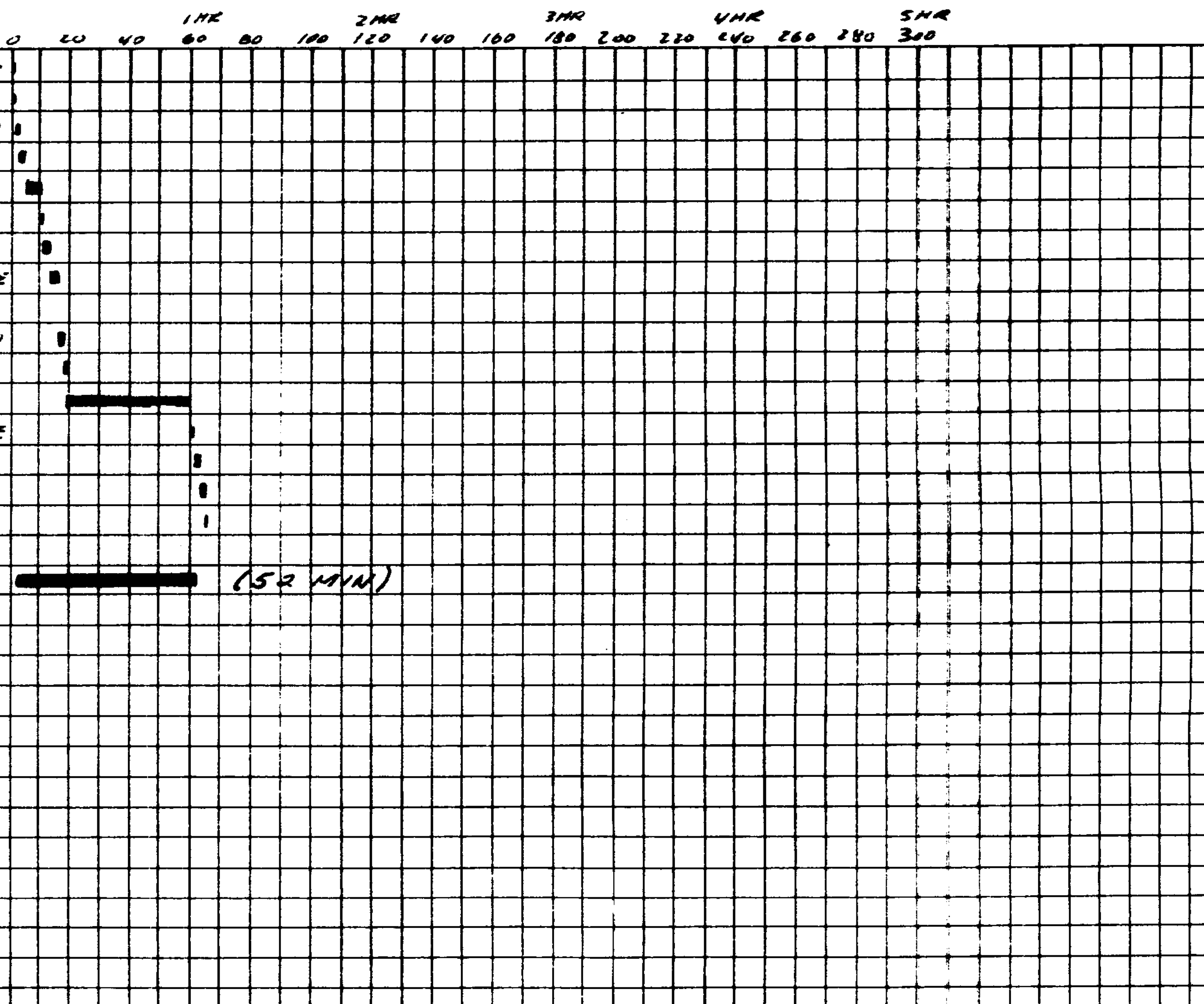
TIME LINE SHEET	FUNCTION SCENARIO 1A - LST APERTURE END TASKS	LOCATION	TYPE OF MAINTENANCE (IF APPLICABLE) PLANNED

SOURCE OF FUNCTION	FUNCTION & CORRESPONDING TASKS (IF APPLICABLE)
1	TRANSLATE TO PAYLOAD BAY
2	RETRIEVE SEC. MIR. MOD.
3	TRANSLATE TO APERTURE END
4	ENTER & PREPARE WORKSITE
5	R&R. SEC. MIRROR MOD.
6	PREPARE & EVACUATE WORKSITE
7	TRANSLATE TO PAYLOAD BAY
8	STOW SEC. MIR. MOD AND RETRIEVE GAGES & INST.
9	TRANSLATE TO APERTURE END
10	ENTER & PREPARE WORKSITE
11	REPLACE GAGES & INST.
12	PREPARE & EVACUATE WORKSITE
13	TRANSLATE TO PAYLOAD BAY
14	STOW GAGES & INST.
15	TRANSLATE TO AIRLOCK
	OFF-UMBILICAL TIME - TOTAL

TIME (MIN) (BAR CHART)



REVISION	DATE	APPROVAL	DOCUMENT NO.	PAGE OF
		P. Wood 10-12-72	FIGURE 1.	

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SCENARIO NO. 1A

FUNCTION NO	TIME TO DO FUNCTION (MIN - SEC)	RUNNING TOTAL (MIN - SEC)	RUNNING TOTAL OFF-UMBILICAL 60	70	80
1	0-20	0-20	0-0	0-0	0-0
2	1-0	1-20	0-0	0-0	
3	2-20	3-40	0-40	0-20	
4	2-0	5-40	2-40	2-20	
5	5-0	10-40	7-40	7-20	
6	1-0	11-40	8-40	8-20	
7	2-20	13-0	9-0	8-40	
8	3-0	16-0	9-0	8-40	
9	2-20	18-20	9-40	9-0	
10	1-0	19-20	10-40	10-0	
11	40-0	59-20	50-40	50-0	
12	2-0	61-20	52-40	52-0	
13	2-20	63-40	53-20	52-20	
14	2-0	65-40			
15	0-20	66-0			0-0

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TIME LINE SHEET	FUNCTION SCENARIO 1B-LST TASKS INSIDE TELESCOPE TUBE	LOCATION	TYPE OF MAINTENANCE (IF APPLICABLE) PLANNED

TIME (MIN) (BAR CHART)

0 20 40 60 (1HR) 80 100 120 (2HR) 140 160 180 (3HR) 200 220 240 (4HR) 260 280 300 (5HR)

SOURCE OF FUNCTION	FUNCTION & CORRESPONDING TASKS (IF APPLICABLE)
1	TRANSLATE TO PAYLOAD BAY
2	RETRIEVE GAGES
3	RETRIEVE CLEANING DEVICE
4	ACTIVATE &C/O CLEANING DEVICE
5	TETHER CLEANING DEVICE
6	TRANSLATE TO APERTURE END
7	STOW GAGES & CLEANING DEVICE
8	OPEN TEL. TUBE ACCESS PANEL
9	RET. HANDRAIL FOR INTO TUBE
10	ERECT HANDRAIL FOR INTO TUBE
11	RET. HANDRAIL FOR INSIDE TUBE
12	ENTER TEL. TUBE WITH HANDRAIL
13	CLOSE ACCESS PANEL
14	ERECT HANDRAIL INSIDE TUBE
15	ASCEND TO ACCESS PANEL
16	OPEN ACCESS PANEL
17	RETRIEVE GAGES
18	CLOSE ACCESS PANEL
19	R&R SEC. MIR. GAGES (2)
20	R&R PRI. MIR. GAGES (2)
21	ASCEND TO ACCESS PANEL
22	OPEN ACCESS PANEL
23	STOW GAGES & RET. CLEANING DEV.
24	ENTER TUBE WITH CLEANING DEVICE
25	CLOSE ACCESS PANEL
26	CLEAN SEC. MIR. SURFACE
27	CLEAN PRI. MIR. SURFACE
28	ASCEND TO ACCESS PANEL
29	OPEN ACCESS PANEL
30	EXIT TUBE & STOW CLEANING DEV.
31	ENTER TUBE TO INSIDE HANDRAIL
32	CLOSE ACCESS PANEL

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		P. Wood 10-12-72	FIGURE 2	1	2

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TIME LINE SHEET	FUNCTION SCENARIO 1B - LST TASKS INSIDE TELESCOPE TUBE	LOCATION	TYPE OF MAINTENANCE (IF APPLICABLE) PLANNED

SOURCE OF FUNCTION	FUNCTION & CORRESPONDING TASKS (IF APPLICABLE)
33	COLLAPSE HANDRAIL
34	ASCEND WITH HANDRAIL
35	OPEN ACCESS PANEL
36	STOW INSIDE HANDRAIL
37	COLLAPSE HANDRAIL FOR INTO TUBE
38	STOW HANDRAIL
39	CLOSE ACCESS PANEL
40	RETRIEVE CLEANING DEV. & GAGES
41	TRANSLATE TO PAYLOAD BAY
42	STOW CLEANING DEV. & GAGES
43	TRANSLATE TO AIRLOCK
	OFF-UMBILICAL TIME (70')
	OFF-UMBILICAL TIME (80')

TIME (MIN) (BAR CHART)

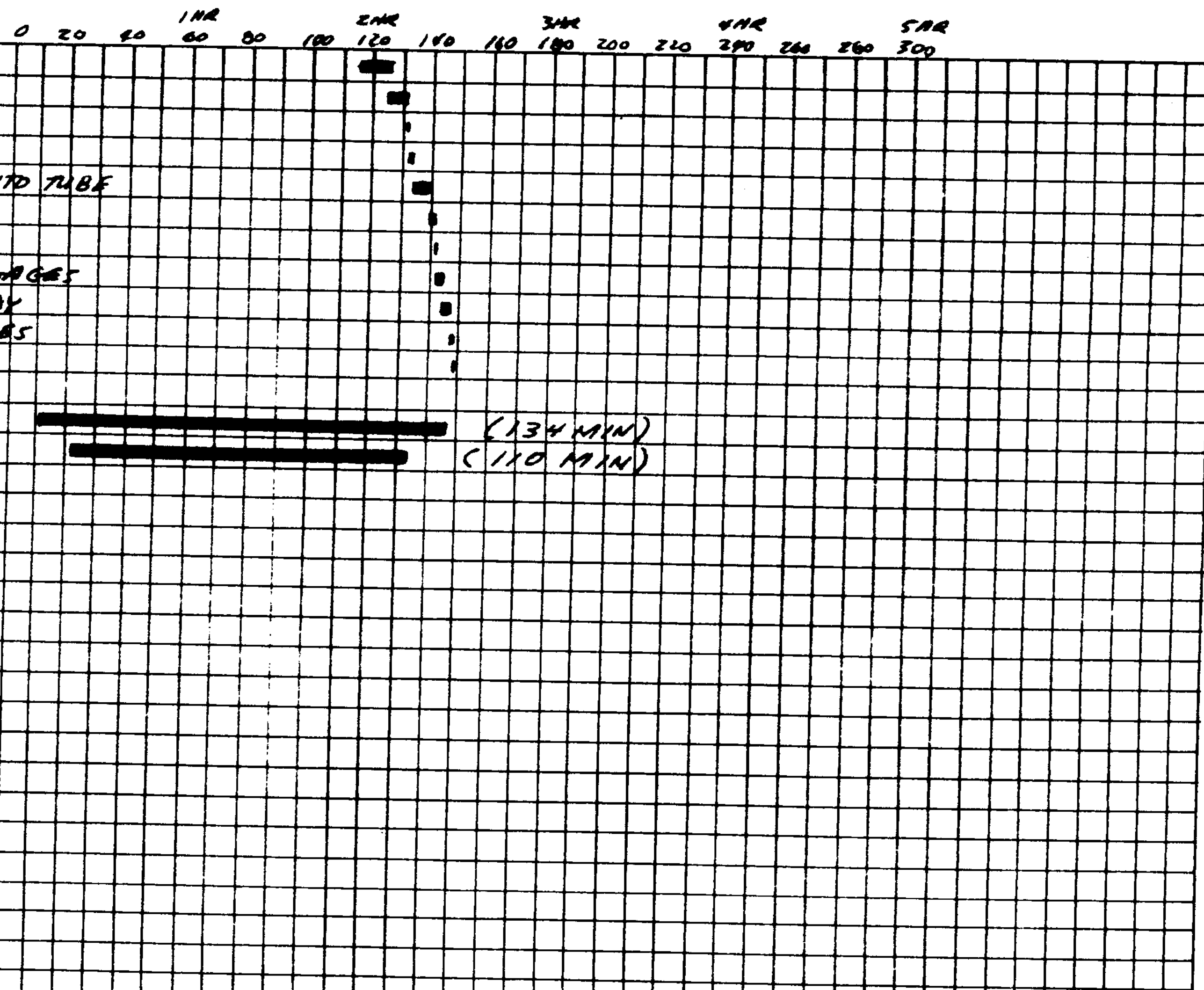

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			FIGURE 2	2	2

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• ASSUME ERECTABLE HANDRAILS ARE AVAILABLE AT APERTURE END OF LST.

SCENARIO NO. 1B

FUNCTION NO	TIME TO DO FUNCTION (MIN - SEC)	RUNNING TOTAL (MIN - SEC)	RUNNING TOTAL OFF-UMBILICAL 60	RUNNING TOTAL OFF-UMBILICAL 70	RUNNING TOTAL OFF-UMBILICAL 80
1 ≈10'	0-20	0-20		0-0	0-0
2	1-0	1-20			
3	1-0	2-20			
4	5-0	7-20			
5	1-0	8-20			
6 ≈70'	2-20	10-40		0-20	
7	2-0	12-40		2-20	
8	1-0	13-40		3-20	
9	2-0	15-40		5-20	
10	5-0	20-40		10-20	
11	2-0	22-40		12-20	
12	5-0	27-40		17-20	5-0
13	1-0	28-40		18-20	6-0
14	10-0	38-40		28-20	16-0
15 ≈15'	2-0	40-40		30-20	18-0
16	1-0	41-40		31-20	19-0
17	1-0	42-40		32-20	20-0
18	1-0	43-40		33-20	21-0
19	10-0	53-40		43-20	31-0
20	10-0	63-40		53-20	41-0
21	2-0	65-40		55-20	43-0
22	1-0	66-40		56-20	44-0
23	3-0	69-40		59-20	47-0
24	1-0	70-40		60-20	48-0
25	1-0	71-40		61-20	49-0
26	10-0	81-40		71-20	59-0
27	20-0	101-40		91-20	79-0
28	5-0	106-40		96-20	84-0
29	1-0	107-40		97-20	85-0
30	5-0	112-40		102-20	90-0
31	2-0	114-40		104-20	92-0
32	1-0	115-40		105-20	93-0
33	10-0	125-40		115-20	103-0
34	5-0	130-40		120-20	108-0
35	1-0	131-40		121-20	109-0
36	2-0	133-40		123-20	111-0

SCENARIO NO. ________

FUNCTION NO	TIME TO DO FUNCTION	RUNNING TOTAL	RUNNING TOTAL OFF-UMBILICAL 60	70	80
	MIN - SEC				(111-0)
37	5-0	138-40		128-20	
38	2-0	140-40		130-20	
39	1-0	141-40		131-20	
40	3-0	144-40		134-20	
41	2-20	147-0		134-40	
42	2-0	149-0			
43	0-20	149-20			

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TIME LINE SHEET	FUNCTION SCENARIO 1C - REPLACEMENT OF RCS MODULES ON CST	LOCATION	TYPE OF MAINTENANCE (IF APPLICABLE) PLANNED

TIME (MIN.) (BAR CHART): 0 20 40 60 (1HR) 80 100 120 (2HR) 140 160 180 (3HR) 200 220 250 (4HR) 260 280 300 (5HR)

SOURCE OF FUNCTION	FUNCTION & CORRESPONDING TASKS (IF APPLICABLE)
1	TRANSLATE TO PAYLOAD BAY
2	RETRIEVE 1 RCS MODULE
3	TRANSLATE TO RCS WORKSITE
4	ENTER AND PREPARE WORKSITE
5	R&R RCS MODULE
6	PREPARE & EVACUATE WORKSITE
7	TRANSLATE TO PAYLOAD BAY
8	STOW 1 RCS MODULE & RETRIEVE ANOTHER
9	TRANSLATE TO RCS WORKSITE
10	ENTER & PREPARE WORKSITE
11	R&R RCS MODULE
12	PREPARE & EVACUATE WORKSITE
13	TRANSLATE TO PAYLOAD BAY
14	STOW RCS MODULE
15	TRANSLATE TO AIRLOCK

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			FIGURE 3		

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SCENARIO NO. 1C

FUNCTION NO	TIME TO DO FUNCTION (MIN - SEC)	RUNNING TOTAL (MIN - SEC)	RUNNING TOTAL OFF-UMBILICAL 60	70	80
1	0-20	0-20			
2	1-0	1-20			
3 ≈ 30'	1-0	2-20			
4	1-0	3-20			
5	5-0	8-20			
6	1-0	9-20			
7	1-0	10-20			
8	2-0	12-20			
9 ≈ 30'	1-0	13-20			
10	1-0	14-20			
11	5-0	19-20			
12	1-0	20-20			
13	1-0	21-20			
14	1-0	22-20			
15	0-20	22-40			

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TIME LINE SHEET	FUNCTION SCENARIO 1D- REPLACE SOLAR CELL ASSY ON LST	LOCATION	TYPE OF MAINTENANCE (IF APPLICABLE) PLANNED

SOURCE OF FUNCTION	FUNCTION & CORRESPONDING TASKS (IF APPLICABLE)
1	TRANSLATE TO PAYLOAD BAY
2	RETRIEVE 1 SOLAR CELL ASSY
3	TRANSLATE TO WORKSITE
4	ENTER AND PREPARE WORKSITE
5	R&R SOLAR CELL ASSY
6	PREPARE & EVACUATE WORKSITE
7	TRANSLATE TO PAYLOAD BAY
8	STOW SOLAR CELL ASSY
9	TRANSLATE TO AIRLOCK
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	
20	
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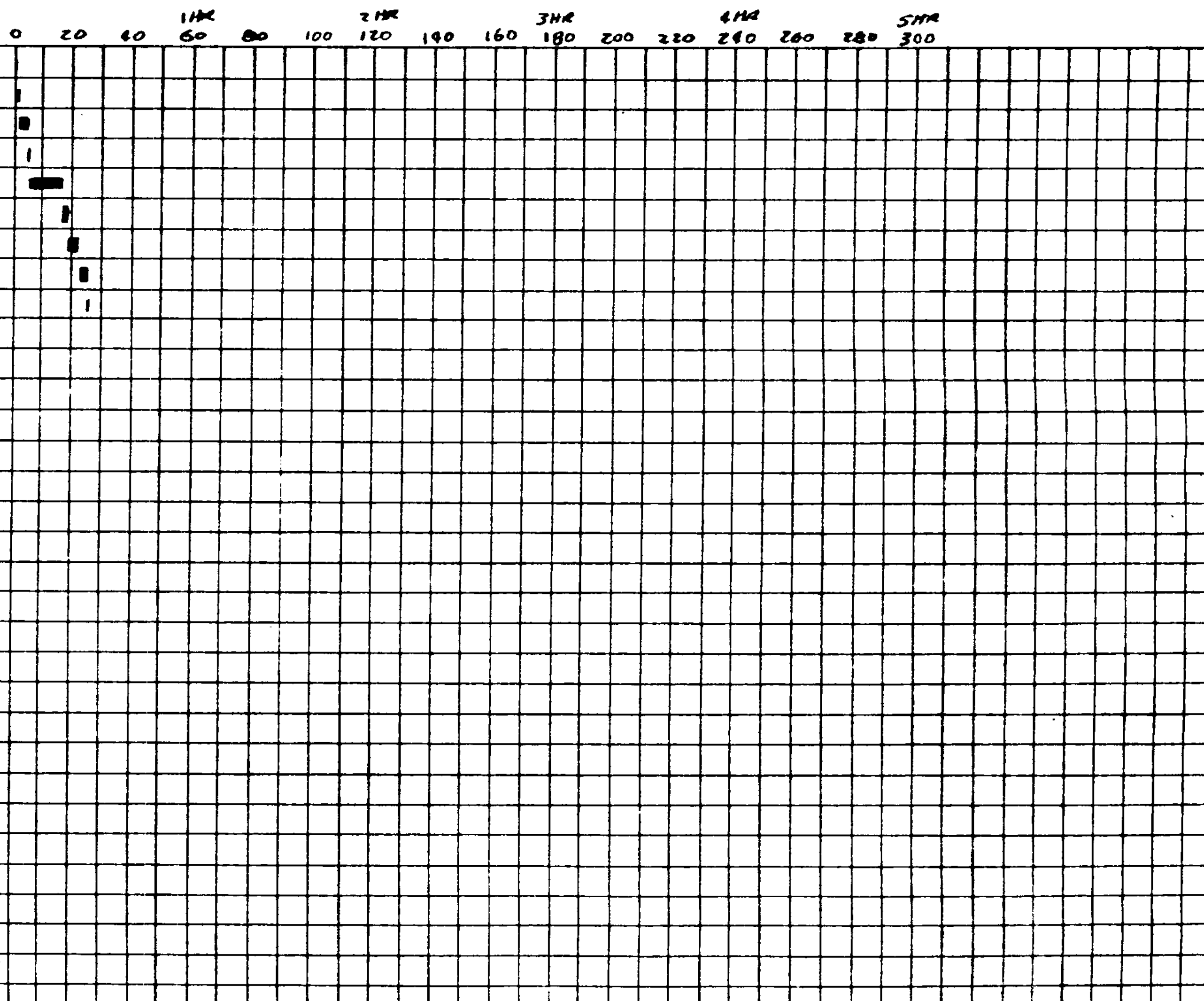
23	
24	
25	
26	
27	
28	
29	
30	
31	
32	

TIME (MIN) (BAR CHART)



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		P. N. Hood 10-25-72	FIGURE 4	

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SCENARIO NO. 1D

FUNCTION NO	TIME TO DO FUNCTION (MIN - SEC)	RUNNING TOTAL (MIN - SEC)	RUNNING TOTAL OFF-UMBILICAL 60	70	80
1	0-20	0-20			
2	2-0	2-20			
3 ≈30'	3-0	5 20			
4	2-0	7-20			
5	10-0	17-20			
6	2-0	19-20			
7 ≈30'	3-0	22-20			
8	2-0	25-20			
9	0-20	25-40			

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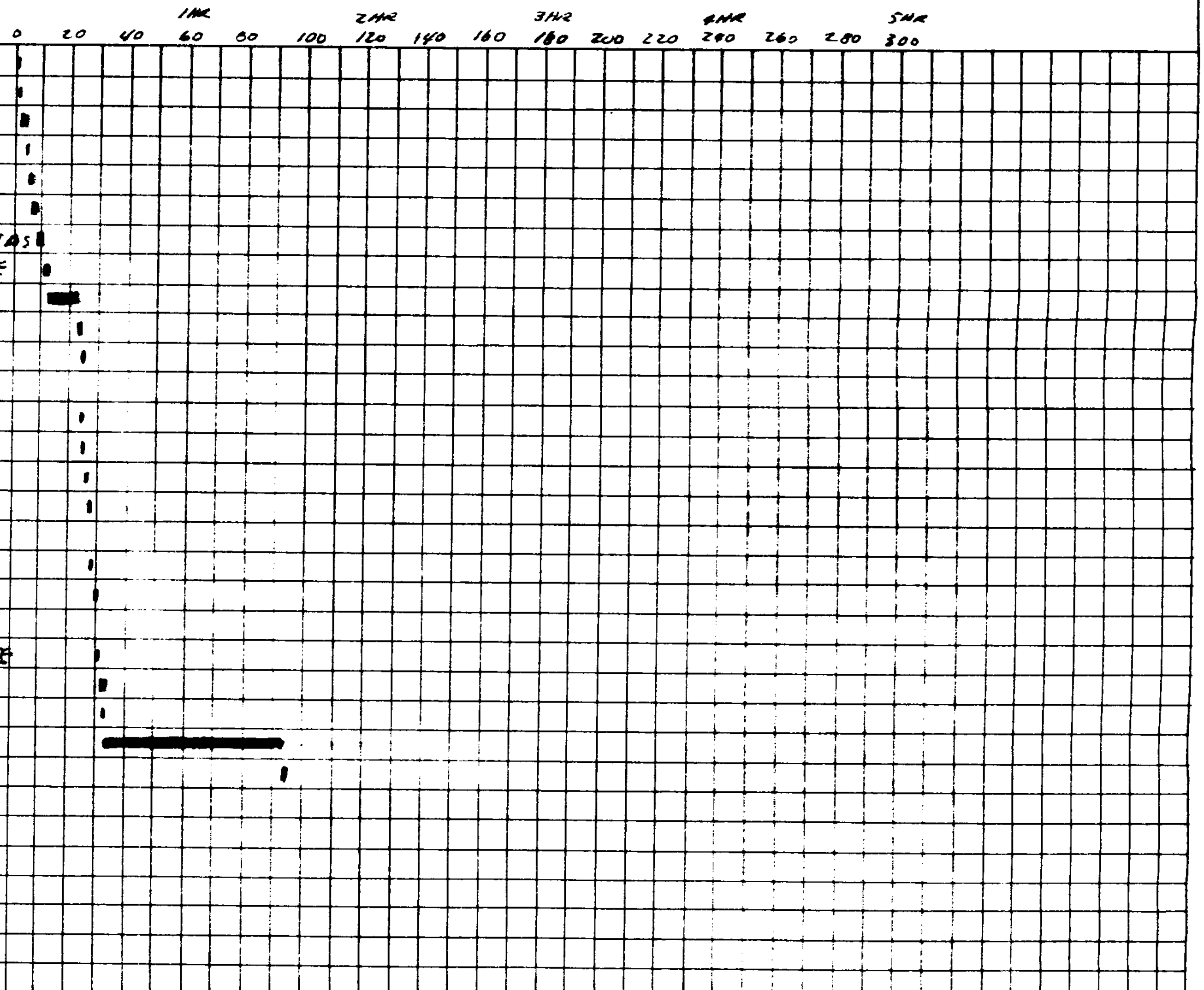
TIME LINE SHEET	FUNCTION SCENARIO 2A - PREPARATION OF EARTH OBSERVATION SORTIE EXPERIMENTS	LOCATION	TYPE OF MAINTENANCE (IF APPLICABLE) PLANNED

TIME (MIN) (BAR CHART)

SOURCE OF FUNCTION	FUNCTION & CORRESPONDING TASKS (IF APPLICABLE)
1	TRANSLATE TO FIRST CAM
2	ENTER WORKSITE
3	INSTALL FILM MAG.
4	EXIT WORKSITE
5	RETURN TO AIRLOCK
6	RETRIEVE 4 FILM MAG.
7	TRANSLATE TO SMALL CAMERAS
8	ENTER & PREPARE WORKSITE
9	INSTALL 4 FILM MAG.
10	PREPARE & EXIT WORKSITE
11	TRANSLATE TO ANT. ERECT WORKSITE
12	ENTER WORKSITE
13	UNSTOW & ERECT ANT BASE
14	EXIT WORKSITE
15	TRANSLATE TO ANT. SEG. STOWAGE SITE
16	UNSTOW 1 ANT SEGMENT
17	TRANSLATE TO ANT. BASE WORKSITE W/ANT. SEG.
18	ENTER ANT. BASE WORKSITE
19	ASSY 1 ANT SEG.
20	EXIT ANT. BASE WORKSITE
21	REPEAT 15-20 9 TIMES
22	TRANSLATE TO AIRLOCK



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		R. Ward 10-12-72	FIGURE 5	

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SCENARIO NO. 2A

FUNCTION NO	TIME TO DO FUNCTION (MIN - SEC)	RUNNING TOTAL (MIN - SEC)	RUNNING TOTAL OFF-UMBILICAL 60	70	80
1 ≈ 50'	1-40	1-40			
2	0-30	2-10			
3	2-30	4-40			
4	0-30	5-10			
5	1-40	6-50			
6	2-0	8-50			
7 ≈ 60'	2-0	10-50			
8	2-0	12-50			
9	10-0	22-50			
10	1-0	23-50			
11 ≈ 10'	0-20	24-10			
12	0-30	24-40			
13	2-0	26-40			
14	0-30	27-10			
15 ≈ 20'	0-40	27-50			
16	0-30	28-20			
17 ≈ 40'	2-0	30-20			
18	0-30 } 6-40	30-50			
19	2-30	33-20			
20	0-30	33-50			
21	60-0	93-50			
22 ≈ 70'	2-20	96-10			

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TIME LINE SHEET	FUNCTION SCENARIO 2B - SUPPORT EARTH OBSERVATION SORTIE EXPERIMENTS	LOCATION	TYPE OF MAINTENANCE (IF APPLICABLE) PLANNED

SOURCE OF FUNCTION	FUNCTION & CORRESPONDING TASKS (IF APPLICABLE)	TIME (MIN) (BAR CHART) 0 20 40 1HR 60 80 100 2HR 120 140 160 3HR 180 200 220 4HR 240 260 280 5HR 300
1	TRANSLATE TO FIRST CAM	
2.	ENTER & PREPARE WORKSITE	
3.	R.&R. FILM MAG	
4	PREPARE & EXIT WORKSITE	
5	TRANSLATE TO AIRLOCK	
6	STOW 1 FILM MAG. &	
	RETRIEVE 4 FILM MAG.	
7	TRANSLATE TO SMALL CAMERAS	
8	ENTER & PREPARE WORKSITE	
9	R&R 4 FILM MAG.	
10	PREPARE & EXIT WORKSITE	
11	TRANSLATE TO AIRLOCK	

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		P. Hood 10-12-72	FIGURE 6	

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SCENARIO NO. 2B

FUNCTION NO	TIME TO DO FUNCTION (MIN - SEC)	RUNNING TOTAL (MIN - SEC)	RUNNING TOTAL OFF-UMBILICAL (MIN - SEC)		
			60	[illegible]	[illegible]
1 ≈ 50'	1-40	1-40			
2	1-0	2-40			
3	5-0	7-40			
4	1-0	8-40			
5	1-40	10-20			
6	3-0	13-20			
7 ≈ 60'	2-0	15-20			
8	1-0	16-20			
9	20-0	36-20			
10	1-0	37-20			
11 ≈ 60'	2-0	39-20			

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TIME LINE SHEET	FUNCTION SCENARIO 2C - STOWAGE OF EARTH OBSERVATION RADIOMETER ANTENNA	LOCATION	TYPE OF MAINTENANCE (IF APPLICABLE) PLANNED

SOURCE OF FUNCTION	FUNCTION & CORRESPONDING TASKS (IF APPLICABLE)	TIME (MIN) (BAR CHART) 0 20 40 60 (1HR) 80 100 120 (2HR) 140 160 180 (3HR) 200 220 240 (4HR) 260 280 300 (5HR)
1	TRANSLATE TO ANT. BASE WORKSITE	
2	ENTER ANT. BASE WORKSITE	
3	REMOVE 1 ANT. SEG.	
4	EXIT ANT. BASE WORKSITE W/ANT SEGMENT	
5	TRANSLATE TO ANT. SEG STOWAGE SITE	
6	STOW 1 ANT. SEG	
7	TRANSLATE TO ANT. BASE WORKSITE	
8	REPEAT 2-7 9 TIMES	
9	TRANSLATE TO AIRLOCK	

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		Paul Ward 10-12-72	FIGURE 7	

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SCENARIO NO. 2C

FUNCTION NO	TIME TO DO FUNCTION (MIN - SEC)	RUNNING TOTAL (MIN - SEC)	RUNNING TOTAL OFF UMBILICAL 60	70	80
1 ≈70'	2-20	2-20			
2	0-30	2-50			
3	2-30	5-20			
4	7-20 0-30	5-50			
5 ≈40'	2-0	7-50			
6	0-30	8-20			
7 ≈40'	1-20	9-40			
8	57-0	66-40			
9	2-20	69-0			

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TIME LINE SHEET	FUNCTION SCENARIO 2D- STOWAGE OF FILM FOLLOWING EARTH OBSERVATIONS (IVA IN CLOSED PAYLOAD BAY)	LOCATION	TYPE OF MAINTENANCE (IF APPLICABLE) PLANNED

SOURCE OF FUNCTION	FUNCTION & CORRESPONDING TASKS (IF APPLICABLE)	TIME (MIN) (BAR CHART) 0 20 40 60 (1 HR) 80 100 120 (2 HR) 140 160 180 (3 HR) 200 220 240 (4 HR) 260 280 300 (5 HR)
1	TRANSLATE TO ACCESS PNL	
2	ENTER ACCESS PANEL	
3	TRANSLATE TO FIRST CAM	
4	ENTER WORKSITE	
5	REMOVE FILM MAG.	
6	EXIT WORKSITE	
7	TRANSLATE TO ACCESS PNL	
8	STOW FILM MAG.	
9	TRANSLATE TO SML CAM	
10	ENTER WORKSITE	
11	REMOVE 4 FILM MAG	
12	EXIT WORKSITE	
13	TRANSLATE TO ACCESS PNL	
14	EXIT ACCESS PNL	
15	TRANSLATE TO AIRLOCK	
16	STOW 4 FILM MAG	
17	TRANSLATE TO ACCESS PNL	
18	RETRIEVE / FILM MAG	
19	TRANSLATE TO AIRLOCK	

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		Paul [illegible] 10-13-72	FIGURE 7	

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SCENARIO NO. 2D

FUNCTION NO	TIME TO DO FUNCTION (MIN - SEC)	RUNNING TOTAL (MIN - SEC)	RUNNING TOTAL OFF-UMBILICAL 60	70	80
1 ≥ 40'	1-20	1-20			
2	0-30	1-50			
3 ≥ 20'	0-40	2-30			
4	0-30	3-0			
5	2-30	5-30			
6	0-30	6-0			
7 ≥ 20'	0-40	6-40			
8	0-30	7-10			
9 ≥ 30'	1-0	8-10			
10	0-30	8-50			
11	10-0	18-50			
12	2-0	20-50			
13 ≥ 30'	1-0	21-50			
14	0-30	22-20			
15 ≥ 40'	1-20	23-40			
16	2-0	25-40			
17 ≥ 40'	1-20	27-0			
18	0-30	27-30			
19 ≥ 40'	1-20	28-50			

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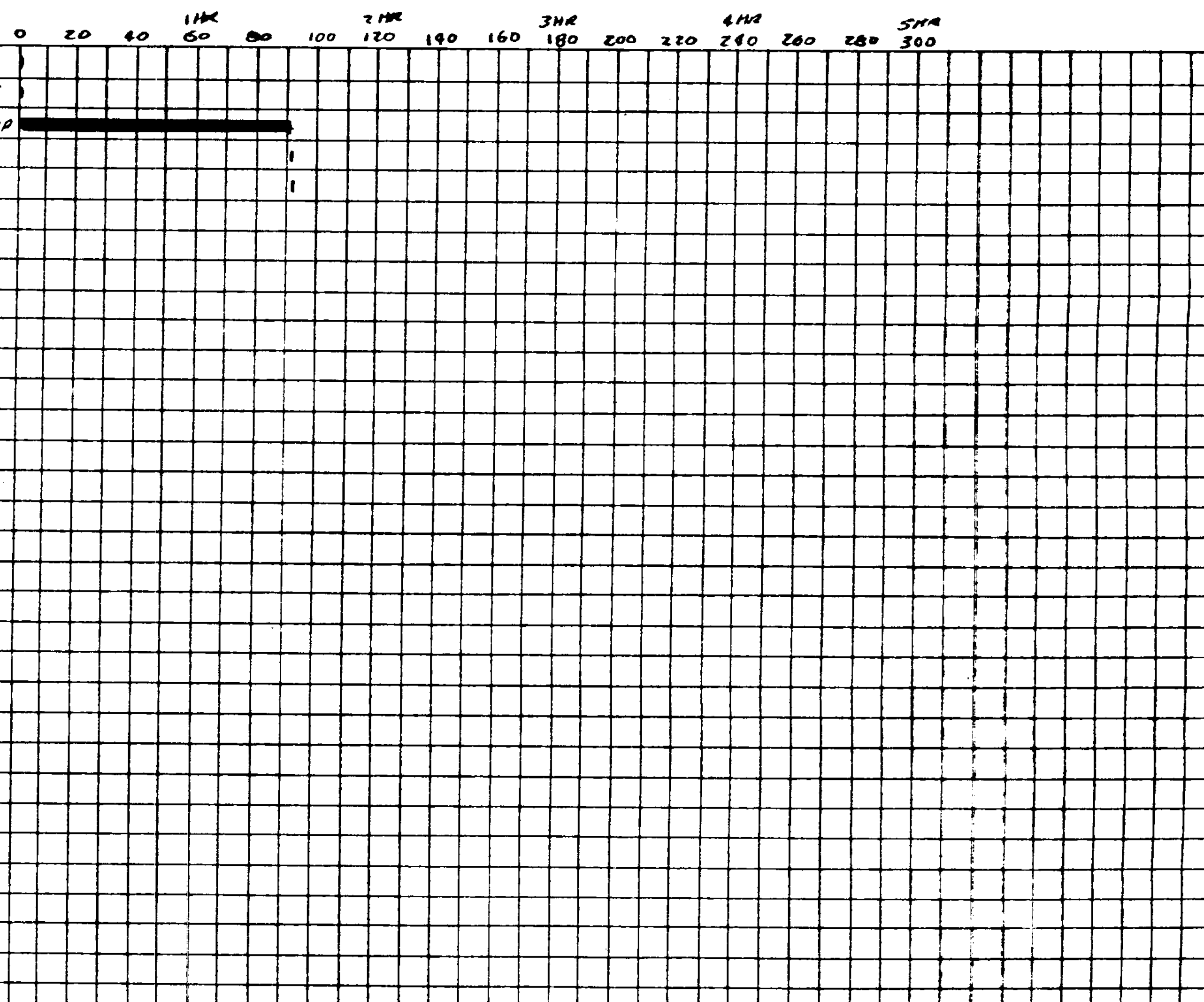
* ASSUME DATA FROM ONE ORBIT IS REQUIRED.

TIME LINE SHEET	FUNCTION SCENARIO 2E - CONDUCT EXPERIMENTS IN UNPRESSURIZED EARTH OBSERVATIONS LAB. - IVA	LOCATION	TYPE OF MAINTENANCE (IF APPLICABLE) UNSCHEDULED

SOURCE OF FUNCTION	FUNCTION & CORRESPONDING TASKS (IF APPLICABLE)
1	TRANSLATE TO TELESCOPE
2	ENTER & PREPARE WORKSITE
3 *	SIGHT THRU TELE. & CONTROL EQUIP
4	PREPARE & EVACUATE WORKSITE
5	RETURN TO AIRLOCK
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	
20	
21	
22	
23	
24	
25	
26	
27	
28	
29	
30	
31	
32	

TIME (MIN) (BAR CHART)



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		P. W. Hood	10-25-72	FIGURE 9	

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* ASSUME DATA FROM ONE ORBIT IS REQUIRED (APPROX 90 MIN - COULD BE MORE OR LESS, DEPENDANT UPON ORBITAL ALTITUDE).

SCENARIO NO. 2E

FUNCTION NO	TIME TO DO FUNCTION (MIN - SEC)	RUNNING TOTAL (MIN - SEC)	RUNNING TOTAL OFF-UMBILICAL 60	70	80
1 ≈ 10'	0-20	0-20			
2	1-0	1-20			
3 *	90-0	91-20			
4	1-0	92-20			
5	0-20	92-40			

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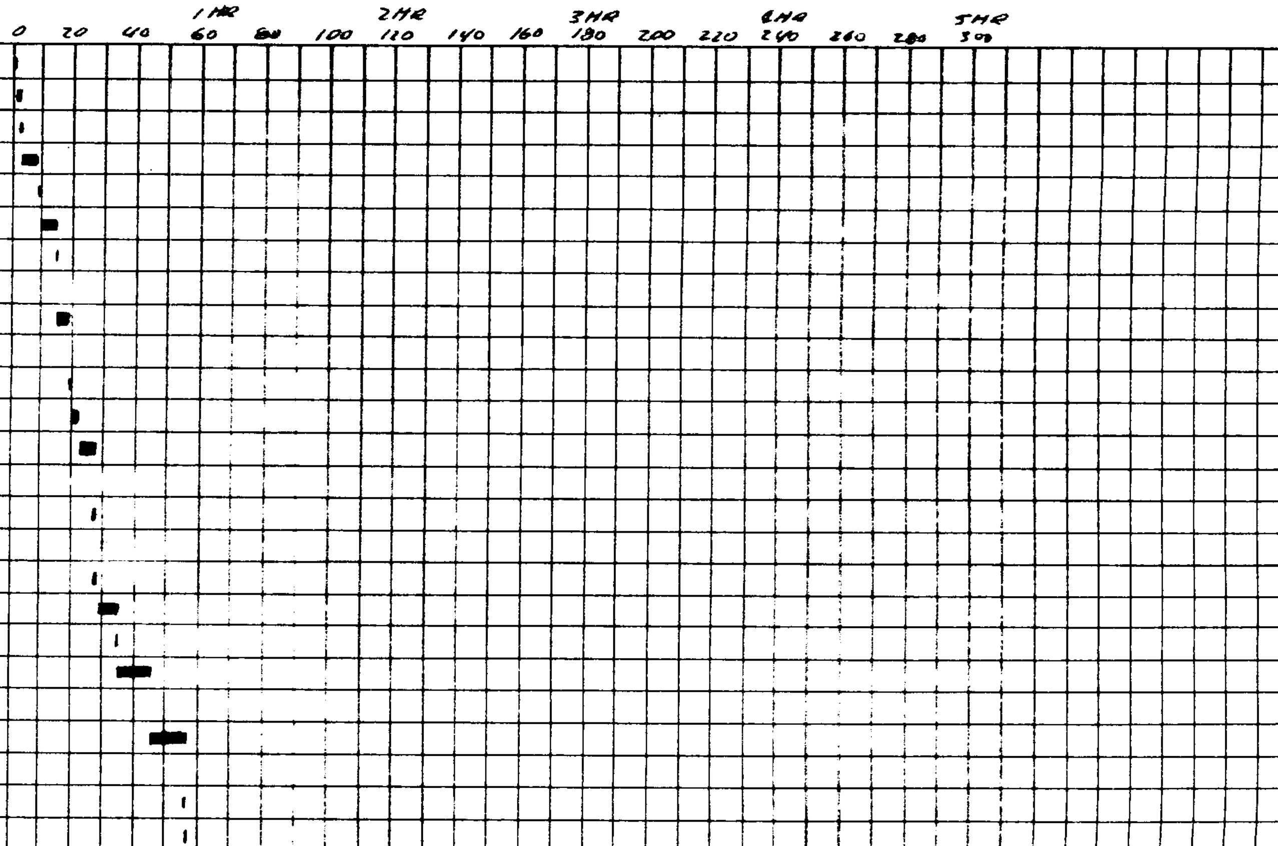
TIME LINE SHEET	FUNCTION SCENARIO 3 - SATELLITE AND TUG RETRIEVAL AND DEPLOYMENT READINESS	LOCATION	TYPE OF MAINTENANCE (IF APPLICABLE) PLANNED OR UNSCHEDULED

SOURCE OF FUNCTION	FUNCTION & CORRESPONDING TASKS (IF APPLICABLE)
1	TRANSLATE TO PAYLOAD BAY
2	TRANSLATE TO SEO
3	ESTABLISH WORKSITE
4	ROTATE SOLAR CELL PANEL
5	INSTALL 2 LENS COVERS
6	STOW ANT.
7	MANUALLY OPEN VALVES
	TO PURGE PROPELLANTS
8	PERFORM SAFETY CHECK
	ON SEO
9	EXIT WORKSITE
10	TRANSLATE TO AIRLOCK
11	OBSERVE RET. OF TUG
	& SEO INTO PAYLOAD BAY
12	TRANSLATE TO TUG
	UMBILICAL
13	ESTABLISH WORKSITE
14	CONNECT UMBILICAL
15	EXIT WORKSITE
16	TRANSLATE TO A.I.D
	INSPECT TIEDOWNS
17	OBTAIN INSTRUMENT
	AND PERFORM SAFETY CHECK
18	STOW INSTRUMENT
19	TRANSLATE TO AIRLOCK

TIME (MIN) (BAR CHART)



REVISION	DATE	APPROVAL	DOCUMENT NO.	PAGE OF
		P. Wood 10-13-72	FIGURE 10	

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SCENARIO NO. 3

FUNCTION NO		TIME TO DO FUNCTION (MIN - SEC)	RUNNING TOTAL (MIN - SEC)	RUNNING TOTAL OFF-UMBILICAL 60	70	80
1	≈10'	0-20	0-20			
2	≈70'	2-20	2-40			
3		1-0	3-40			
4		5-0	8-40			
5		1-0	9-40			
6		5-0	14-40			
7		1-0	15-40			
8		3-0	18-40			
9		1-0	19-40			
10	≈80'	2-40	22-20			
11		5-0	27-20			
12	≈30'	1-0	28-20			
13		1-0	29-20			
14		5-0	34-20			
15		1-0	35-20			
16	≈80'	10-0	45-20			
17		10-0	55-20			
18		1-0	56-20			
19	≈20'	0-40	57			

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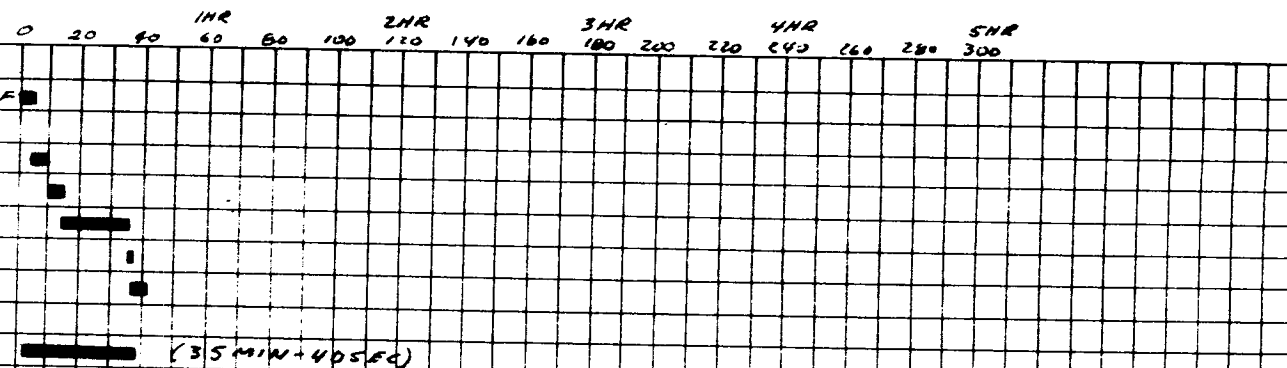
TIME LINE SHEET	FUNCTION SCENARIO 4 - INSPECTION AND REPAIR OF THE ORBITER VEHICLE EXTERIOR	LOCATION	TYPE OF MAINTENANCE (IF APPLICABLE) UNSCHEDULED OR CONTINGENCY

SOURCE OF FUNCTION	FUNCTION & CORRESPONDING TASKS (IF APPLICABLE)	TIME (MIN) (BAR CHART)
1	TRANSLATE TO THE AREA OF THE WINGTIP	
2	INSPECT AREA	
3	PREPARE AREA FOR REPAIR	
4	APPLY TEMPORARY PATCH	
5	PREPARE TO LEAVE AREA	
6	RETURN TO AIRLOCK	
	OFF-UMBILICAL TIME	(35 MIN + 40 SEC)



REVISION	DATE	APPROVAL	DOCUMENT NO.	PAGE OF
		P. Word 10-11-72	FIGURE 11	

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SCENARIO NO. 4

FUNCTION NO	TIME TO DO FUNCTION (MIN - SEC)	RUNNING TOTAL (MIN - SEC)	RUNNING TOTAL OFF-UMBILICAL (MIN - SEC)		
			60	70	80
ASSUME DAMAGE TO THE AREA AROUND THE UNDERSIDE OF A WINGTIP.					
1 ≈150'	5-0	5-0		2-20	
2	5-0	10-0		7-20	
3	EST. 5-0	15-0		12-20	
4	EST. 20-0	35-0		32-20	
5	1-0	36-0		33-20	
6 ≈150'	5-0	41-0		35-40	

P.B.- PAYLOAD BAY

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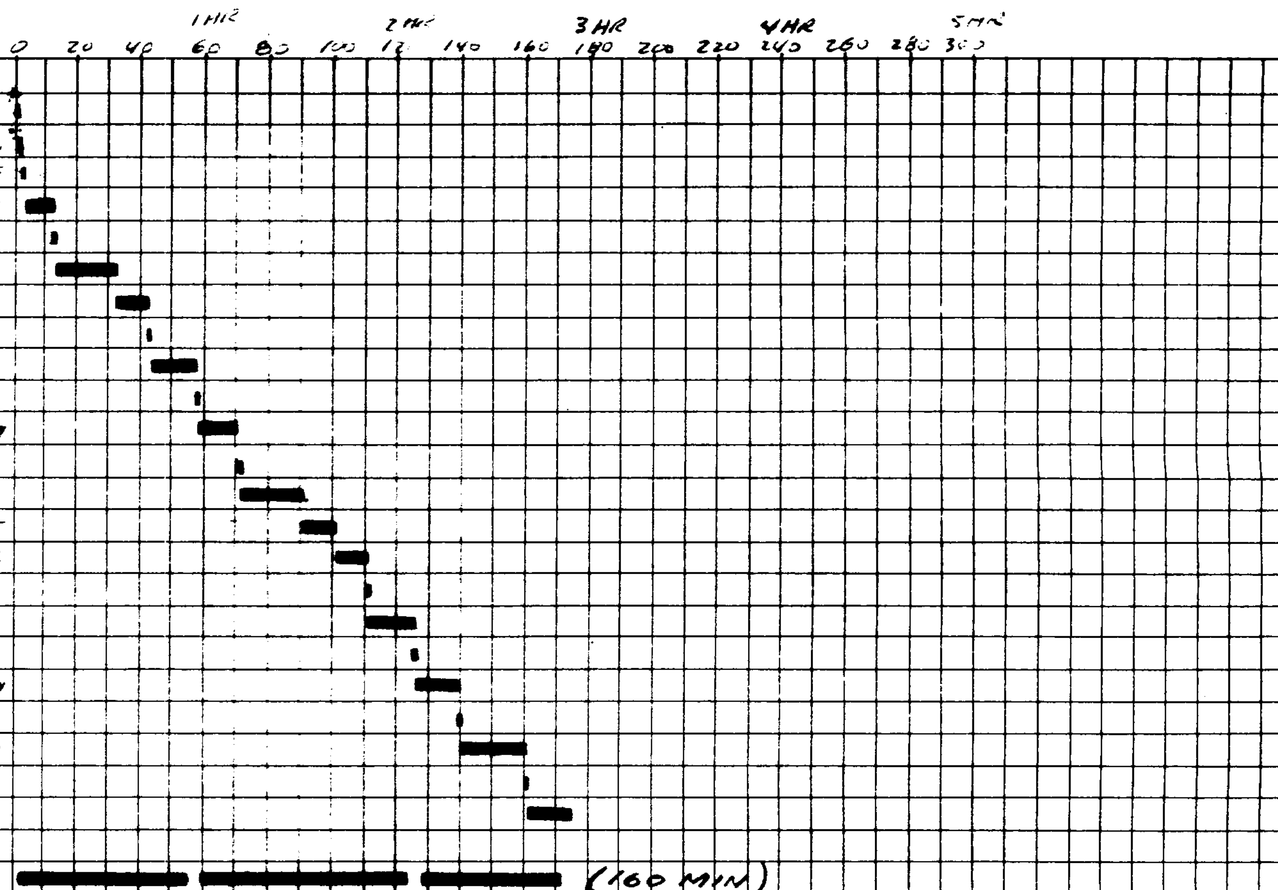
TIME LINE SHEET	FUNCTION SCENARIO 5A - REPLACE SENSOR ON END OF 120 FT BOOM FOR PLASMA WAKE EXPERIMENTS	LOCATION	TYPE OF MAINTENANCE (IF APPLICABLE) UNSCHEDULED

SOURCE OF FUNCTION	FUNCTION & CORRESPONDING TASKS (IF APPLICABLE)
1	TRANSLATE TO P.B.
2	TRANSLATE OVER SERV. MOD.
3	TRANSLATE TO BOOM BASE
4	TRANSLATE TO END OF BOOM
5	ESTABLISH WORKSITE
6	REMOVE & REPLACE SENSOR #1
7	" #2
8	LEAVE WORKSITE
9	TRANSLATE TO AIRLOCK
10	STOW #1 & #2 & ATTACH #4, #5, & #6
11	TRANSLATE TO END OF BOOM
12	ESTABLISH WORKSITE
13	REMOVE & REPLACE SENSOR #4
14	" #5
15	" #6
16	LEAVE WORKSITE
17	TRANSLATE TO AIRLOCK
18	STOW #4, #5 & #6 & ATTACH #3
19	TRANSLATE TO END OF BOOM
20	ESTABLISH WORKSITE
21	REMOVE & REPLACE SENSOR #3
22	LEAVE WORKSITE
23	TRANSLATE TO AIRLOCK
	OFF-UMBILICAL TIME - 70 FT

TIME (MIN) (BAR CHART)



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		R. Hood 10-11-72	FIGURE 12		

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SCENARIO NO. 5A

FUNCTION NO	TIME TO DO FUNCTION (MIN - SEC)	RUNNING TOTAL (MIN - SEC)	RUNNING TOTAL OFF-UMBILICAL 60	70	80
1	0-20	0-20		0-0	
2	0-30	0-50		0-0	
3	1-0	1-50		0-0	
4	10-40	12-30		10-40	
5	1-0	13-30		11-40	
6	20-0	33-30		31-40	
7	10-0	43-30		41-40	
8	1-0	44-30		42-40	
9	12-30	57-0		53-20	
10	1-0	58-0		53-20	
11	12-30	70-30		64-00	
12	1-0	71-30		65-0	
13	20-0	91-30		85-0	
14	10-0	101-30		95-0	
15	10-0	111-30		105-0	
16	1-0	112-30		106-0	
17	12-30	125-0		116-40	
18	2-0	127-0		116-40	
19	12-30	139-30		127-20	
20	1-0	140-30		128-20	
21	20-0	160-30		148-20	
22	1-0	161-30		149-20	
23	12-30	174-0		160-00 (2HRS-40MIN)	

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TIME LINE SHEET	FUNCTION SCENARIO 5B-IVA MANUAL RETRACTION OF A BOOM ON PLASMA WAKE EXPERIMENT SORTIE	LOCATION	TYPE OF MAINTENANCE (IF APPLICABLE) UNSCHEDULED

SOURCE OF FUNCTION	FUNCTION & CORRESPONDING TASKS (IF APPLICABLE)	TIME (MIN) (BAR CHART) 0, 20, 40, 60 (1 HR), 80, 100, 120 (2 HR), 140, 160, 180 (3 HR), 200, 220, 240 (4 HR), 260, 280, 300 (5 HR)
1	TRANSLATE TO BOOM AIRLOCK	
2	ENTER & PREPARE WORKSITE	
3	OPEN AIRLOCK INNER DOOR	
4	INSTALL CRANK	
5	CRANK IN BOOM (160')	
6	CLOSE AIRLOCK OUTER DOOR	
7	REMOVE CRANK	
8	PREPARE & EVACUATE WORKSITE	
9	TRANSLATE TO AIRLOCK	
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		
25		
26		
27		
28		
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31		
32		

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		P. W. Wood 10-25-72	FIGURE 13	

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*ASSUME 4 TURNS OF CRANK IN 5 SEC
(4 TURNS = 1 FT RETRACTION) + RESTS EVERY 2 MIN.

SCENARIO NO. 5B

FUNCTION NO	TIME TO DO FUNCTION (MIN - SEC)	RUNNING TOTAL (MIN - SEC)	RUNNING TOTAL OFF-UMBILICAL 60	70	80
1 ≈25'	1-0	1-0			
2	1-0	2-0			
3	1-0	3-0			
4	0-30	3-30			
5 *	30-0	33-30			
6	1-0	34-30			
7	0-30	35-0			
8	1-0	37-0			
9	1-0	38-0			

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TIME LINE SHEET	FUNCTION SCENARIO 5C - EVA MANUAL RETRACTION OF A BOOM ON PLASMA WAKE EXPERIMENT SORTIE	LOCATION	TYPE OF MAINTENANCE (IF APPLICABLE) UNSCHEDULED

SOURCE OF FUNCTION	FUNCTION & CORRESPONDING TASKS (IF APPLICABLE)
1	TRANSLATE TO BOOM AIRLOCK
2	ENTER & PREPARE WORKSITE
3	MANUALLY RETRACT BOOM
4	CLOSE OUTSIDE BOOM AIRLOCK DOOR
5	PREPARE & EVACUATE WORKSITE
6	TRANSLATE TO AIRLOCK OPENING
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	
20	
21	
22	
23	
24	
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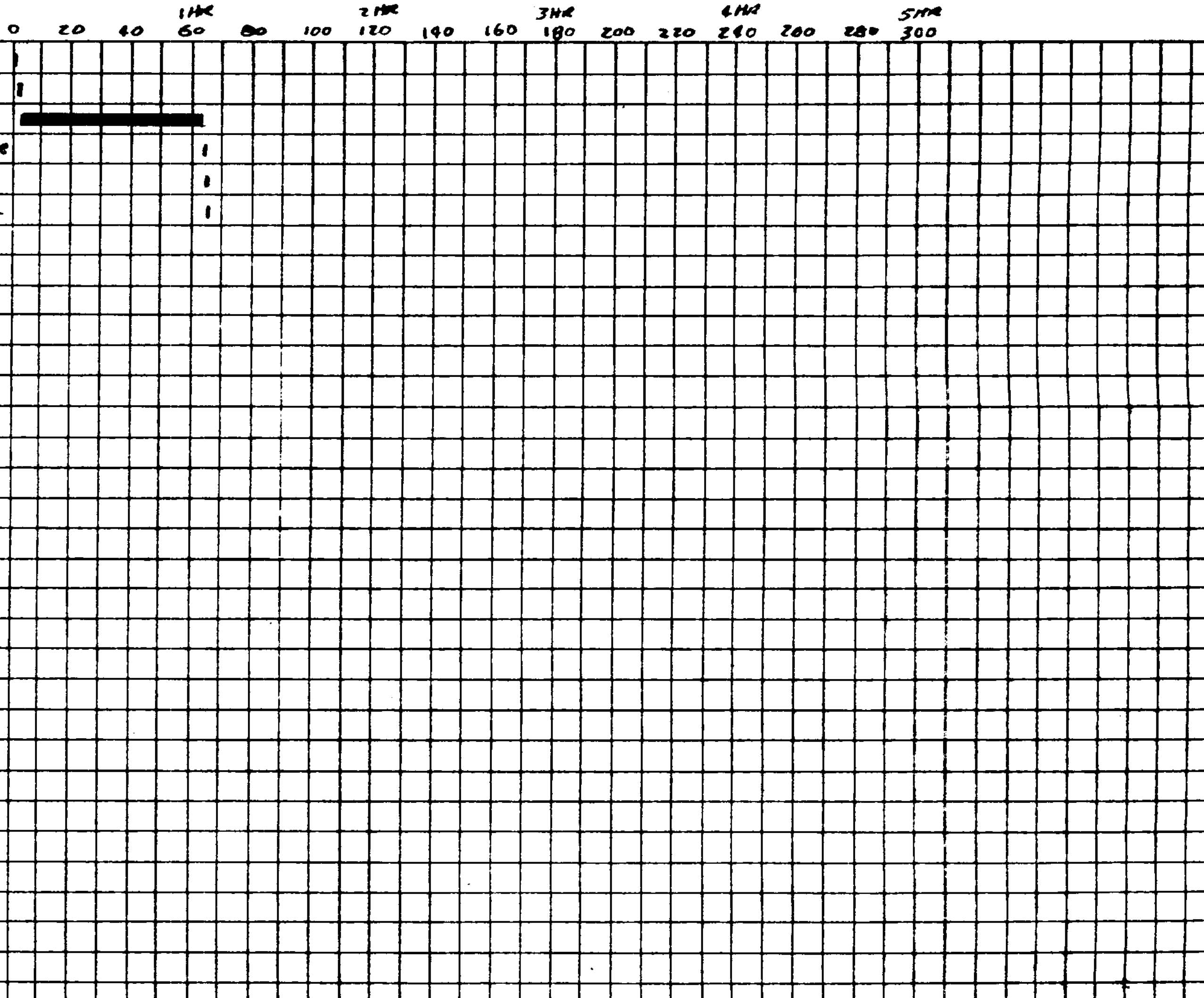
26	
27	
28	
29	
30	
31	
32	

TIME (MIN) (BAR CHART)



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* ASSUMED TO TAKE TWICE AS MUCH TIME TO MANUALLY RETRACT WITHOUT A CRANK.

SCENARIO NO. 5C

FUNCTION NO	TIME TO DO FUNCTION (MIN - SEC)	RUNNING TOTAL (MIN - SEC)	RUNNING TOTAL OFF-UMBILICAL 60	70	80
1 ≈ 40'	1-20	1-20			
2	2-0	3-20			
3 *	60-0	63-20			
4	1-0	64-20			
5	1-0	65-20			
6 ≈ 40'	1-20	66-40			

P.B. - PAYLOAD BAY

* POSITIONING AID IS A BLOCK & TACKLE DEVICE OR A MANUAL SCREW JACK DEVICE.

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TIME LINE SHEET	FUNCTION SCENARIO 5D & 5E - MANUALLY DEPLOY OR STOW SORTIE LAB. - EVA	LOCATION	TYPE OF MAINTENANCE (IF APPLICABLE) UNSCHEDULED

SOURCE OF FUNCTION	FUNCTION & CORRESPONDING TASKS (IF APPLICABLE)
1	TRANSLATE TO STOW AREA IN P.B.
2	RETRIEVE POSITIONING AID*
3	TRANSLATE TO POSITIONING WORKSITE
4	ESTABLISH WORKSITE
5	SETUP POSITIONING AID*
6	MANUALLY POSITION SORTIE LAB.
7	BREAKDOWN & REMOVE POSITIONING AID*
8	EVACUATE WORKSITE
9	TRANSLATE TO STOW AREA
10	STOW POSITIONING AID*
11	TRANSLATE TO AIRLOCK
12	
13	
14	
15	
16	
17	
18	
19	
20	
21	
22	
23	
24	
25	
26	
27	
28	
29	
30	
31	
32	

TIME (MIN) (BAR CHART)

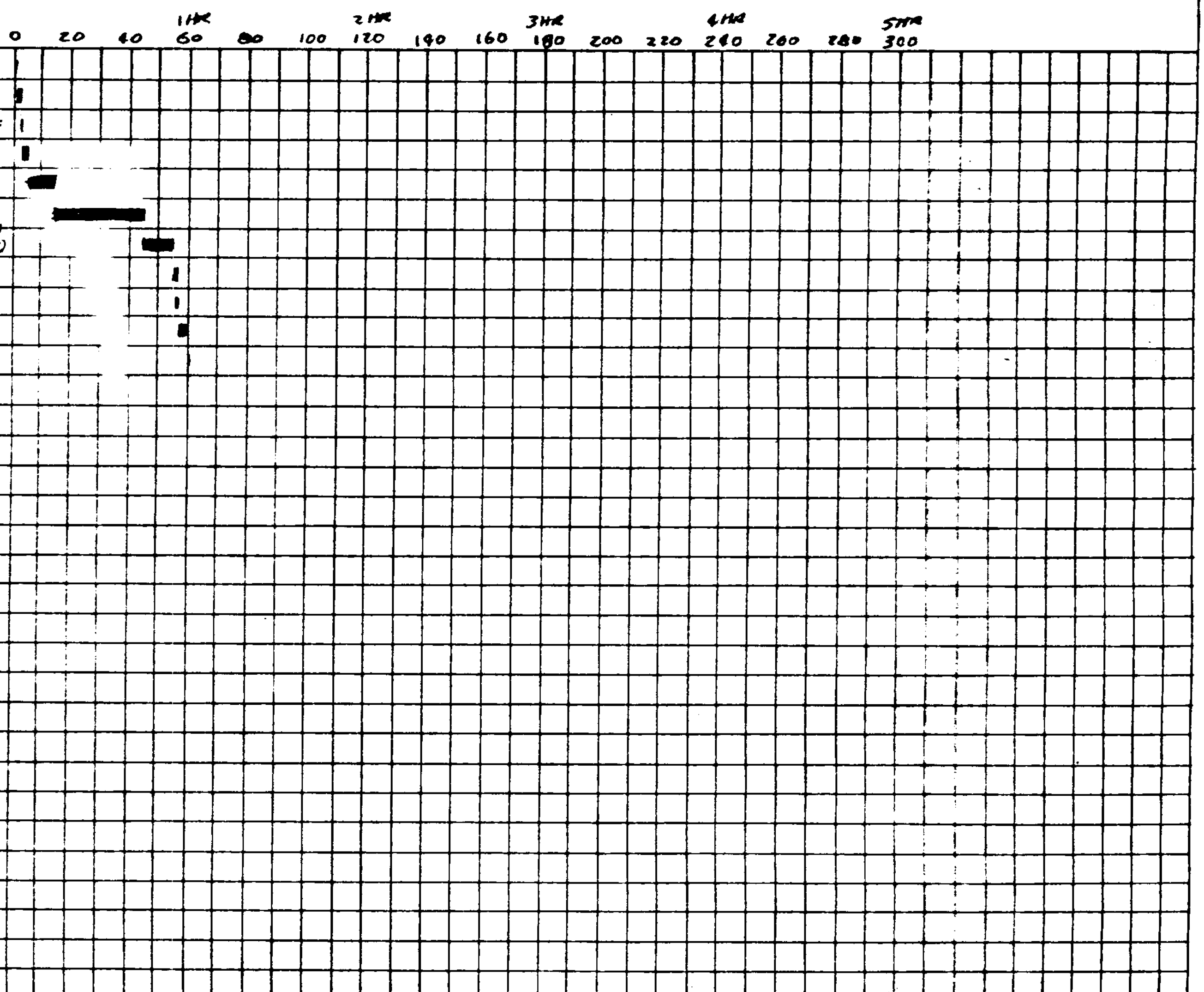

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			FIGURE 15		

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SCENARIO NO. 5D & 5E

FUNCTION NO	TIME TO DO FUNCTION (MIN - SEC)	RUNNING TOTAL (MIN - SEC)	RUNNING TOTAL OFF-UMBILICAL 60	70	80
1 ≈ 20'	0 - 40	0 - 40			
2	2 - 0	2 - 40			
3 ≈ 20'	0 - 40	3 - 20			
4	2 - 0	5 - 20			
5	10 - 0	15 - 20			
6	30 - 0	45 - 20			
7	10 - 0	55 - 20			
8	2 - 0	57 - 20			
9 ≈ 20'	0 - 40	58 - 0			
10	2 - 0	60 - 0			
11 ≈ 20'	0 - 40	60 - 40			

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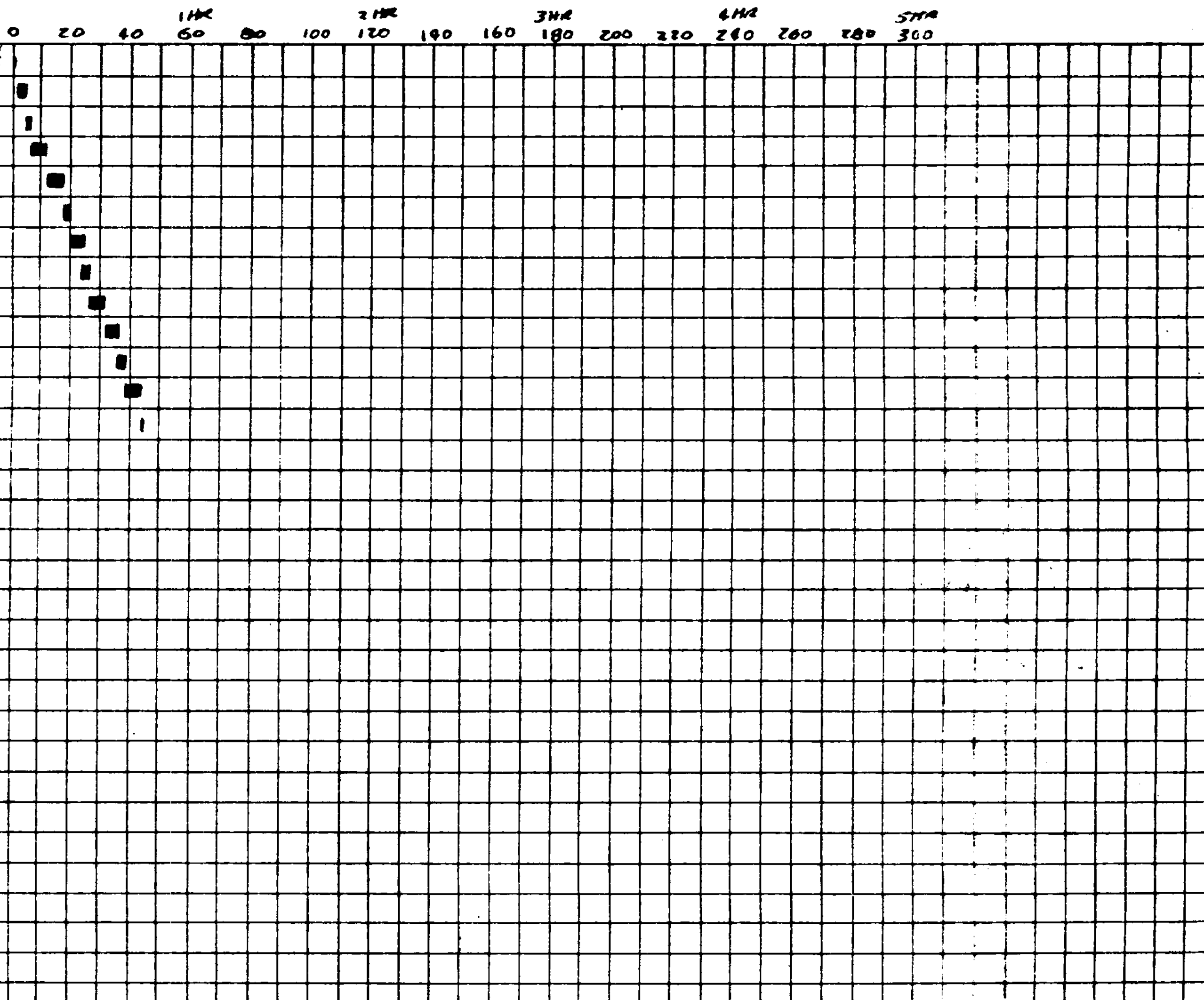
* ASSUME PRESSURIZABLE COMPARTMENT IS DEPRESSURIZED
& REPLACEMENT SENSORS ARE INSIDE COMPARTMENT
** ASSUME PERMANENT HANDRAILS INSTALLED
& DEPLOYABLE WORKSITE INSTALLED

TIME LINE SHEET	FUNCTION SCENARIO 6A, 6B & 6C - REPLACE LARGE APERTURE END SENSORS IN X-RAY ASTRONOMY OBSERVATORY - IVA	LOCATION	TYPE OF MAINTENANCE (IF APPLICABLE) PLANNED

SOURCE OF FUNCTION	FUNCTION & CORRESPONDING TASKS (IF APPLICABLE)
1	TRANSLATE TO TUBE ACCESS PANEL *
2	OPEN ACCESS PANEL
3	RETRIEVE REPLACEMENT SENSOR
4	ENTER TUBE WITH SENSOR
5	TRANSLATE TO WORKSITE **
6	PREPARE & ENTER WORKSITE
7	R&R SENSOR
8	PREPARE & EXIT WORKSITE
9	TRANSLATE TO ACCESS OPENING
10	EXIT TUBE
11	STOW REPLACED SENSOR
12	CLOSE ACCESS PANEL
13	TRANSLATE TO AIRLOCK
14	
15	
16	
17	
18	
19	
20	
21	
22	
23	
24	
25	
26	
27	
28	
29	
30	
31	
32	

TIME (MIN) (BAR CHART)



REVISION	DATE	APPROVAL	DOCUMENT NO.	PAGE OF
		10-26-72	FIGURE 13	

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1. ASSUME MUCH SLOWER TRANSLATION
DUE TO CRAMPED SENSITIVE SURROUNDINGS
2. WILL TAKE MORE TIME DUE TO HEAVY COMPONENT & CRAMPE QUARTERS

SCENARIO NO. 6A, B & C

FUNCTION NO	TIME TO DO FUNCTION (MIN - SEC)	RUNNING TOTAL (MIN - SEC)	RUNNING TOTAL OFF-UMBILICAL 60	70	80
1. ≈20'	0-40	0-40			
2.	5-0	5-40			
3.	2-0	7-40			
4.	5-0	12-40			
5. ≈30' 1.	5-0	17-40			
6.	2-0	19-40			
7. 2.	15-0	24-40			
8.	2-0	26-40			
9. ≈30'	5-0	31-40			
10.	5-0	36-40			
11.	2-0	38-40			
12.	5-0	43-40			
13.	0-40	44-20			

ORBITER EVA AND IVA

MISSION ANALYSES

1. Representative EVA's and IVA's for Payloads

Each type payload in Reference 2 was reviewed and representative planned or unscheduled EVA's and IVA's that could be applicable were selected from Reference 1. These assumptions were made in the selection of representative EVA's and IVA's for the payloads.

A. EVA and IVA are established operational techniques.

B. EVA will be utilized for removal of covers from payloads containing optical devices and sensors and for deploying calibration sources for payloads requiring them for on-orbit checkout.

C. On 5% of the orbiter 597 flights a malfunction will occur where an EVA would be required to inspect the orbiter exterior or payload bay.

D. No EVA activity on Space Station Payloads.

Table I shows the selected representative EVA or IVA for each payload. The information in Ref. 3 was the primary source for payload definition. The information was studied and where potential EVA or IVA was applicable a representative EVA/IVA was selected based on the similarity of the equipment on the payload and the equipment in the scenarios or similarity of the task to be accomplished on the payload and the tasks defined in the scenarios. Table I is arranged by payload type with the payload reference number, title, orbit weight and 12 years total shown in addition to the selected EVA or IVA.

Reference 2 does not consider the retrieval possibilities, but two retrieval possibilities exist (1) Shuttle plus Tug, (2) Shuttle only. For

Shuttle plus Tug retrieval, when a reusable Tug has delivered a payload to its position in space, the Tug could be used to bring a nearby payload back to the shuttle for retrieval. From the Tasks, Guidelines and Constraints Briefing, 74 Tug flights would have the capability for retrieval. Assuming 50% utilization, 37 Tug flights would retrieve a satellite and #3 EVA could be applicable. For the shuttle only retrieval, shuttles having completed the delivery mission or sortie missions could retrieve payloads if there is sufficient maneuver capability and load carrying capability. Again from the Tasks, Guidelines and Constraints Briefing, 185 shuttle flights would have the capability for retrieval. Assuming 50% utilization, 92 shuttle flights would retrieve a satellite and #3 EVA could be applicable. NASA Payload retrieval total is 129 - #3 EVA.

In order to relate the EVA's and IVA's to the 305 DOD payloads, it is assumed that 50% or 152 of the 305 DOD payloads in Ref. 4 are for surveillance or reconnaissance containing covered optics and sensors, and #3 EVA could be applicable. The other 153 would be navigation or communication satellites and no EVA or IVA is assumed applicable. To consider the retrieval possibilities of the DOD flights it is assumed that the Tug will be used in the same manner for DOD satellites as it is for NASA payloads. It is also assumed that the 152 navigation and communication satellites are delivered to geosynchronous orbit by the Tug. Using the same ratio of Tug flights as for NASA payloads, 74 of 101, then 111 of the 152 DOD Tug flights would have retrieval capability, and, for 50% utilization, 55 would retrieve a payload and #3 EVA could be applicable. For this analysis Shuttle only retrieval is not considered since the lack of information on DOD payloads makes analyses of the possibilities impossible at this time.

It is assumed that on 5% of the 597 Orbiter missions some malfunction or damage to the orbiter exterior or payload bay will occur which will require inspection or repair; therefore, in the 12 year period a total of 30 - #4 EVA's could be required.

Again from the retrieval analysis summarized in Tasks, Guidelines, and Constraints Briefing, 260 currently orbiting satellites plus 29 satellites from the traffic model, or a total of 289 satellites, are within the rendezvous capability of the Orbiter. It is assumed that a 25%, or 75, of these satellites, if repaired or serviced, will continue to provide useful data, therefore in the 12 year period a total of 75 - #7 EVA's could be applicable.

Table II is a summary of the EVA's and IVA's which could be applicable to NASA and DOD Shuttle Payloads.

2. Umbilical Length and Desirability

Each EVA and IVA was analyzed to determine the length which an umbilical would need to be if one was used and when an umbilical would limit maneuverability and be undesirable. Whether or not an umbilical would be undesirable was a subjective opinion of the writer based upon the complexity of the path to be traversed and how confined the path and worksite appear to be. Table III presents the results of this analysis.

3. Contamination Sensitivity

Using Reference 3 as a data source, General Dynamics Convair determined those payloads which are sensitive to water vapor, based upon the type and temperature of the sensors on the payload. Table IV shows the results of this analysis. Reference 3 data was used to determine which payloads are sensitive to particulate or grease contamination in addition to those already determined to be sensitive to water vapor contamination.

Table V is a summary of the contamination analyses.

4. Representative EVA's for Orbiter Flights

The payloads identified for each Orbiter flight in Ref. (2) were reviewed and representative planned and unscheduled EVA's and IVA's were selected for each flight that could be applicable. The EVA's and IVA's selected for the payloads in this analysis are those shown in Table I as modified by the following ground rules.

A. The potential for an unscheduled EVA or IVA exists on each Orbiter Flight.

B. On each Orbiter flight where a Tug is used to orbit one or more satellites the potential for one unscheduled No. 3 EVA (Satellite and Tug Retrieval and Deployment Readiness - EVA) and one unscheduled No. 5D EVA (Manually Position Sortie for Experiment - EVA) exists.

C. For each satellite individually orbited, if no planned EVA or IVA exists, the potential for one unscheduled No. 3 EVA exists for each satellite on the Orbiter Flight.

D. EVA/IVA is planned for (Ref. 1):

(1) Maintenance/Servicing of Large Astronomy Observatories

(2) On-Orbit Maintenance/Servicing of Retrieved Satellite

(3) De-Orbit Readiness of Payload in Cargo Bay

(4) Retrieval of Experiment Packages Including Sorties

(5) Free Flying Operations

Table VI shows the results of this analysis. Selected EVA's and IVA's and the EVA/IVA times per flight are shown. The times shown are EVA/IVA durations.

REFERENCES

1 Tasks, Guidelines, and Constraints Briefing, 15 June 1972, LTV Aerospace.

2. DIR No. T-192-DIR-07 Revised Shuttle Traffic Model, Dec. 7, 1972.

3. NASA Payload Data Book, Report No. ATR-72(7312)-1, The Aerospace Corp., 31 July 1972.

4. Shuttle Traffic Model In Support of The March 1972 RFP NASA MSC-06746, Dated March 21, 1972.

TABLE I - EVA OR IVA SELECTION FOR PAYLOADS

REF 2 PAYLOAD NUMBER	PAYLOAD TITLE	ORBIT (DEGREES X N.MILES)	WEIGHT (LB)	12 YEAR TOTAL	REPRESENTATIVE EVA OR IVA AND NO. OF TIMES USED (NOTE 1)
	EXPLORER CLASS			60	
	SCIENCE				
1a	Explorer - LEO (AST) (SAS-C SAT.)	28.5x550	373	16	3-16
1b	Explorer - SYNC (AST) (SAS-C SAT.)	28.5x19,323	373		
3	Explorer-Upper Atmosphere (Space Phy)	90x100-180	1160	18	3-18
4	Explorer-Medium Altitude (Space Phy)	0-90x1000-20,000	570		
5	Explorer-High Altitude (Space Phy)	1 A.U., ECLIPTIC	640		
	APPLICATIONS				
29	Small Applications Tech. Sat. Sync.	0x19,323	300	12	3-12
30	Small Applications Tech. Sat. Polar	90x300-3000	300	12	3-12
	LIFE SCIENCES				
43	Bioresearch Module	28.5x300	370	2	3-2
	INTERMEDIATE CLASS			85	
	SCIENCE				
7	Gravity & Relativity Satellites-LEO	90x500	1020	4	3-4
8	Gravity & Relativity Satellites-SOLAR	.3/10 A.U.xECLIPTIC	770		
89a	Environment Perturbation Sat-Mission A	55x6900	4350	4	3-4
89b	Environment Perturbation Sat-Mission B	55x6900	8700		
90	Heliocentric & Interstellar Spacecraft	ESCAPE	616	1	3-1
	APPLICATIONS				
21	Earth Observation Satellite	98x500-926	2400	7	3-7
22	Synchronous Earth Observatory Sat.(SEOS)	0x19,323	2500	5	3-5
24	Synchronous Meteorological Satellite	0x19,323	535	2	3-2
25	TIROS-O	103x906	1380	1	3-1
26	Earth Resources Satellite (Proto)	98x500	1800	8	3-8
27	Sync. Earth Observ. Satellite (PROTO)	0x19,323	2640	1	3-1
28	Applications Technology Satellite	0x19,323	3000	6	-
84	Disaster Warning Satellite	0x19,323	1760	1	-
85	Geopause	90x270	710	2	3-2
35	Systems Test Satellites	0x19,323	2860	8	-
36	Tracking & Data Relay Satellite (TDRS)	0x19,323	1760	6	-

TABLE I - CO

REF PAYLOAD NUMBER	PAYLOAD TITLE	ORBIT (DEGREES X N.MILES)	WEIGHT (LBS)	12 YEAR TOTAL	REPRESENTATIVE EVA OR IVA AND NO. OF TIMES USED
	PLANEATRY				
50	Mars Viking	M-NAX17,838-811	7491	2	3-2
51	Mars Rover	SUR.TRAV.90-270NM	5548	1	3-1
52	Venus Pioneer	——	878	1	3-1
53	Venus Radar Mapper	V-POLARx270	2087	2	3-2
54	Venus Large Lander	——	1169	2	3-2
55	Pioneer-Jupiter ORBITER	——	1948	1	3-1
56	Mariner-Jupiter/Uranus Flyby	——	1540	2	3-2
86	Pioneer-Saturn Probe	——	850	2	3-2
87	Pioneer-Jupiter Probe	——	794	2	3-2
88	Mercury Orbiter	M-27x270	5166	2	3-2
57	Mariner-Jupiter Orbiter	——	2500	2	3-2
58	Uranus Probe/Neptune Flyby	——	4990	2	3-2
59	Asteroid Rendezvous	——	3640	2	3-2
60	Encke Rendezvous	——	3193	2	3-2
60-1	Encke Slow Flyby	——	3159	1	3-1
60-3	Mariner-Saturn Orbiter	——	2368	2	3-2
	LIFE SCIENCES				
46	Teleoperator	28.5x300	960	1	3-1
	SPACE TECHNOLOGY				
96	Meteoroid & Exposure Module	28.5x500	10,000	2UP,2DN	1C-4
	LARGE OBSERVATORIES				
91	Large High Energy Telescope (X-Ray)	28.5x400	15,781	1UP	3-1
92	X-Ray Telescope Revisit		3500	1	1C-1, 6B-1
13	High Energy Astronomy Observatory (HEAO-C)	28.5x250	18,264	3UP,3DN	3-6
14	HEAO-C Revisit	28.5x250	3500	12	1A-4,6A-4,5E-1 1C-4,6B-4 1D-4,6C-4
15	Large Space Telescope (LST)	28.5x330	18,581	3UP,2DN	3-5
16	LST Revisit	28.5x330	3500	9	1A-3,6A-3 1B-2,6B-3 1C-2 1D-2,6C-3

TABLE 1 - CON

REF 2 PAYLOAD NUMBER	PAYLOAD TITLE	ORBIT (DEGREES X N.MILES)	WEIGHT (LBS)	12 YEAR TOTAL	REPRESENTA E EVA OR IVA AND NO. OF TIMES USED
17	Large Solar Observatory (LSO)	28.5-90x500	32,282	1UP	3-1
18	LSO Revisit		3500	4	1A-2,6A-2 1C-1,6B-1 1D-1,6C-1
19	Radio Astronomy Observatory (RAO)	28.5x38,646	2385	1UP	3-1
	SORTIES				
38	Sortie - Astronomy/Physics Observations	55x270	23,569	20	3-20 5A-3,5B-3 5C-3,5D-1 2E-2,5E-1
82	Sortie - Comm/Nav Experiments	28x200	17,910	6	5A-1,5B-1 5C-1,5E-1
83	Sortie - Comm/Nav Laboratory	28x200	17,510	4	5A-1,5B-1 5C-1
93	Sortie - Mini 7-Day Module	0x463	14,041	3	2A-3,2B-3 2C-3,2D-3
94	Sortie - Mini 30-Day Module	0x463	18,891	2	2A-2,2B-2 2C-2,2D-2
97	Sortie - Material Science Experiments	Any	2720	7	2A-4,2B-4 2C-4,2D-4 2E-1,5E-1
98	Sortie - Advanced Technology Experiments	28.5x250	13,781	3	2A-3,2B-3 2C-3,2D-3
42	Sortie - Earth Observation Laboratory	90x100	25,581	11	3-6, 2A-5 2B-5, 2C-5 2D-5,2E-1 5E-1
	SPACE STATION				
62	Space Station Modules		20,000	5	—
100	Space Station-Crew/Ops Logistics Module		20,000	35	—
64	Physics Lab - Space Station RAM		22,811	2UP,2DN	—
68	Space Station - (RAM) Comm/Nav Lab		36,500	2UP,2DN	—
95	Space Station - Mini 30-Day Module	55x270	26,576	2UP,2DN	—
66	Space Station - Life Sciences Lab		28,984	1UP	—
99	Space Station - RAM Tech & Mat Sci Lab		19,113	1UP	—

TABLE I - CONT.

REF 2 PAYLOAD NUMBER	PAYLOAD TITLE	ORBIT (DEGREES X N.MILES)	WEIGHT (LBS)	12 YEAR TOTAL	REPRESENTATIVE EVA OR IVA AND NO. OF TIMES USED
	NON-NASA PAYLOADS				
70	COMSAT	0x19,323	1490	11	—
71	U.S. Domestic Comm	0x19,323	3545	21	5D-1
72	Foreign Domestic Comm	0x19,323	1030	26	5D-1
73	Nav & Traffic Control	28.5x39,000-16,000	725	10	—
74	Nav & Traffic Control	5x19,300	725	6	—
75	TOS Meteorological	100.7x700	1030	12	—
76	Sync Meteorological	0x19,323	1035	12	—
77	Polar Earth Resources	99.75x500	2590	22	5D-1, 3-22
78	Sync Earth Resources	0x19,323	1030	8	3-8
79	Comm Satellites General	0x19,323	850	48	5D-1
80	Broadcast Satellites	0x19,323	2500	24	—
81	Broadcast Satellites	0x19,323	1000	24	—

NOTE 1 - Representative EVA or IVA code:

1. Maintenance of LST
   A. Aperture End - EVA
   B. Inside Telescope Tube - EVA
   C. RCS Modules - EVA
   D. Solar Cell Panels - EVA

2. Support of Earth Orbit Sortie
   A. Experiment Preparation - EVA
   B. Experiment Support - EVA
   C. Antenna Stowage - EVA
   D. Payload Bay Film Stowage - IVA
   E. Conduct Experiments in Sortie Facility - IVA

3. Satellite & Tug Retrieval or Deployment Readiness - EVA

4. Inspection of Repair of Orbiter - EVA

5. Deployment and Retractions of Plasma Wake Exp.
   A. Replace Boom Mounted Sensors - EVA
   B. Boom Retractions - IVA
   C. Boom Retractions - EVA
   D. Man. Position Storie for Experiment - EVA
   E. Man. Stow Sortie for Return - EVA

6. Maintenance of X-Ray Obs.
   A. Replace Prop. Counter Array - IVA
   B. Replace Scintillation Counter - IVA
   C. Replace Crystal Spectrograph - IVA

7. Maintenance of an Astronomy Explorer Satellite - EVA

TABLE II - REPRESENTATIVE EVA & IVA SUMMARY

REPRESENTATIVE EVA OR IVA SCENARIO	NASA PAYLOADS				DOD PAYLOADS		
	TABLE I USAGE	ORBITER ON-ORBIT REPAIR	SATELLITE ON-ORBIT REPAIR	RETRIEVAL	PAYLOAD LAUNCH	RETRIEVAL	TOTALS
1. Maintenance of LST							
A - Aperture End - EVA	9						9
B - Inside Telescope Tube - EVA	2						2
C - RCS Modules - EVA	12						12
D - Solar Cell Panels - EVA	7						7
2. Support of Earth Orbit Sortie							
A - Experiment Preparation - EVA	17						17
B - Experiment Support - EVA	17						17
C - Antenna Stowage - EVA	17						17
D - Payload Bay Film Stowage - IVA	17						17
E - Conduct Experiment in Sortie Facility - IVA	4						4
3. Satellite & Tug Retrieval or Deployment Readiness - EVA	194			129	152	55	530
4. Inspection and Repair of Orbiter - EVA		30					30
5. Deployment and Retractions of Plasma Wake Exp.							
A - Replace Boom Mounted Sensors - EVA	5						5
B - Boom Retractions - IVA	5						5
C - Boom Retractions - EVA	5						5
D - Man. Position Sortie for Experiment - EVA	5						5
E - Man. Stow Sortie for Return - EVA	5						5
6. Maintenance of X-Ray Obs.							
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							788

TABLE III - UMBILICAL LENGTH AND DESIRABILITY

EVA OR IVA	REQUIRED UMBILICAL LENGTH - FT.	UMBILICAL UNDESIRABLE
1. Maintenance of LST		
1A. Aperture End - EVA	80	
1B. Inside Telescope Tube - EVA	100	X
1C. RCS Modules - EVA	70	
1D. Solar Cell Panels - EVA	60	
2. Support of Earth Orbit Sortie		
2A. Experiment Prep. - EVA	70	X
2B. Experiment Support - EVA	70	
2C. Antenna Stowage - EVA	70	X
2D. Payload Bay Film Stowage - IVA	70	
2E. Conduct Experiment in Sortie Facility - IVA	50	
3. Satellite and Tug Retrieval or Deployment Readiness - EVA	70	X
4. Inspection and Repair of Orbiter - EVA	150	X
5. Deployment and Retraction of Plasma Wake Experiment		
5A. Replace Boom Mounted Sensors - EVA	220	X
5B. Boom Retraction - EVA	50	
5C. Boom Retraction - IVA	60	
5D. Manually Position Sortie for Experiment - EVA	70	
5E. Manually Position Sortie for Deorbit - EVA	70	
6. Maintenance of X-Ray Observatory		
6A. Replace Proportional Counter Array - IVA	40	X
6B. Replace Scintellation Counter - IVA	40	X
6C. Replace Crystal Spectrograph - IVA	40	X
7. Maintenance of an Astronomy Explorer Satellite	70	

TABLE IV- EFFECT OF WATER VAPOR ON SORTIE & MAN-TENDED PAYLOADS

PAYLOAD REFERENCE NO.	PAYLOAD NAME	SENSOR TYPE	COOLED	EST. TEMP. °K	EFFECTS ON SENSOR: ICE	LIGHT SCATTER	SPECTRAL
NA 2-1	Explorer, LEO	Optical	O	293 ± 5°	O	I	I
		X-Ray	O	273 ± 5°	O	I	I
		Gamma-Ray	I	20 - 77°	I	O	O
NA 2-2	Explorer, Sync.	Optical UV	O	293 ± 5	O	I	I
		X-Ray	O	273 ± 5°	O	I	I
		Gamma-Ray	I	20 - 77°	I	O	O
NA 2-3	HEAO C, High Energy Astronomy Observatory	Large X-Ray Telescope					
		Aspect Sensor	O	273 ± 5	O	I	O
		Max. Sens. Det.	I	20 - 77°	I	I	I
		Pos. Sens. Prop. Counter	O	273 ± 5°	O	I	I
		Polarimeter	O	273 ± 5°	O	I	I
		High Res. X-Ray Telescope					
		Aspect Sensor	O	273 ± 5°	O	I	O
		Hi Res. Imaging	O	273 ± 5°	O	I	I
		X-Ray Spectrometer	O	273 ± 5°	O	I	I
		Low Energy Telescope					
		Spectrometer	O	273 ± 5°	O	I	I
		Flare Detector	O	273 ± 5°	O	O	O
NA 2-4	High Energy Astronomy Observatory Revisits	Recharge Cooled Detectors or Replace	I	20 - 77°	I	O	O
NA 2-5	Large Space Telescope*	F/12 Electronic Camera	I	~253°	I	I	I
		3 Ea. F/96 Camera	I	~253°	I	I	I
	*Electronic Camera Image Plane Temperature	5 Ea. Spectrographs	I	~253°	I	I	I
		1 Ea. Slit Jaw Camera	I	~253°	I	I	I
NA 2-6	Large Space Telescope Revisits	Exchange, Test, LST Sensors & Supporting Sys.	I	253° & 293°	I	I	I
NA 2-7	Large Solar Observatory	1.5 m Photoheliograph					
		Electronic Cameras	O	293° +	O	I	I
		Spectrographs	O	293° +	O	I	I
		Magnetographs	O	293° +	O	I	I
		XUV Spectroheliograph					
		Electronic Cameras	O	293° +	O	I	I
		X-Ray Telescope	O	293° +			
		Electronic Camera	O	293° +	O	I	I
		Spectrometer	O	293° +	O	I	I
		Coronagraph Assembly	O	293° +	O	I	I
		+ Auxiliary Instruments	O	293° +	O	I	I
NA 2-8	LSO Revisits	Sensor Exchange, Adjustments, and Subsystem Tests	O	293° +	O	I	I
NA 2-9	Large High Energy Telescope (X-Ray)	High Resolution X-Ray Tele					
		X-Ray Imaging	O	273°	O	I	I
		X-Ray Spectrometer	O	273°	O	I	I
		Proportional Counter	O	273	O	I	I
	(Large Area X-Ray Telescope)	Max. Sensitivity Det.	I	20 - 77°	I	I	I
		Pos. Sens. Counter	O	273	O	I	I
		Polarimeter	O	273	O	I	I
		Transient X-Ray Phenomena Detector	O		O	I	I
NA 2-10	Large High Energy (X-Ray) Telescope Revisits	Exchange Sensors, Adjustments, Repairs & Support Subsystems	I	20 - 77	I	I	I
				273 +	O	I	I
NA 2-11	Radio Astronomy Observatory	Wide Band RF Radiometers & Spectrometers	O		O	O	O

TABLE IV– EFFECT OF WATER VAPOR ON SORTIE & MAN-TENDED PAYLOADS

PAYLOAD REFERENCE NO.	PAYLOAD NAME	SENSOR TYPE	COOLED	EST. TEMP. °K	EFFECTS ON SENSOR		
					ICE	LIGHT SCATTER	SPECTRAL
NA 2-12	Combined Astronomy/Physics Observations	1-m Photoheliograph					
		Hα Sensor	O		O	I	I
		Spectrometers	O		O	I	I
		X-Ray Spectroheliograph	O		O	I	I
		VLF Transmitter and Receivers	O		O	O	O
		Electron Accelerator	O		O	I	I
		Optical Telescope Spectrometers	O		O	I	I
		IR Telescope	I	20°	I	I	I
	SPACE PHYSICS						
NP2-13	Explorers - Upper Atmosphere	N. A.	O		O	O	O
NP2-14	Explorers - Medium Altitude	N. A.	O		O	O	O
NP2-15	Explorers - High Altitude	N. A.	O		O	O	O
NP2-16	Gravity and Relativity - LEO	Gyros & Telescopes in Dewar	I	1.6	I	I	O
NP2-17	Gravity and Relativity - Solar	Telescope	O		O	I	O
		Prec. Star Tracker	O		O	I	O
NP2-18	Environment Perturbation Mission A	N. A.	O		O	O	O
NP2-19	Environment Perturbation Mission B	N. A.	O		O	O	O
NP2-20	Heliocentric and Interstellar Spacecraft	N. A.	O		O	O	O
NP2-21	Space Station RAM - Physics Lab	Telescope	O		O	I	O
		Photometric Cluster	O		O	I	I
		Spectrometers	O		O	I	I
		Aspect Sensors	O		O	I	O
		TV Cameras	O		O	I	O
		Guide Star Trackers	O		O	I	O
		Optical Meteoroid Detector	O		O	I	O

*Checkout

I = YES O = NO ? = NOT DETERMINED YET

TABLE IV - EFFECT OF WATER VAPOR ON SORTIE & MAN-TENDED PAYLOADS

PAYLOAD REFERENCE NO.	PAYLOAD NAME	SENSOR TYPE	COOLED	EST. TEMP. °K	EFFECTS ON SENSOR: ICE	LIGHT SCATTER	SPECTRAL
NU 2-22	Mars Viking	IR Radiometer	I	77	I	I	I
		IR Spectrometer	I	77	I	I	I
		TV	O		O	I	O
		Imagers	O		O	I	O
NU 2-23	Mars Rover	IR Radiometer	I	77	I	I	I
		TV	O		O	I	O
NU 2-24	Venus Pioneer	IR Radiometer	I	77	I	I	I
NU 2-25	Venus Radar Mapper		O		O	O	O
NU 2-26	Venus Large Lander	Spectrometer	O		O	I	I
NU 2-27	Mercury Orbiter	IR Imager	I	77	I	I	I
		Vidicons	O		O	I	I
		UV Spectrometer	O		O	I	I
NU 2-28	Pioneer - Jupiter Orbiter	IR Radiometer	I	77	I	I	I
		TV	O		O	I	O
		UV Spectrometer	O		O	I	I
NU 2-29	Mariner-Jupiter/Uranus Flyby	IR Spectrometer	I	77	I	I	I
		TV	O		O	I	O
		UV Radiometer	O		O	I	I
		UV Spectrometer	O		O	I	I
NU 2-30	Pioneer - Jupiter Probe		O		O	O	O
NU 2-31	Pioneer - Saturn Probe		O		O	O	O
NU 2-32	Mariner - Jupiter Orbiter	IR Radiometer	I	77	I	I	I
		TV	O		O	I	O
		Spectrometers	O		O	I	I
NU 2-33	Uranus Probe/Neptune Flyby	IR Radiometer	I	77	I	I	I
		TV	O		O	I	O
		Spectrometers	O		O	I	I
NU 2-34	Mariner - Saturn Orbiter	Radiometer	I	77	I	I	I
		TV	O		O	I	O
		Spectrometers	O		O	I	I
NU 2-35	Encke Slow Flyby	TV	O		O	I	O
		Radiometers	I	77	I	I	I
		Spectrometers	O		O	I	I
NU 2-36	Encke Rendezvous	IR Radiometer	I	77	I	I	I
		TV Imager	O		O	I	O
		UV Spectrometer	O		O	I	I
NU 2-37	Asteroid Rendezvous	IR Radiometer	I	77	I	I	I
		Imager	O		O	I	O

CHECKOUT ON ORBIT BEFORE LAUNCH

4

I = YES O = NO ? = NOT DETERMINED YET

TABLE IV - EFFECT OF WATER VAPOR ON SORTIE & MAN-TENDED PAYLOADS

PAYLOAD REFERENCE NO.	PAYLOAD NAME	SENSOR TYPE	COOLED	EST. TEMP. °K	EFFECTS ON SENSOR: ICE	LIGHT SCATTER	SPECTRAL	
	EARTH OBSERVATIONS							
NE 2-38	Earth Observatory Sat.	Radiometer	I	77	I	I	I	
NE 2-39	SEOS	IR Scanners	I	77	I	I	I	
		Imaging Spectrometer	O		O	I	O	
		Cameras	O		O	I	O	
NE 2-40	TIROS-O	High Res. Radiometer	I	77	I	I	I	
		Vert. Temp. Sounders	I	77	I	I	I	
NE 2-41	Sync. Met. Sat.	MS. Radiometer	I	77	I	I	I	
NE 2-42	Earth Res. Sat.	Radiometer	I	77	I	I	I	
		Atmos. Sounder	I	77	I	I	I	
NE 2-43	SEOS - Prototype	MS. Scanners	I	77	I	I	I	
		MS Radiometers	I	77	I	I	I	
		Spectrometers	O		O	I	O	
NE 2-44	Earth Observation Laboratory - Sortie	Cameras	O		O	I	I	*
		MS. Scanner	I	77	I	I	I	*
		Radar	O		O	O	O	
		Scatterometer	O		O	O	O	
		M.S. Spectrometer	I	77	I	I	I	*
		Observation Telescope	O		O	I	O	*
		Microwave Scanner	O		O	O	O	
		M.S. Radiometer	I	77	I	I	I	
		Polarimeter	O		O	I	O	*
		Optical Radar	O		O	I	O	*
	*NOTE: Only if water dump during or shortly before observations. Otherwise contamination covers on sensors.							
NE 2-45	Geopause		O		O	O	O	
	COMM/NAV							
NC 2-46	ATS		O		O	O	O	*
NC 2-47	SATS - SYNC.		O		O	O	O	*
NC 2-48	SATS - POLAR		O		O	O	O	*
NC 2-49	TDRS	Laser	O		O	I	O	**
NC 2-50	Disaster Warning		O		O	O	O	*
NC 2-51	System Test Sat.		O		O	O	O	*
NC 2-52	Sortie - Comm/Nav. Exp.	Laser System	O		O	I	O	
NC 2-53	Sortie - Comm/Nav. Lab.	Laser System	O		O	I	O	

* No Effect

** Only if C/O on orbit

I = YES O = NO ? = NOT DETERMINED YET

TABLE IV – EFFECT OF WATER VAPOR ON SORTIE & MAN-TENDED PAYLOADS

PAYLOAD REFERENCE NO.	PAYLOAD NAME	* SENSOR TYPE	COOLED	EST. TEMP. °K	EFFECTS ON SENSOR		
					ICE	LIGHT SCATTER	SPECTRAL
NT2-61	Meteoroid and Exposure Module	N. A.	O		O	O	O
NT2-62	Sortie – Material Science Experiments	N. A.	O		O	O	O
NT2-63	Sortie – Advanced Technology Experiments	Laser Ranger Altimeter	O		O	I	O
		LIDAR	O		O	I	O
		Photographic Cameras	O		O	I	O
		TV Cameras	O		O	I	O
		Landmark Tracker	O		O	I	O
		Star Trackers	O		O	I	O
		Tunable Laser.	I	1.6	O	I	I
		Multispectral Scanner	?	?	?	I	I
		UV Meteor Spectrograph	O		O	I	I
		Fatigue Experiment	O		O	O	O
		Material Sample Arrays	O		O	O	O
NT2-64	Space Station – RAM Technology and Material Science Lab	N. A.	O		O	O	O

* H_2O could modify experiment results

I = YES O = NO ? = NOT DETERMINED YET

TABLE V - CONTAMINATION SENSITIVE PAYLOADS

REF. PAYLOAD NUMBER	PAYLOAD TITLE	WATER VAPOR DEPOSITION (ICE)	WATER VAPOR LIGHT SCATTER & SPECTRAL	PARTICLE AND GREASE
	EXPLORER CLASS			
	SCIENCE			
1a	Explorer - LEO (AST)(SAS-C SAT.)	x	x	
1b	Explorer - SYNC (AST) (SAS-C SAT.)	x	x	
3	Explorer - Upper Atmosphere (Space Phy)			x
4	Explorer - Medium Altitude (Space Phy.)			x
5	Explorer - High Altitude (Space Phy)			x
	APPLICATIONS			
29	Small Applications Tech. Sat. Sync.			
30	Small Applications Tech. Sat. Polar			
	LIFE SCIENCES			
43	Bioresearch Module			
	INTERMEDIATE CLASS			
	SCIENCE			
7	Gravity & Relativity Satellites - LEO	x	x	
8	Gravity & Relativity Satellites - SOLAR	x	x	
89a	Environment Perturbation Sat-Mission A			x
89b	Environment Perturbation Sat-Mission B			x
90	Heliocentric & Interstellar Spacecraft			x
	APPLICATIONS			
21	Earth Observation Satellite	x	x	
22	Synchronous Earth Observatory Sat. (SEOS)	x	x	
24	Synchronous Meteorological Satellite	x	x	
25	TIROS-O	x	x	
26	Earth Resources Satellite (Proto)	x	x	
27	Sync. Earth Observ. Satellite (Proto)	x	x	
28	Applications Technology Satellite			
84	Disaster Warning Satellite			
85	Geopause			
35	Systems Test Satellites			
36	Tracking & Data Relay Satellite (TDRS)		x	
	PLANEATRY			
50	Mars Viking	x	x	
51	Mars Rover	x	x	
52	Venus Pioneer	x	x	
53	Venus Radar Mapper			
54	Venus Large Lander		x	
55	Pioneer-Jupiter ORBITER	x	x	
56	Mariner-Jupiter/Uranus Flyby	x	x	
86	Pioneer-Saturn Probe			

TABLE V - CONTAMINATION SENSITIVE PAYLOADS - (CONT.)

REF, PAYLOAD NUMBER	PAYLOAD TITLE	WATER VAPOR DEPOSITION (ICE)	WATER VAPOR LIGHT SCATTER & SPECTRAL	PARTICLE AND GREASE
87	Pioneer-Jupiter Probe			
88	Mercury Orbiter	x	x	
57	Mariner-Jupiter Orbiter	x	x	
58	Uranus Probe/Neptune Flyby	x	x	
59	Asteroid Rendezvous	x	x	
60	Encke Rendezvous	x	x	
60-1	Encke Slow Flyby	x	x	
60-3	Mariner-Saturn Orbiter	x	x	
	LIFE SCIENCES			
46	Teleoperator			
	SPACE TECHNOLOGY			
96	Meteoroid & Exposure Module			
	LARGE OBSERVATORIES			
91	Large High Energy Telescope (X-Ray)	x	x	
92	X-Ray Telescope Revisit	x	x	
13	High Energy Astronomy Observatory (HEAO-C)	x	x	
14	HEAO-C Revisit	x	x	
15	Large Space Telescope (LST)	x	x	
16	LST Revisit	x	x	
17	Large Solar Observatory (LSO)		x	
18	LSO Revisit		x	
19	Radio Astronomy Observatory (RAO)			
	SORTIES			
38	Sortie - Astronomy/Physics Observations	x	x	
82	Sortie - Comm/Nav Experiments		x	
83	Sortie - Comm/Nav Laboratory		x	
93	Sortie - Mini 7-Day Module			
94	Sortie - Mini 30-Day Module			
97	Sortie - Material Science Experiments			
98	Sortie - Advanced, Technology Experiments	x	x	
42	Sortie - Earth Observation Laboratory	x	x	

TABLE V - CONTAMINATION SENSITIVE PAYLOADS - (CONT.)

REF. PAYLOAD NUMBER	PAYLOAD TITLE	WATER VAPOR DEPOSITION (ICE)	WATER VAPOR LIGHT SCATTER & SPECTRAL	PARTICLE AND GREASE
	SPACE STATION			
62	Space Station Modules			
100	Space Station-Crew/Ops Logistics Module			
64	Physics Lab - Space Station RAM			
68	Space Station - (RAM) Comm/Nav Lab			
95	Space Station - Mini 30-Day Module			
66	Space Station - Life Sciences Lab			
99	Space Station - RAM Tech & Mat Sci Lab			
	NON -NASA PAYLOADS			
70	COMSAT			
71	U. S. Domestic Comm			
72	Foreign Domestic Comm			
73	Nav & Traffic Control			
74	Nav & Traffic Control			
75	TOS Meteorological			
76	Sync Meteorological			
77	Polar Earth Resources			X
78	Sync Earth Resources			X
79	Comm Satellites General			
80	Broadcast Satellites			
81	Broadcast Satellites			

TABLE VI - EVA/IVA SELECTION FOR ORBITER FLIGHTS

1979

ORBITER FLIGHT NO.(1)	PAYLOAD NOS.	RETRIEV. CAP.(2)	TUG RETRIEV. CAP (2)	PLANNED EVA/IVA NOS.	PLANNED EVA/IVA TIME (MIN.)	UNSCHED. EVA/IVA NOS.	UNSCHED EVA/IVA TIME (MI
1	1a, 43	x o		3, 3	278	3	139
2	1a, 13	x				3, 3	278
3	3,73,5	x o		3	139	5D,3,3	425
4	80, 73					5D, 3	286
5	28,4,73					5D, 3	286
6	98	x		2A,B,C,D	566	5E	147
7	50					5D, 3	286
8	56	x o		3	139	5D, 3	286
9	56	x				5D, 3	286
10	79, 81					5D, 3	286
11	70					5D, 3	286
12	79,36,81					5D, 3	286
13	79,80,29					4 5D,3	107 + 286
14	74, 79	x o		3	139	5D, 3	286
15	71					5D, 3	286
16	70, 76					5D, 3	286
17	21, 77	x				5D, 3	286
18	30	x o		3	139	5D, 3	286
19	77,75	x				5D, 3	286
20	77	x o		3	139	5D, 5D,3	147 + 286
21	77	x				5D, 3	286

1980

ORBITER FLIGHT NO.(1)	PAYLOAD NOS.	RETRIEV. CAP.(2)	TUG RETRIEV. CAP (2)	PLANNED EVA/IVA NOS.	PLANNED EVA/IVA TIME (MIN.)	UNSCHED. EVA/IVA NOS.	UNSCHED EVA/IVA TIME (MI
1	85,3,4					5D, 3	286
2	85,73,5					5D, 3	286
3	97, 26	x o		3,2A,B,C,D	705	5E, 3	286
4	97,14	x		6A,1A,2A B, C, D	836	4, 5E 5D	254 +147
5	82,14	x o		3,1C,6A		5A, 5D	373+147
6	46	x				3	139
7	93	x o		3,2A,B,C,D	323	5E	147
8	60-1					5D, 3	286
9	52	x				5D, 3	286
10	1b,84,80					5D, 3	286
11	79,1b,70					5D, 3	286
12	80,36,22					5D, 3	286
13	36,81,79					5D, 3	286
14	81,79,29					5D, 3	286
15	89,76,79					5D, 3	286
16	71, 72					5D, 3	286
17	71, 72					5D, 3	286
18	21, 75	x o		3	139	4, 5D, 3	107 + 286
19	85, 30	x				5D, 3	286
20	42(A)	x o		3,2A,B,C,D	705	5E	147

1981

ORBITER FLIGHT NO.	PAYLOAD NOS.	ORBITER RET.CAP.	ORBITER PLUS TUG RET.CAP.	PLANNED EVA NO.	PLANNED EVA TOT. TIME	UNSCHED. EVA NO.	UNSCHED. EVA TOT.TIME
1	73, 5					5D, 3	286
2	13, 1a	x				5D, 3	286
4	73, 8	x o		3	139	5D, 3	286
5	15					3	139
6	14,82	x		1D	77	5B,5E	101+147
7	14, 83	x o		3,1A,6A	409	5A,5E	373+147
8	93	x		2A,B,C,D	566	5E	147
9	50					5D, 3	286
10	27,81,79					5D, 3	286
11	28,72,1b					4,5D,3	107+286
12	80,72,79					5D, 3	286
13	80,81,29					5D, 3	286
14	35,72,79					5D, 3	286
15	35,72,79					5D, 3	286
16	36,72,76					5D, 3	286
17	74, 70	x o		3	139	5D, 3	286
18	71, 72					5D, 3	286
19	38	x				5E	147
20	38	x o		3	139	5A, 5E	373+147
21	97			2A,B,C,D	566	5E	147
22	98			2A,B,C,D	566	5E	147
23	3,30	x				5D, 3	286
24	85, 4	x o		3	139	4,5D,3	107+286
25	42 (A)	x		3,2A,B, C,D	705	5E	147
26	21,77	x o		3	139	5D, 3	286
27	77, 25	x				5D, 3	286
28	77, 75	x o		3	139	5D, 3	286
29	77	x				5D, 3	286

ORBITER FLIGHT NO.	PAYLOAD NOS.	ORBITER RET.CAP.	ORBITER PLUS TUG RET.CAP.	PLANNED EVA NO.	PLANNED EVA TOT. TIME	UNSCHED. EVA NO.	UNSCHED. EVA TOT.TIME
1	3,4,5	x o		3	139	5D, 3	286
2	16,83			1c	71	5B,5D,5E	101+294
3	93,14,1a	x		6B,1D, 2A,B,C,D	756	5D,5E,3	433
4	14,16,1a			6B,1A,1B 6B	706	5E,3	286
5	53					5D, 3	286
6	55					5D, 3	286
7	55					5D, 3	286
8	60					4, 5D, 3	107+286
9	22,27	x o		3	139	5D, 3	286
10	35,79,29					5D, 3	286
11	24,27,81					5D, 3	286
12	81,80,79					5D,3	286
13	76,80,79					5D,3	286
14	35,72,79					5D,3	286
15	71, 72					5D,3	286
16	38	x				5E	147
17	38	x o		3	139	5B, 5E	101+147
18	38	x				5E	147
19	97			2A,B,C,D	566	5E	147
20	96			3,1C,3, 1C	420	5D	147
21	42 (A)			3,2A,B,C D	705	4, 5E	107
22	85, 30	x o		3	139	5D, 3	286
23	42	x		3	139	5E	147
24	42	x o		3,3	278	5E	147
25	21,75	x				5D, 3	286

ORBITER FLIGHT NO.	PAYLOAD NOS.	ORBITER RET.CAP.	ORBITER PLUS TUG RET.CAP.	PLANNED EVA NO.	PLANNED EVA TOT. TIME	UNSCHED. EVA NO.	UNSCHED. EVA TOT.TIME
1	14,98	x o		3,1C	210	5D,5E	294
2	1a,73,5	x				5D, 3	286
3	14,16,1a			6C,1D, 1A,6C	460	5D, 3	286
4	15a,13D			3	139	5E, 3	286
5	16, 97			1C, 6C	184	5D, 5E	294
6	17					5D, 3	286
7	87					5D, 3	286
8	24, 74	x o		3	139	5D, 3	286
9	36,81, 79					4, 5D,3	107+286
10	28,27, 79					5D, 3	286
11	36,81 79					5D, 3	286
12	80,29 79					5D,3	286
13	80, 76					5D, 3	286
14	35,70					5D, 3	286
15	35,70					5D, 3	286
16	71, 72					5D, 3	286
17	71, 72					5D, 3	286
18	38	x				5E	147
19	38	x o		3	139	5C, 5E	159+147
20	38	x				5E	147
21	38	x o		3	139	5E	147
22	94			2A,B,C, D	566	4, 5E	107+147
23	96			3,1C,3 1C	420	3	139
24	3,4	x				5D, 3	286
25	85,30	x o		3	139	5D, 3	286
26	21, 77	x				5D, 3	286
27	77, 75	x o		3	139	5D, 3	286
28	77	x				5D, 3	286
29	77	x o		3	139	5D,3	286

1984

ORBITER FLIGHT NO.	PAYLOAD NOS.	ORBITER RET.CAP.	ORBITER PLUS TUG RET.CAP.	PLANNED EVA NO.	PLANNED EVA TOT. TIME	UNSCHED. EVA NO.	UNSCHED. EVA TOT.TIME
2	14,1a,5			1D,6A	190	5D, 3	286
3	14, 16	x		6A,1A, 1B, 6A	706	5E,5E	294
4	16, 18	x o		6A,3,1C 1D,6B	513	5E, 5E	294
5	18	x		1A,6B	270	5E	147
6	59	x o		3	139	4, 3	107+139
7	28,22,16	x				5D, 3	286
8	36,81,79					5D, 3	286
9	71, 79					5D, 3	286
10	80,76,79					5D, 3	286
11	35,79,29					5D, 3	286
12	71					5D, 3	286
13	80, 81					5D, 3	286
14	35, 70					5D, 3	286
15	38	x				5E	147
16	38	x o		3	139	5D, 5E	147+147
17	38	x				5E	147
18	38	x o		3	139	5E	147
19	97			2A,B,C, D	566	4, 5E	107+147
20	97			2A,B,C D	566	5E	147
21	94	x		2A,B,C D	566	5E	147
22	82	x o		3	139	5C, 5E	159+147
23	42	x		3	139	5E	147
24	42	x o		3,3	278	5E	147
25	3,4	x				5D, 3	286
26	7, 30	x o		3	139	5D, 3	286
27	21,75	x				5D, 3	286

ORBITER FLIGHT NO.	PAYLOAD NOS.	ORBITER RET.CAP.	ORBITER PLUS TUG RET.CAP.	PLANNED EVA NO.	PLANNED EVA TOT. TIME	UNSCHED. EVA NO.	UNSCHED. EVA TOT.TIME
1 T	5,4,86		x	3	139	5D,3	286
2 T	3,86,73		x			5D,3	286
3	13u,15D			3	139	5D,5D,3	433
4	14,16	x		6B,3,1C 1D,6C	513	5D,5D	294
5	14,18	x		6C,1A,1C 6C	454	4, 5D,5D	107
6	17	x		3	139	5D, 3	286
7	18,19	x		1D,6A	190	5D,5D,3	433
8 T	54					5D, 3	286
9 T	57					5D, 3	286
10 T	60					5D, 3	286
11 T	78,1b,81		x			5D, 3	286
12 T	79,1b,78		x	3	139	5D,5D,3	147+286
13 T	29,80					5D, 3	286
14 T	35, 79		x	3	139	5D, 3	286
15 T	35, 79		x			5D, 3	286
16 T	71					5D, 3	286
17 T	71					5D, 3	286
18 T	70		x	3	139	4, 5D,3	107+286
19 T	79,76,78		x			5D,3	286
20 T	80,78					5D, 3	286
21 T	74,81		x	3	139	5D, 3	286
SS 22	99	x		3	139	5D	147
SS 23	62					5D	147
SS 24	62					5D	147
SS 25	62					5D	147
SS 26	62					5D	147
SS 28	66					5D	147
SS 29	95					5D,5E	294
30	38	x				5E	147
31	38	x		3	139	4,5E	254
32	28	x				5E	147
33	82	x		3	139	5E	147
34	83	x				5C	159
35	42	x		3,3	278	5E	147
SS 36	100	x				5E, 5D	294
SS 37	100	x		3	139	5E, 5D	294
SS 38	100	x				5E, 5D	294
SS 39	100	x		3	139	5E, 5D	294
40 T	85,30	x	x			5D, 3	286
41 T	21,75	x	x	3	139	5D, 3	286
42 T	77,25	x	x			5D,3	286
43 T	77	x		3	139	5D,3	286
44 T	77	x				4, 5D,3	107+286
45 T	77	x		3	139	5D, 3	286
SS 46	64					5E	147
SS 47	68					5E	147

ORBITER FLIGHT NO.	PAYLOAD NOS.	ORBITER RET.CAP.	ORBITER PLUS TUG RET.CAP.	PLANNED EVA NO.	PLANNED EVA TOT. TIME	UNSCHED. EVA NO.	UNSCHED. EVA TOT.TIME
1 T	5					5D, 3	286
2	14,18,1a			6A,1A, 1C,6A	454	5D,5D,3	433
3	16,1a			1D,6C	190	5D,3	286
4	14,16	x		6B,1A, 1C,6B	454	5D,5D	294
5	18	x o		3,1D,6B	329	5D	147
6 T	58					5D, 3	286
7 T	28					5D, 3	286
8 T	22,76,79		x o	3	139	5D, 3	286
9 T	29, 81		x			5D, 3	286
10 T	35, 79		x o	3	139	4, 5D,3	107+286
11 T	35, 79		x			5D, 3	286
12 T	72, 79		x			5D, 3	286
13 T	71					5D,5D,3	147+286
14 T	71					5D, 3	286
15 T	72, 80					5D, 3	286
16 T	72, 80					5D, 3	286
17 T	72, 81		x o	3	139	5D,5D,3	147+286
SS 23	95					4, 5D	107+147
24	42	x		3	139	5E	147
SS 25	100	x o		3	139	5D,5E	294
SS 26	100	x				5D,5E	294
SS 27	100	x o		3	139	5D,5E	294
SS 28	100	x				5D, 5E	294
SS 29	100	x o		3	139	5D, 5E	294
SS 30	100	x				5D, 5E	294
SS 31	100	x o		3	139	5D, 5E	294
SS 32	100	x				5D, 5E	294
33 T	3,4		x			5D, 3	286
34 T	21	x o	x	3	139	5D, 3	286
35 T	26	x	x			5D, 3	286
36 T	26,75	x o	x	3	139	4, 5D,3	107+286
37 T	30	x	x			5D, 3	286

1987

ORBITER FLIGHT NO.	PAYLOAD NOS.	ORBITER RET.CAP.	ORBITER PLUS TUG RET.CAP.	PLANNED EVA NO.	PLANNED EVA TOT. TIME	UNSCHED. EVA NO.	UNSCHED. EVA TOT.TIME
1 T	8,89					5D, 3	286
2	14,16,1a			6C,1A,1C 6C	454	5D,5D,3	433
3 T	5,73					5D,3	286
4	15u,13D			3	139	5D,5D,3	433
5	14,18	x o		6C,3,1D, 1A,6A	599	5D, 5D	294
6	16	x		1C,6A	184	5D	147
7	19	x o		3	139	5D, 3	286
8	17					5D, 3	286
9	18	x		1D, 6A	190	5D	147
10 T	57					5D, 3	286
11 T	74,36		x o	3	139	5D,3	286
12 T	29, 1b		x			4, 5D, 3	107+286
13 T	72, 79		x o	3	139	5D, 3	286
14 T	27, 81		x			5D, 3	286
15 T	72, 79		x o	3	139	5D, 3	286
16 T	25, 79		x			5D, 3	286
17 T	35, 79		x o	3	139	5D, 3	286
18 T	80, 72					5D, 3	286
19 T	80, 72					5D, 3	286
20 T	36, 76					5D, 3	286
21 T	81, 72		x			5D, 3	286
22 T	71					5D, 3	286
23 T	71					5D, 3	286
24	42	o		3, 3	278	5E	147
25	82					4, 5D	107+147
SS 26	100	x o		3	139	5D, 5E	294
SS 27	100	x				5D, 5E	294
SS 28	100	x o		3	139	5D, 5E	294
SS 29	100	x				5D, 5E	294
SS 36	100	x o		3	139	5D, 5E	294
SS 37	100					5D, 5E	294
SS 38	100	x o		3	139	4,5D,5E	107+294
39 T	3,4	x	x			5D, 3	286
40 T	30	x o	x	3	139	5D, 3	286
41 T	26,75	x	x			5D, 3	286
42 T	26	x o	x	3	139	5D, 3	286
43 T	26	x	x			5D, 3	286
44 T	26	x o	x	3	139	5D, 3	286
45	66					5D	147
SS 46	100					5D, 5E	294
SS 47	68					5D, 5E	294
48 T	21	x				5D, 3	286

1988

ORBITER FLIGHT NO.	PAYLOAD NOS.	ORBITER RET.CAP.	ORBITER PLUS TUG RET.CAP.	PLANNED EVA NO.	PLANNED EVA TOT. TIME	UNSCHED. EVA NO.	UNSCHED. EVA TOT.TIME
1 T	1a,3,88					5D, 3	286
2	1a, 14	x				5D, 3	286
3 T	5,4,88					4, 5D,3	107+286
4	14	x o		3,1A,6B	409	5D	147
5	16, 18	x		6B,1C, 1D,6B	374	5D, 5D	294
6	16	x o		3,1A,6A	409	5D	147
7 T	54					5D, 3	286
8 T	78, 79		x o	3	139	5D, 3	286
9 T	78, 22		x			5D, 3	286
10 T	78,79,27		x o	3	139	5D, 3	286
11 T	78,79,27		x			5D, 3	286
12 T	79,72		x o	3	139	5D, 3	286
13 T	80, 72					5D, 3	286
14 T	28					5D, 3	286
15 T	29,80					5D, 3	286
16 T	35,81					4,5D,3	107+286
17 T	35,81					5D, 3	286
18 T	36, 76					5D, 3	286
19 T	70		x			5D, 3	286
20 T	70		x o	3	139	5D, 3	286
21 T	71					5D, 3	286
22 T	71					5D, 3	286
23	42	x		3	139	5E	147
SS 24	100	x o		3	139	5E, 5D	294
SS 25	100	x				5D, 5E	294
SS 26	100	x o		3	139	5D, 5E	294
SS 27	100	x				5D, 5E	294
SS 28	100	x o		3	139	5D, 5E	294
SS 29	100	x				4,5D,5E	107+294
SS 30	100	x o		3	139	5D, 5E	294
SS 31	100	x				5D, 5E	294
32 T	30	x o	x	3	139	5D, 3	286
33 T	21,75	x	x			5D, 3	286

ORBITER FLIGHT NO.	PAYLOAD NOS.	ORBITER RET.CAP.	ORBITER PLUS TUG RET.CAP.	PLANNED EVA NO.	PLANNED EVA TOT. TIME	UNSCHED. EVA NO.	UNSCHED. EVA TOT.TIME
1	1a,14,16			1C,1D	148	5D,5D,3	433
2	1a	x o		3	139	3	139
3 T	5,73					4,5D,3	107+286
5	13U,15D			3	139	5D,5E,3	433
6	14,18	x		6A,1A,1C, 6A	454	5D,5D	294
7	16	x o		3,1D,6B	329	5D	147
8	17					5D, 3	286
9	18	x		1A, 6B	270	5D	147
10	19					5D, 3	286
11 T	58					5D, 3	286
12 T	60-3					5D, 3	286
13 T	28				139	5D, 3	286
14 T	29, 79		x o	3		5D, 3	286
15 T	35, 79		x			5D, 3	286
16 T	35, 79		x o	3	139	5D, 3	286
17 T	79,80					4, 5D,3	107+286
18 T	70		x			5D, 3	286
19 T	80,81					5D, 3	286
20 T	71					5D, 3	286
21 T	72, 81		x o	3	139	5D, 3	286
22 T	74, 76		x			5D, 3	286
23 T	3, 4		x o	3	139	5D, 3	286
24	42	x o		3, 3	278	5D	147
25	83	x				5E	147
26	91	x o		3	139	5E	147
SS 27	100	x				5E, 5D	294
SS 28	100	x o		3	139	5D, 5E	294
SS 29	100	x				5D, 5E	294
SS 30	100	x o		3	139	4, 5D, 5E	107+294
SS 31	100					5D, 5E	294
SS 32	100					5D, 5E	294
40 T	30	x	x			5D, 3	286
41 T	85	x o	x	3	139	5D, 3	286
42 T	21,75	x	x			5D, 3	286
43 T	77	x o	x	3	139	4,5D,3	107+286
44 T	77	x	x			5D, 3	286
45 T	77	x o	x	3	139	5D, 3	286
46 T	77	x	x			5D, 3	286
47 T	77	x o	x	3	139	5D, 3	286
48 T	77	x	x			5D, 3	286
49 T	71					5D, 3	286

1990

ORBITER FLIGHT NO.	PAYLOAD NOS.	ORBITER RET.CAP.	ORBITER PLUS TUG RET.CAP.	PLANNED EVA NO.	PLANNED EVA TOT. TIME	UNSCHED. EVA NO.	UNSCHED. EVA TOT.TIME
1 T	5					5D,3	286
2	14,16	x		6B,1A,1C, 6C	454	5D,5D	294
3	14,18	x o		6C,3,1D,1A 6C	599	5D,5D	294
4	16,92	x		6A,1C,1C, 6A	368	5D,5E	294
5	18	x o		3,1A,6A	409	5D	147
6 T	51					5D, 3	286
7 T	51					4, 5D, 3	107+286
8 T	79,1b		x o	3	139	5D, 3	286
9 T	72, 1b		x			5D, 3	286
10 T	29, 72		x o	3	139	5D, 3	286
11 T	35, 79		x			5D, 3	286
12 T	35, 79		x o	3	139	5D, 3	286
13 T	79, 80					5D, 3	286
14 T	71					5D, 3	286
15 T	71					5D, 3	286
16 T	80, 81					5D, 3	286
17 T	22,76,81		x			5D,3	286
18	42	x	x	3	139	5E	147
19	82	x o	x	3	139	5D	147
SS 20	100	x				4,5D,5E	107+294
SS 21	100	x o		3	139	5D,5E	294
SS 22	100	x				5D, 5E	294
SS 23	100	x o		3	139	5D, 5E	294
SS 24	100	x				5D, 5E	294
SS 25	100	x o		3	139	5D, 5E	294
SS 26	100	x				5D, 5E	294
SS 31	100						
32 T	3, 4	x o	x	3	139	5D, 3	286
33 T	7, 30	x	x			4,5D,3	107+286
34 T	25, 75	x o	x	2	139	5D, 3	286
35 T	21	x	x			5D, 3	286
36	69					5D	147
SS 37	100					5D	147

NOTES:

(1) T - Indiates a recoverable Tug is used on that flight.

SS - Indicates a space station support flight.

(2) x - Indicates retrieval capability (from early analysis by Copeland).

o - Indicates this flight will retrieve a satellite (50% of those flights having retrieval capability).

APPENDIX D

PREBREATHING REQUIREMENTS

DESIGN INFORMATION ~~REQUEST~~ - RELEASE

MODEL (S) AND EFF. Prebreathing Data Summary For Use In The VMSC	DIR. NO. T-192-DIR-01		REV. A
Space Shuttle EVA/IVA Equipment Study	DATE 26 July 1972	PAGE 1	OF 12
SYSTEM	REF. G. O. NUMBER 3356-BA-1160		

Fill in block below for Information Request	Fill in block below for Information Release	
TO ____ GROUP ____	IN REPLY TO DIR. NUMBER None	
REQ. BY ____ GROUP ____	REL. TO R. L. Cox GROUP 3-52010	
REASON	PREPARED BY B. Webbon B.W DATE 7/26/72	CHECKED BY R. L. Cox RLC DATE 7/28/72
LTV ONLY ☐ BWR ☐ BUWEPS ☐ ☒ Below	GROUP APP. R. J. French RJF DATE 7/31/72	PROJ OFFICE R L Cox DATE 7/28/72

CC D. Boydston - NASA-MSC(2) J. Davis - Brooks AFB P. Wood R. French
D. Horrigan " " R. Cox J. Williams EC/LS Files (5)

DESIGN INFORMATION:

INTRODUCTION

An investigation of the pertinent data on prebreathing requirements for decompressions from a two gas atmosphere to final pressures ranging from about 3 psia to sea level was conducted as part of the VMSC space shuttle EVA/IVA equipment study. The purpose of the investigation was to determine the physiological requirements to prevent bends for various spacecraft and suit operating pressures. A further consideration was the effect of interruptions to the prebreathing cycle. These interruptions, during which the shuttle cabin's O_2-N_2 atmosphere would be breathed, could occur during the donning of the EVA/IVA equipment. The effect is to extend the prebreathing time but the time extension could be considerably greater than the interruption time due to the rapid resaturation of the body with nitrogen. This DIR summarizes the results of this investigation and presents curves for use later in the study.

TECHNICAL DISCUSSION

The effect of variations in the initial Orbiter cabin pressure on the final suit pressure is shown in Figure 1. This figure, which is taken from data in Reference 1, is based on an empirically modified analytical expression that is intended to predict the onset of bends symptoms. The boundaries of the general population range shown on the figure represent the threshold of expected symptoms. The figure is in good agreement with data for decompressions from 14.7 psia, that indicate that almost no subjects drawn from the general population will suffer bends following decompression to 25,000 feet (5.46 psia) while nearly all subjects will exhibit symptoms when decompressed below 3.47 psia (35,000 feet), particularly when exercising. The empirical data available for correlation for decompressions from initial pressures below standard sea level are much more limited. However, the limited data (Reference 1) are in agreement with the trend shown on the figure. The figure shows that reducing the Orbiter pressure to 11.7 psia (≈ 6,000 feet), which is greater than the cabin pressure in most commercial airliners, will allow the use of current suit pressure with almost no risk of bends for any subjects. The data are insufficient to allow firm recommendations for an optimum reduced Orbiter pressure. However, the advantages of using current low pressure suit technology with modifications only as required for increased mobility and comfort, ease of donning, longer lifetime, etc.; are sufficient to indicate further physiological research is required in this area. The relative advantages and disadvantages to the Orbiter vehicle and safety at a reduced cabin pressure should also be considered. An initial pressure of 14.7 psia will be assumed henceforth for all the data presented in this paper.

The prebreathing curves (Reference 2) shown in Figure 2 result from an analytical solution of equations describing both the diffusion of N_2 out of the body and the onset of bubble formation in the blood. The two different curves result from different assumptions on the initial size of a stable bubble. The curves are in agreement with other data presented in Reference 3 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. These curves are more conservative than the data shown in Figure 1 since they indicate that approximately 0.5 hour minimum prebreathing is required to decompress from sea level to 25,000 feet. However, the data points for U-2 flight operations indicate that actual flight operational experience is more in line with the data in Figure 1 (Reference 4).

It is well known that the susceptibility of individuals to the bends varies widely (References 5 and 6). It is possible to classify individuals into groups with similar susceptibility by examining factors such as age, the amount of body fat present, and the condition of the circulatory and respiratory system. Following such classification, the expected probability of bends can be estimated for each individual by utilizing data compiled for his group. Other data presented in Figure 3 (Reference 1) show this variation between groups classified according to age. Thus the curve that indicated 90% probability of no bends for the general population, actually corresponds to a much higher degree of protection for individuals in good physical condition. A physical examination, perhaps similar to that now required for experimenters on military aircraft, could be used to screen candidate experimenters and other passengers who have low expected tolerance to the bends (References 5 and 6).

Another factor that may be of particular importance in the case of emergency decompression is shown in Figure 4. This figure shows that in most cases bends symptoms don't appear for 15 to 20 minutes. This time interval is significant since it is greater than the expected duration of many credible emergencies, so that a low pressure emergency suit might be satisfactory with no prebreathing in some cases.

Figure 5 shows the influence of interruptions to prebreathing on the incidence of bends symptoms. 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 starting points of the curves assumes that 50% of the subjects would suffer bends symptoms with no prebreathing. This corresponds to a condition of mild exercise. Increasing the exercise rate tends to increase the incidence of bends symptoms.

Figure 6 shows a cross-plot of these same data. The curves show that the effect of interruptions is increased as the prebreathing time increases. This occurs because the incidence of symptoms is reduced as the prebreathing time is increased. However, since nitrogen is initially rapidly reabsorbed during the interruption, the expected incidence of symptoms also increased rapidly. This can also be seen in Figure 7. Figure 7 was calculated from Figure 5 by determining the time difference between each of the interrupted prebreathing curves and the continuous prebreathing curve for a given % incidence of symptoms. For example, 3 hours prebreathing corresponds to 19% incidence of symptoms following 1/2 hour of air breathing. 19% corresponds to 1.6 hours on the continuous prebreathing curve so that the time difference between curves is 1.4 hours. This and similarly derived points are plotted on Figure 7. This figure shows the prebreathing time lost when the denitrogenation period is interrupted by breathing air at sea level conditions. For example, if 3 hours prebreathing (which might be required for a 3.5 psia suit) was followed by 15 minutes of breathing air during final donning of the EVA/IVA equipment, the figure shows that about 50 additional minutes of prebreathing are required to regain the same level of bends protection. Figures 5, 6, and 7 were all compiled from data based on decompression from sea level to 3.5 psia O_2 final pressure. The prebreathing time lost as shown on Figure 7 should be conservative for decompressions to a higher final pressure or starting from a lower cabin pressure.

CONCLUSIONS

The baseline prebreathing curve to be used by VMSC is the lower limit of the shaded region shown on Figure 2. This curve represents a very high degree of certainty that none of the crewmen who are likely to fly in the shuttle, generally those in better physical condition than the general population as a whole, will suffer bends symptoms for the decompressions indicated. The effects of using the upper limit curve for suit pressures greater than 5 psia on items such as contingency concepts, prebreathing gas expendables and increasing the man-hour overhead for performing EVA will also be calculated for comparison. Consideration will also be given to the effects of reducing the Orbiter cabin pressure as shown in Figure 1. This has a significant impact on the suit technology required for shuttle operations, particularly for the case of contingencies involving cabin decompression. The final recommendations for suit and Orbiter pressures and prebreathing requirements will be made following this quantitative analysis. Since the physical condition and other requirements for the shuttle crewmen may be more stringent than those required for the experiments it is possible that the prebreathing time requirements may be different for each. Data presented in Reference 5 indicate that subjects having less than 12 kg of body fat, independent of the body's total mass, are unlikely to suffer bends symptoms. Thus a determination of the body fat content might be a useful screening criteria for candidate experimenters.

Since data showing the effects of interrupted prebreathing are apparently missing for decompression other than to 3.5 psia, and they are limited even for this case, Figure 7 will be used for all cases.

Further experimental work is required to more precisely determine the physiological parameters required for an accurate prediction of an individual's susceptibility to the bends. Data such as those shown in Figure 3 indicate that bends susceptibility generally increases with age. However, other factors such as the ratio of fat to lean mass in the body and deterioration of the respiratory and circulatory system also increase with age. The data are generally insufficient to determine precisely which parameters should be used for screening criteria. An additional related study to investigate the effects of prebreathing interruptions for higher final pressures is required.

REFERENCES

1) Decompression Sickness; W. B. Saunders Co.; Philadelphia & London; 1951.

2) Degner, E. A.; et al; "Dissolved Nitrogen and Bends in Oxygen-Nitrogen Mixtures During Exercise at Decreased Pressures", Aerospace Medicine; May 1965 pp 418-425

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

4) Meader, W. L.; "Decompression Sickness in High-Altitude Flight", Aerospace Medicine; March 1967.

5) Allen, T. H.; et al; "Body Fat, Denitrogenation and Decompression Sickness in Men Exercising After Abrupt Exposure to Altitude", Aerospace Medicine; May 1971.

6) Goldman, R. F.; "Physical Fitness, Flight Requirements and Age", Aerospace Medicine; June 1971.

FIGURE 1 EFFECT OF INITIAL CABIN PRESSURE ON SUIT PRESSURE WITHOUT PREBREATHING

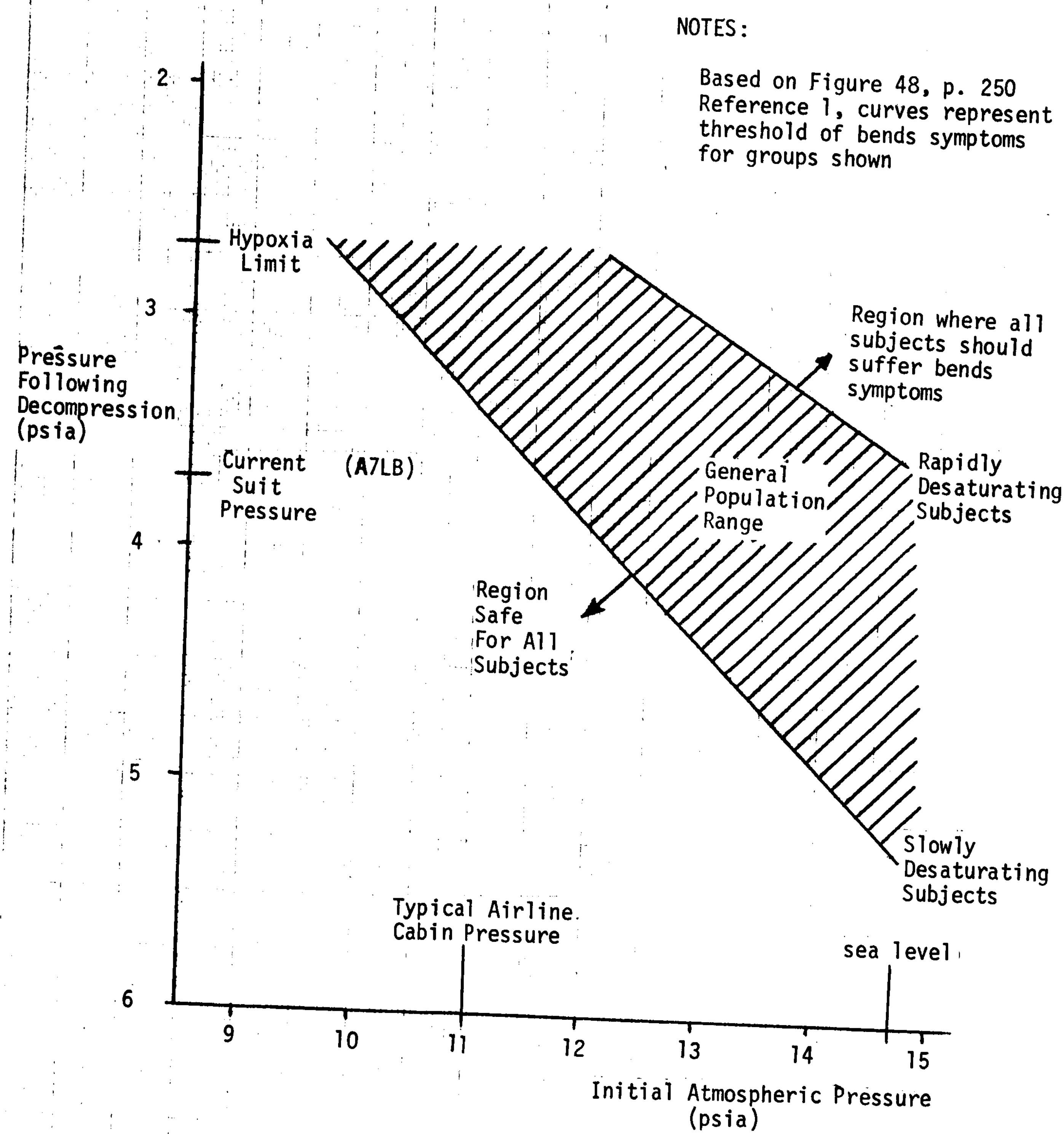
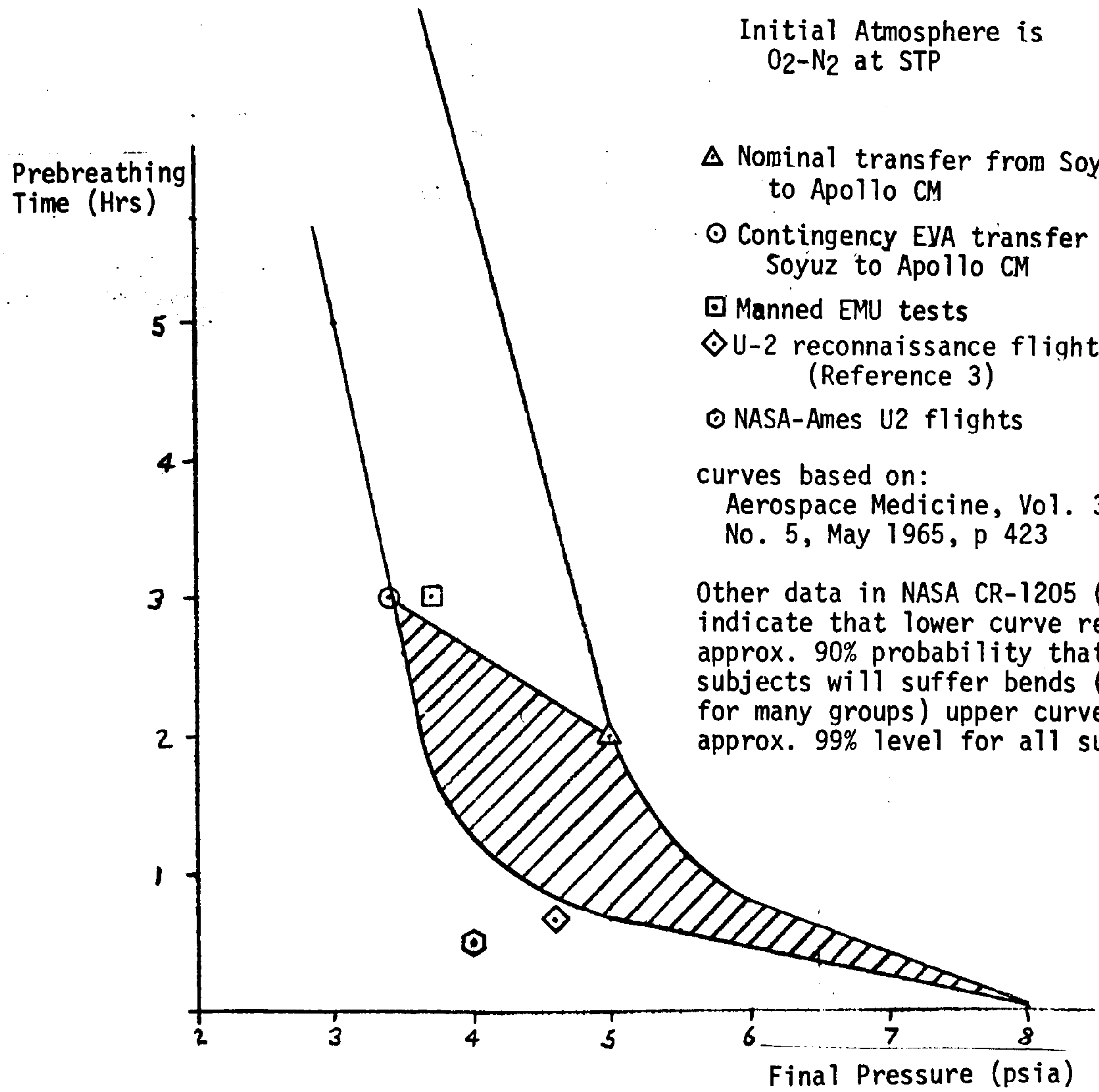


FIGURE 2

PREBREATHING TIME AS A FUNCTION OF SUIT PRESSURE



NOTES:

Initial Atmosphere is O_2-N_2 at STP

△ Nominal transfer from Soyuz to Apollo CM

⊙ Contingency EVA transfer from Soyuz to Apollo CM

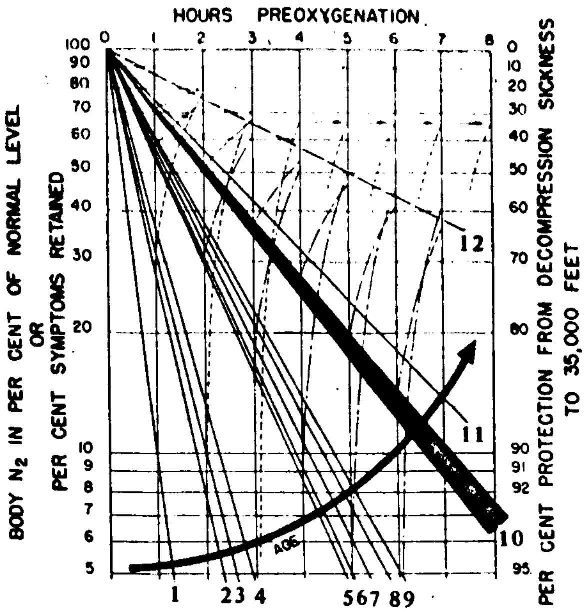
⊡ Manned EMU tests

◇ U-2 reconnaissance flights (Reference 3)

⊙ NASA-Ames U2 flights

curves based on:
Aerospace Medicine, Vol. 36, No. 5, May 1965, p 423

Other data in NASA CR-1205 (III) indicate that lower curve represents approx. 90% probability that no subjects will suffer bends (100% for many groups) upper curve is approx. 99% level for all subjects.



Compilation of All Data Bearing on Rate of Protection by Preoxygenation and Rate of Nitrogen Loss from Critical Tissues

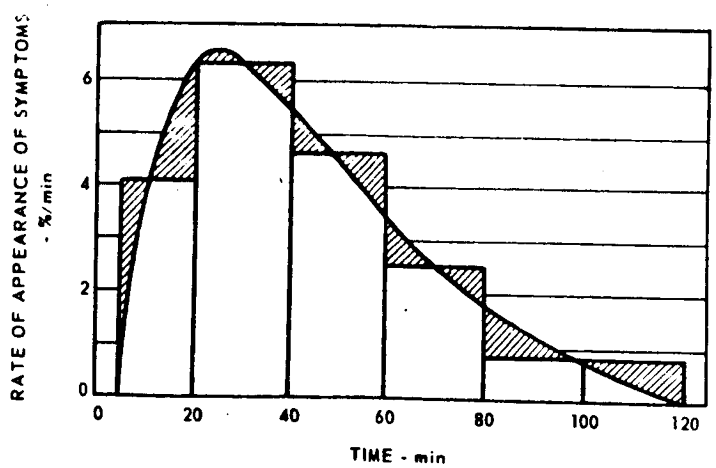
Curves 6, 7, and 9 represent data of three different investigators on same age group.

Legend

1. 18 yr old group (fastest curve) - 35,000 ft.
2. 18 yr old group (average curve) - 35,000 ft.
3. <24 yr old group (fastest curve) - 35,000 ft.
4. 17 yr old group (average curve) - 38,000 ft.
5. 27 yr old group (average curve) - 38,000 ft.
6. <24 yr old group (average curve) - 35,000 ft.
7. <24 yr old group (average curve) - 35,000 ft.
8. Mixed group average protection rate - 35,000 ft.
9. <24 yr old group (average curve) - 35,000 ft.
10. <24 yr old group (slowest curve) - 35,000 ft.
11. 35 yr old group (average curve) - 38,000 ft.
12. Single subject (slowest curve) - 35,000 ft.

(35,000 ft. = 3.5 psia)

FIGURE 3



Rate of Appearance of New Symptoms

FIGURE 4

Reference 3

FIGURE 5

INCIDENCE OF BENDS SYMPTOMS FOR INTERRUPTED PREBREATHING

NOTES:

- Decompression from sea level to 3.5 psia
- 50% of subjects would experience symptoms with no prebreathing (mild exercise)
- % incidence = 0.5 (100-n) where n = % probable protection

Curves constructed from data in: NASA CR-1205 (III), pp 12-5 to 12-9, and Tables 12-6 and 12-7

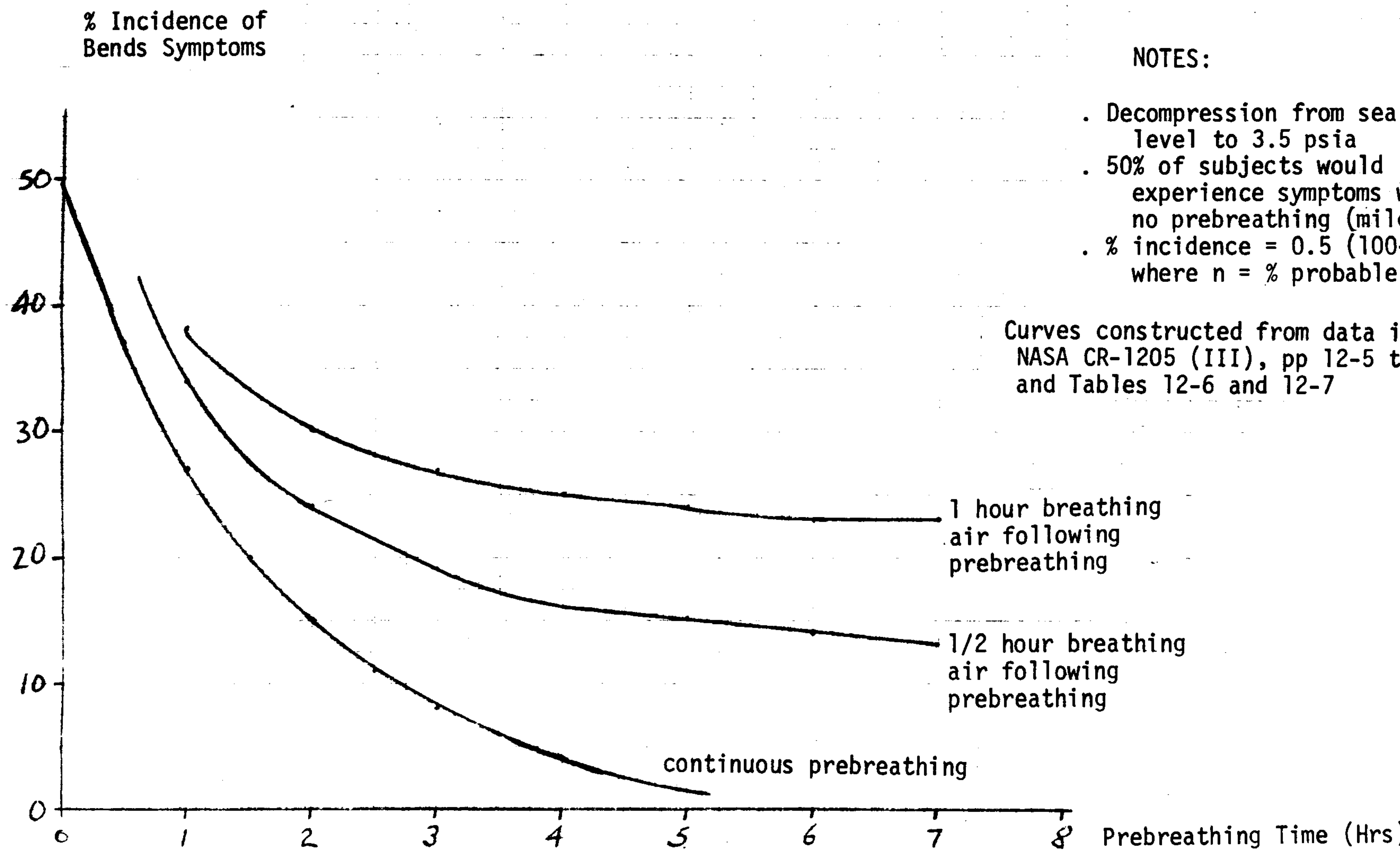
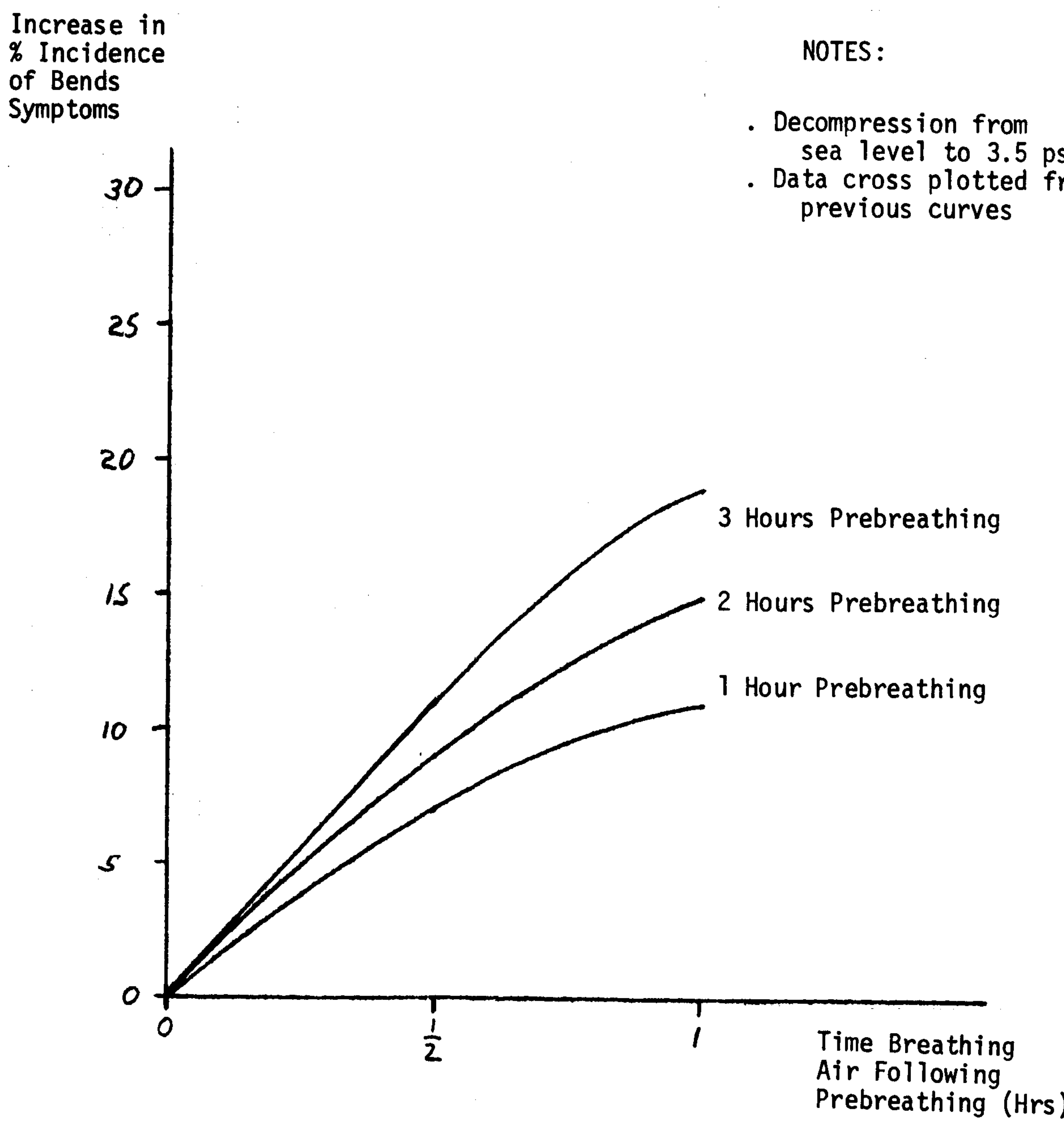


FIGURE 6

INCREASE IN BENDS INCIDENCE CAUSED BY INTERRUPTED PREBREATHING

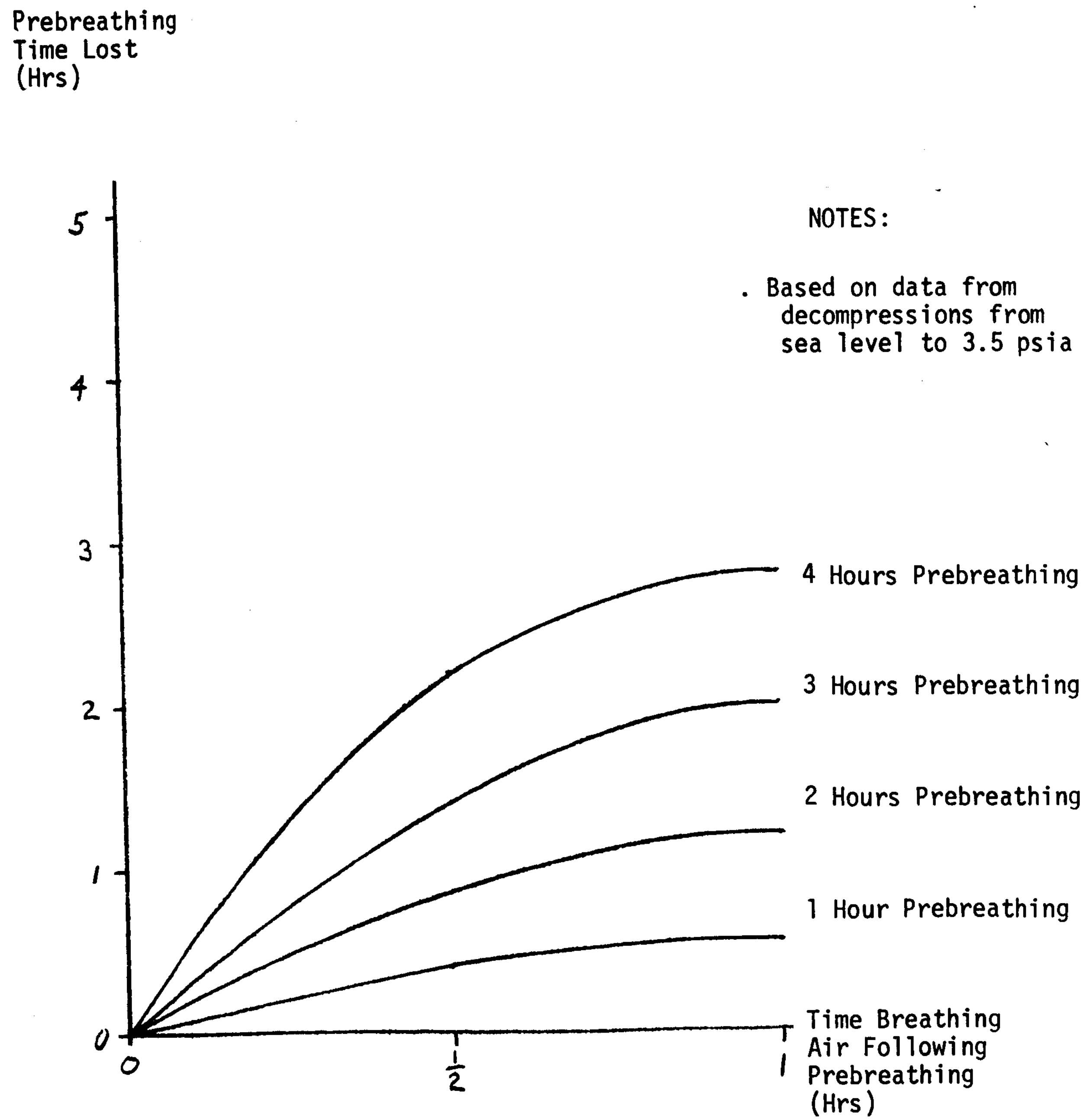


NOTES:

- Decompression from sea level to 3.5 psia
- Data cross plotted from previous curves

FIGURE 7

PREBREATHING TIME LOST BY BREATHING AIR FOLLOWING DENITROGENATION



NOTES:

. Based on data from decompressions from sea level to 3.5 psia