EO66(06-96)

IN-12

92945

National Aeronautics and
Space Administration
George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

LAUNCH DEPLOYMENT ASSEMBLY EXTRAVEHICULAR ACTIVITY NEUTRAL BUOYANCY DEVELOPMENT TEST REPORT

Prepared by:
Science and Engineering Directorate
Mission Operations Laboratory
Training and Crew Systems Division
Systems Branch

Launch Deployment Assembly
Extravehicular Activity
Neutral Buoyancy
Development Test Report

Prepared By:

4-22-96

T. Loughead/Sigmatech
Test Coordinator

Date:

Approved By:

22 April 1996

C. Dischinger/EO66
Test Conductor
Systems Branch

Date:

4/24/96

C. Lewis/EO61
Chief, Training and Crew Systems Division

Date:

4-24-96

G. Hullett–Smith/EO66
Chief, Systems Branch

Date:

TABLE OF CONTENTS

Page

TABLE OF CONTENTS i

LIST OF TABLES iii

LIST OF FIGURES iv

ACRONYMS AND ABBREVIATIONS vi

1.0 INTRODUCTION 1

1.1 Purpose 1
  1.1.1 Test Objectives 2
    1.1.1.1 Primary Test Objectives 2
    1.1.1.2 Secondary Test Objectives 2
1.2 Scope 3

2.0 HARDWARE DESCRIPTION 4

2.1 Overview 4
2.2 Space Station RMS 7
2.3 PDGF Rigid Umbilical Assembly 10
2.4 UHF Antenna and Deployment Assembly 11
2.5 Lab Cradle Assembly 11
2.6 SSRMS Bolt Stowage 12
2.7 Utility Cable Stowage Facility 12
2.8 Module to Truss Support Attachment Structure-Passive 12
2.9 Launch Support Assembly 12
2.10 Flight Releasable Grapple Fixture 13

3.0 NEUTRAL BUOYANCY HARDWARE DESCRIPTION 14

3.1 Overview 14
3.2 SSRMS Mockup 15
3.3 PDGF Rigid Umbilical Mockup 16
3.4 UHF Antenna Mockup 16
3.5 LCA Mockup 16
3.6 Bolt Stowage Facility Mockup 17
3.7 Utility Cable Stowage Mockup 17
3.8 MTSAS-P Mockup 17
3.9 LSA Mockup 17
3.10 FRGF Mockup 18
3.11 Crew Aids 18
  3.11.1 Handrails 18
  3.11.2 WIFs 18
  3.11.3 APFRs 18

4.0 LDP DEVELOPMENTAL TEST METHODOLOGY....20

4.1 Test Subjects....20
4.2 Test Setting....20
4.3 Test Data....24
4.4 Test Readiness Reviews....24
4.5 One-G Walk-Through....24
4.6 Test Procedures....24
4.6.1 Pre-Test Briefing....25
4.6.2 Test Conduct....25
4.6.3 APFR Settings....25
4.6.4 Debriefing....26
4.6.5 Quick Look Test Reports....26

5.0 TEST RESULTS AND DISCUSSION....27

5.1 SSRMS Related Tasks....27
5.1.1 SSRMS Boom Deployment....27
5.1.2 EDF Drive....31
5.1.3 Clutch Manipulation....34
5.1.4 FSEGF Operations....36
5.2 Payload Element Removal Tasks....39
5.2.1 SSRMS Utility Cable Deployment and Stowage....39
5.2.2 Removal and Stowage of the SSRMS Launch Restraint Bolt Assemblies....39
5.2.3 UHF Antenna and Deployment Assembly Removal....45
5.2.4 PDGF Rigid Umbilical Removal....48
5.2.5 LDA-Provided Translation Envelopes....52
5.2.6 Use of SRMS Support as Mobile Platform for Primary Test Objectives....52
5.2.7 Laboratory Cradle Assembly (LCA) Access....53
5.2.8 EDF Drive Operations With SSRMS Booms Stowed....54
5.2.9 APFR Installation at WIF locations....55

Appendix A: Table of Mockup Classes....A-1

Appendix B: Launch Deployment Assembly Developmental Test Procedures....B-1

Appendix C: APFR Settings Listed by Task and Foot Restraint Position....C-1

Appendix D: 6A Launch Deployment Assembly Crew Consensus Report....D-1

LIST OF TABLES

Table 2.1-1. Gross EVA Tasks Listed by Component and EVA Location 6

Table 4.1-1. Summary of Test Type, Date, Conductors, and Subjects 20

LIST OF FIGURES

Figure 2.1-1. Launch Deployment Assembly Hardware Configuration 5

Figure 2.2-1. Space Station Remote Manipulator System in the Deployed (unfolded) Configuration 7

Figure 2.2-3. Space Station Remote Manipulator System Tie-Down Bolt 9

Figure 2.3-1. The PDGF Rigid Umbilical Assembly in the Stowed Position 10

Figure 2.4-1 The UHF Antenna and Deployment Assembly in the Stowed (folded) Position 11

Figure 3.1-1. Neutral Buoyancy Mockup of the Launch Deployment Assembly 15

Figure 4.2-1. Configuration of the Launch Deployment Assembly and Associated Hardware in the Neutral Buoyancy Simulator–Side View 21

Figure 4.2-2. Configuration of the Launch Deployment Assembly and Associated Hardware in the Neutral Buoyancy Simulator–Top View 22

Figure 4.2-3. Neutral Buoyancy Mockup of the Launch Deployment Assembly in Cargo Bay 23

Figure 5.1-1. Rotating the SSRMS Booms by Utilizing a PFR on the SRMS 28

Figure 5.1-2. Manually Raising the Folded SSRMS Booms from Position F3 Using the Spar Micro Tool 29

Figure 5.1-3. Manually Raising the Folded SSRMS Booms from Position F3 Using the ORU Handling Tool 30

Figure 5.1.2-1. Accessing the Lower Starboard EDFs using Position F3 32

Figure 5.1.2-2 Accessing the Lower Port EDFs using Position F3 with the APFR Footplate Rotated 180° 33

Figure 5.1.2-3. Accessing the Upper EDFs from Position F1 34

Figure 5.1.3-1. Manipulating the Joint Clutches on the SSRMS Utilizing a PFR on the SRMS 35

Figure 5.1.4-1. Accessing the FSEGF Upper Starboard Hook-Link Using an Essex Wrench 37

Figure 5.1.4-2. Accessing the FSEGF Inner Port Hook-Link Using a Power Tool 38

Figure 5.2.2-1. Loosening the Tie-Down Bolts from the APFR on the SRMS 40

Figure 5.2.2-2. Removal of the Tie-Down Bolts from the APFR on the SRMS 41

Figure 5.2.2-3. Removal of the Tie-Down Bolts from Position F3 42

Figure 5.2.2-4. Hand-off of the Tie-Down Bolts from Position F3 43

Figure 5.2.2-5. Loosening the Tie-Down Bolts from Positon A1 Using a Power Tool and Right Angle Drive 44

Figure 5.2.3-1. Loosening the Bolts on the UHF Antenna and Deployment Assembly from Position F2. 46

Figure 5.2.3-2. Loosening the Aft Bolt on the UHF Antenna and Deployment Assembly from Position A3 47

Figure 5.2.3-3. Loosening the Bolts on the UHF Antenna and Deployment Assembly from Position F1. 48

Figure 5.2.4-1. Loosening the Forward EVA Bolt on the PDGF Rigid Umbilical from Position F4 49

Figure 5.2.4-2. Loosening the Aft EVA Bolt on the PDGF Rigid Umbilical from Position A2 50

Figure 5.2.4-3 Loosening the Center EVA Bolt on the PDGF Rigid Umbilical from Position A1 51

Figure 5.2.4-4. Unstowing the PDGF Rigid Umbilical from Position A1 52

Figure 5.2.7-1. Removal of a Candidate Lab Cradle Assembly by Two Crew Members 54

Figure 5.2.9-1. Installing APFR in Position F4 Using Provided Handrail 56

ACRONYMS AND ABBREVIATIONS

APFR .... Articulating Portable Foot Restraint
BRT .... Body Restraint Tether
CSA .... Canadian Space Agency
EDF .... Expandable Diameter Fastener
EMU .... Extravehicular Mobility Unit
EVA .... Extravehicular Activity
FRGF .... Flight Releasable Grapple Fixture
FSEGF .... Flight Support Equipment Grapple Fixture
ISS .... International Space Station
IVA .... Intravehicular Activity
JSC .... Johnson Space Center
LCA .... Lab Cradle Assembly
LDA .... Launch Deployment Assembly
LEE .... Latching End Effector
LDP .... Launch Deployment Package
LSA .... Launch Support Assembly
MSFC .... George C. Marshall Space Flight Center
MTSAS-P .... Module to Truss Structure Attachment System - Passive
NASA .... National Aeronautics and Space Administration
NBS .... Neutral Buoyancy Simulator
OHT .... Micro ORU Handling Tool
ORU .... Orbital Replacement Unit
PDGF .... Power Data Grapple Fixture
PVC .... Polyvinyl Chloride
SLP .... Spacelab Logistics Pallet
SRMS .... Shuttle Remote Manipulator System
SSRMS .... Space Station Remote Manipulator System
STS .... Shuttle Transportation System
UHF .... Ultra High Frequency
WETF .... Weightless Environment Training Facility
WIF .... Worksite Interface

1.0 INTRODUCTION

1.1 Purpose

This test evaluated the Launch Deployment Assembly (LDA) design for Extravehicular Activity (EVA) work sites (setup, ingress, egress), reach and visual access, and translation required for cargo item removal. As part of the LDA design, this document describes the method and results of the LDA EVA Neutral Buoyancy Development Test to ensure that the LDA hardware supports the deployment of the cargo items from the pallet. This document includes the test objectives, flight and mockup hardware descriptions, descriptions of procedures and data collection used in the testing, and the results of the development test at the National Aeronautics and Space Administrations (NASA) Marshall Space Flight Center (MSFC) Neutral Buoyancy Simulator (NBS).

1.1.1 Test Objectives

1.1.1.1 Primary Test Objectives

The following is a summary of the test objectives as listed in the MSFC-RQMT-2590 (Launch Deployment Assembly Extravehicular Activity Neutral Buoyancy Development Test Requirements).

- Evaluation of the LDA-provided work envelopes and crew aid locations for the Space Station Remote Manipulator System (SSRMS) boom unstowing, including deployment, expandable diameter fastener (EDF) drive, clutch manipulation, and Flight Support Equipment Grapple Fixture (FSEGF) operations, as established in Space Station Remote Manipulator System, Weightless Environment Training Facility Test Report (JSC 37671).
- Evaluation of the LDA-provided work envelopes and crew aid locations for the SSRMS utility cable deployment and stowage.
- Evaluation of the LDA-provided work envelopes and crew aid locations for the removal and stowage of the SSRMS launch restraint bolt assemblies Tie-down bolts), including evaluation of the hand-off procedure.
- Evaluation of the LDA-provided work envelopes and crew aid locations for the UHF Antenna and Deployment Assembly removal.
- Evaluation of the LDA-provided work envelopes and crew aid locations for the Power and Data Grapple Fixture (PDGF) Rigid Umbilical removal.
- Evaluation of the LDA-provided translation envelopes.
- Evaluation of work site setup, ingress, egress, reach, and visual access of foot restraints.

1.1.1.2 Secondary Test Objectives

- Evaluation of the above primary test objectives using SRMS support to provide the appropriate envelopes.
- Evaluation of the LDA-provided work envelopes and crew aid locations for the Laboratory Cradle Assembly (LCA) access.
- Evaluation of work, reach, and visual envelopes required for the EDF drive operations while the SSRMS booms are in a stowed position.

1.2 Scope

This test was designed to simulate specific operational procedures required for cargo item release during the non-deployed and deployed pallet scenarios. The term "non-deployed pallet" refers to the condition when the Launch Deployment Package (LDP) is located in the Shuttle Cargo Bay prior to removal by the Shuttle Remote Manipulator System (SRMS). The term "deployed pallet" refers to the condition when the LDP has been moved to the International Space Station (ISS) by the SRMS. The non-deployed pallet operational simulations include access to the LCA and release of the Ulta High Frequency (UHF) Antenna and Deployment Assembly and the Rigid Umbilical from their respective mounting adapters. The deployed pallet operational simulations include two of the SSRMS deployment tasks. One is the SSRMS utility cable deployment and return stowage to the LDA-provided restraint assembly. Another is the SSRMS launch restraint bolt assembly removal and stowage. In addition, access to the worksites for boom deployment, EDF drive, clutch operations, and Flight Releasable Grapple Fixture (FRGF) release were examined during this phase of the test.

Results of the Weightless Environment Training Facility (WETF) development testing of the SSRMS, WETF Test Report (JSC 37671) were used as the basis for the development test to assess EVA access envelopes and locations of handrails, foot restraint sockets, and translation paths for LDA tasks related to the SSRMS operations.

Testing was the responsibility of NASA MSFC. Participants included personnel from the NASA Johnson Space Center (JSC), Canadian Space Agency (CSA), Support Contractors, and Product Groups 1 and 3.

2.0 HARDWARE DESCRIPTION

2.1 Overview

The LDA consists of a number of cargo items mounted to a Spacelab Logistics Pallet (SLP) by means of a support structure, the Launch Support Assembly (LSA), and associated mounting adapters (see Figure 2.1-1). The individual cargo items, consisting of the LCA, the UHF Antenna and Deployment Assembly, the PDGF Rigid Umbilical Assembly, and the SSRMS will be transported to the ISS in the Cargo Bay of the Space Shuttle. Mission support components are required to support the EVA operations, support the removal of the pallet from the cargo bay, support the attachment of the pallet to the LCA by mating to the Module to Truss Structure Attachment System - Passive (MTSAS-P), provide stowage for return to Earth of the SSRMS Tie-Down Bolts, and provide stowage of the SSRMS Utility Cable for launch and landing. Additional mission support components are the FRGF and adapter, EVA handrails, tether points, and Worksite Interfaces (WIFs). The latter are the sockets for mounting the EVA foot restraints—Articulating Portable Foot Restraint (APFRs). The positions of WIFs are identified in Figure 2.1-1. Those with an "F" designation are on the forward end of the element, while A1-A4 are on the aft end of the element.

The following is a brief description of each of the above mentioned cargo items and equipment as well as a description of the activities associated with each of the cargo elements. Table 2.2-1 summarizes the location, component name, EVA activities, and location of activity (Cargo Bay or ISS Laboratory Module) for these tasks. The activities listed are only those that were tested in the Development Test Series under the purview of the LDP.

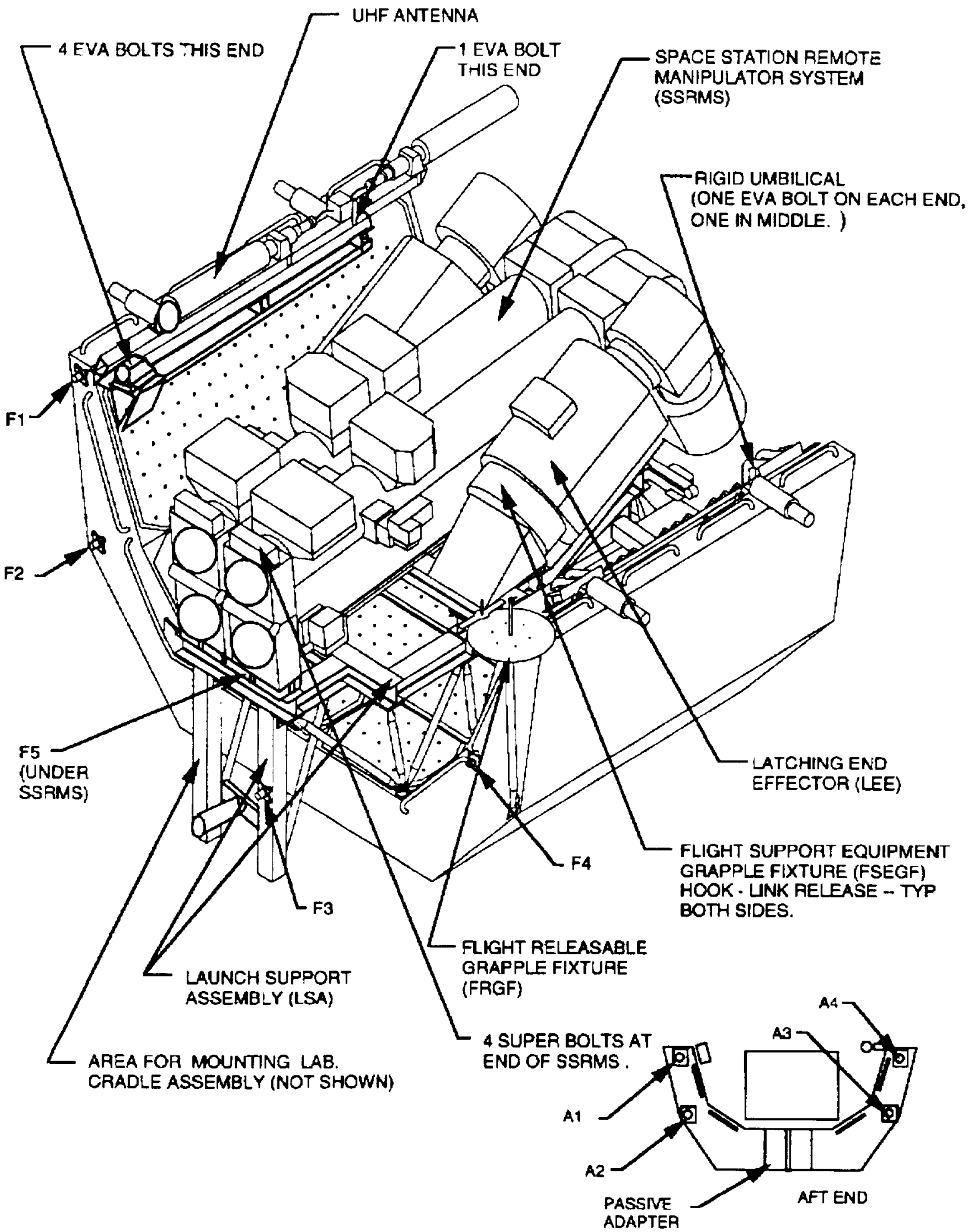

Figure 2.1-1. Launch Deployment Assembly Hardware Configuration

Table 2.1-1. Gross EVA Tasks Listed by Component and EVA Location

COMPONENT	EVA ACTIVITY	LOCATION
Lab Cradle Assy.	Unstow from LSA Adapter	STS Cargo Bay
UHF Antenna Deployment Assy.	Unstow from LSA Adapter	STS Cargo Bay
Rigid Umbilical Assy.	Unstow from LSA Adapter	STS Cargo Bay
Utility Cable	Unstow from launch position on LCA/Pallet	ISS Laboratory Module
Utility Cable	Restow into launch positioned on LCA/Pallet	ISS Laboratory Module
SSRMS	Remove and stow eight Tie-Down Bolts from SSRMS	ISS Laboratory Module
SSRMS	Access Clutch Release from each SSRMS joint	ISS Laboratory Module
SSRMS	Access four each Expandable Diameter Fasteners on both Hinged Joints	ISS Laboratory Module
SSRMS	Access Actuators to unlatch FSEGF from SSRMS End Effectors	Laboratory
FRGF	Contingency Release of FRGF	STS Cargo Bay

2.2 Space Station RMS

The SSRMS is an articulated robotic arm (Figure 2.2-1), similar to the SRMS in the Space Shuttle, which will be used on the ISS to manipulate equipment located on the exterior of the ISS. During launch, the booms of the SSRMS will be folded in the center (Figure 2.2-2), and secured to the LSA by eight tie-down bolts (Figure 2.2-3). Each bolt measures approximately four feet in length, and four bolts will be used at each end. The ends of the unfolded SSRMS, each of which is equipped with a Latching End Effector (LEE), will be secured to FSEGFs equipped with hook-links which will secure the LEEs to the LSA during launch. The hook links must be manually retracted prior to the SSRMSs stepping off the LSA to the ISS. The port FSEGF also will provide electrical power and data interfaces that will be connected to a cable terminated in connectors that will mate with outlets located on the ISS. This utility cable will be used for keep-alive power prior to deployment. During step-off operations, the connectors will power the joint motors and associated equipment and allow data transfer. After deployment and installation of the SSRMS on the ISS, the pallet and LSA are returned to the Shuttle Cargo Bay by the SRMS for return to Earth.

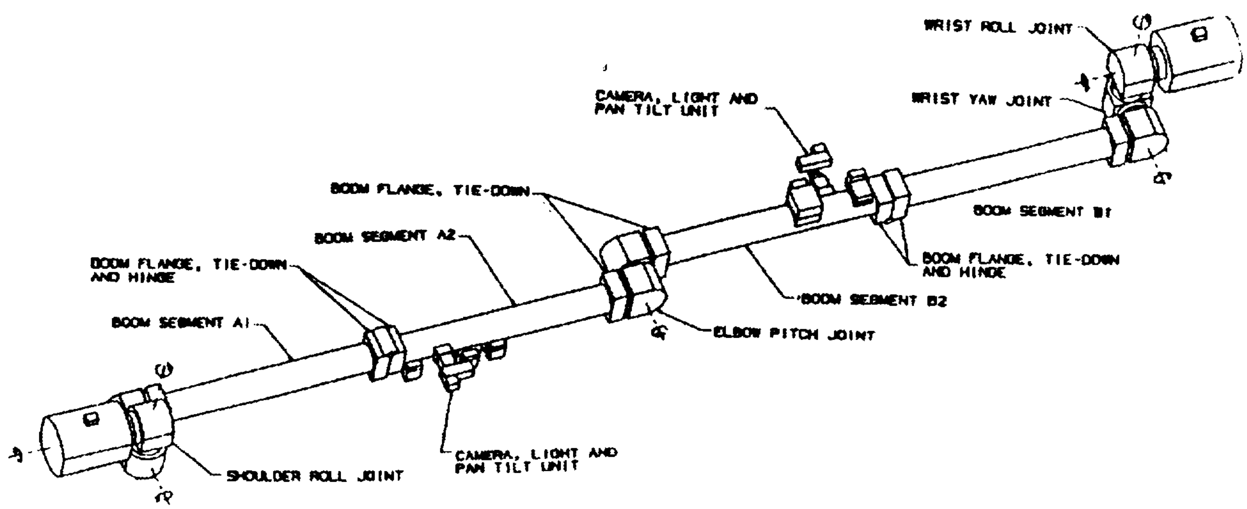

Figure 2.2-1. Space Station Remote Manipulator System in the Deployed (unfolded) Configuration

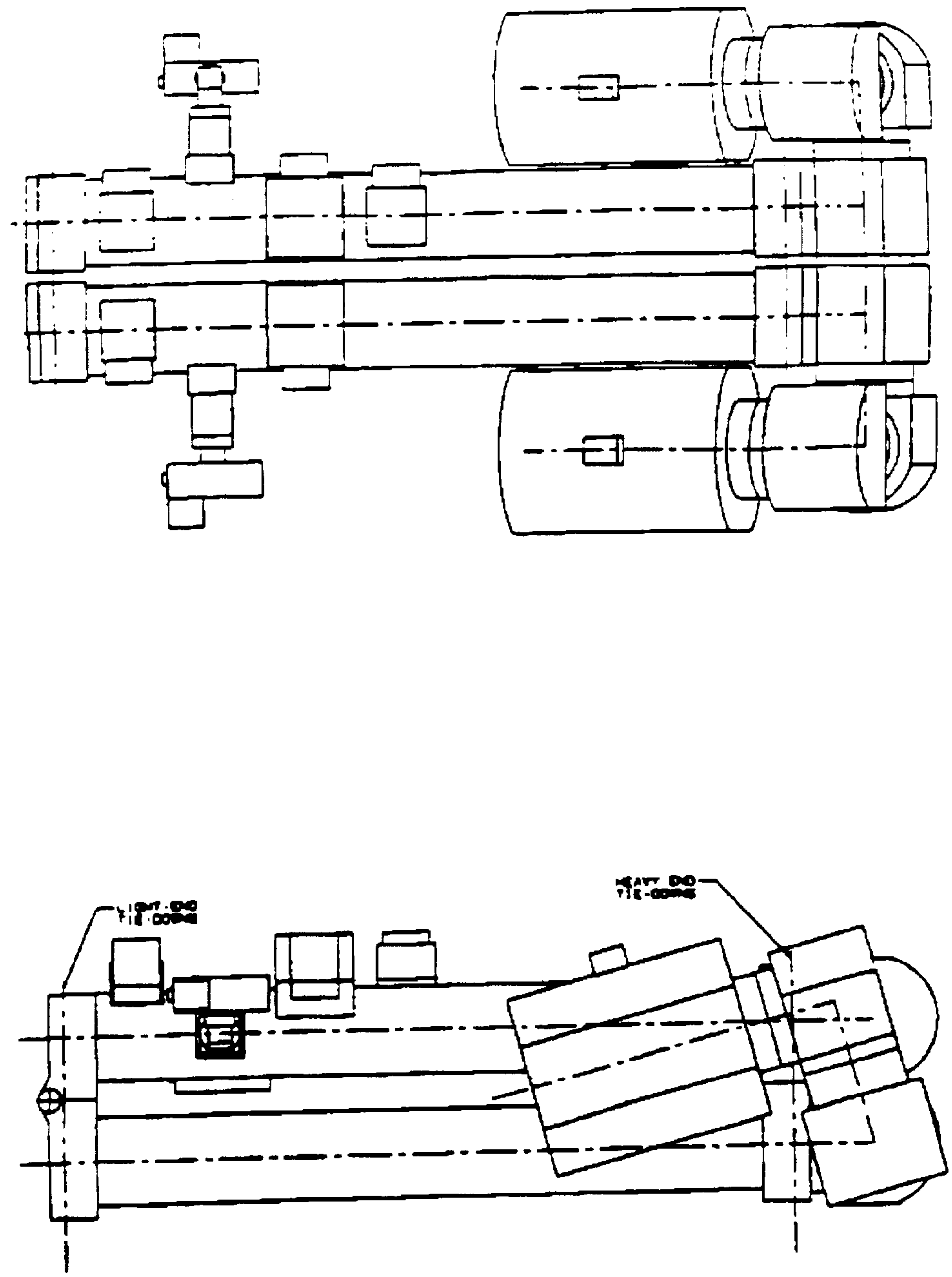

Figure 2.2-2. Space Station Remote Manipulator System in the Pre-Deployment (folded) Configuration

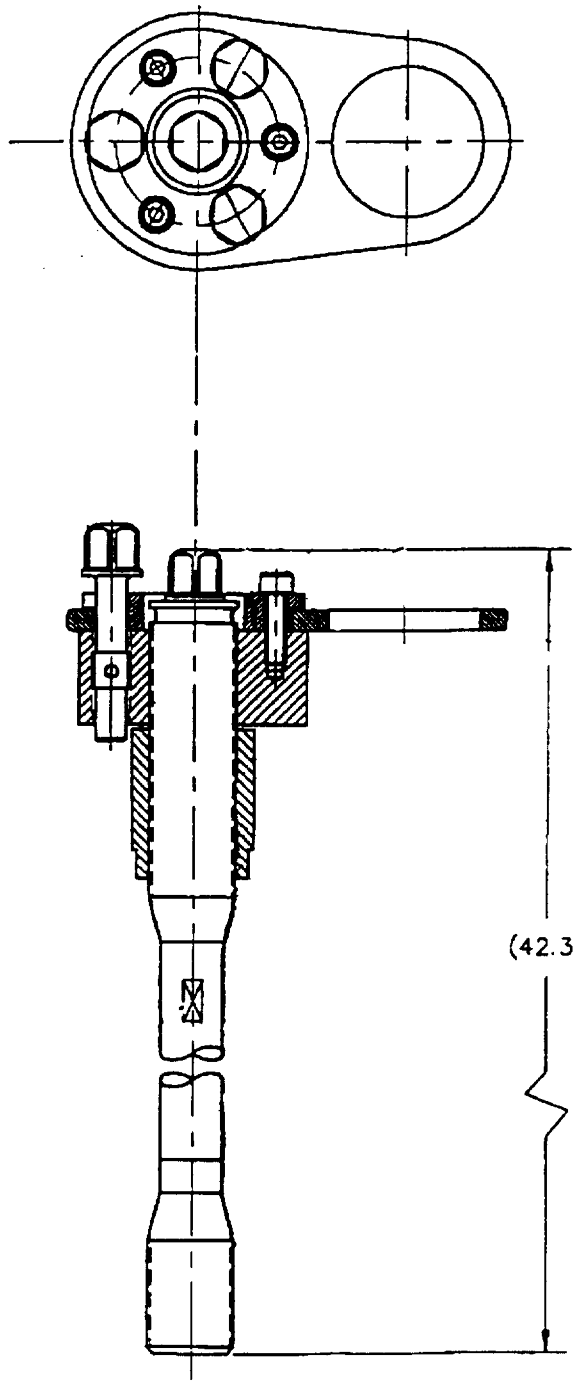

Figure 2.2-3. Space Station Remote Manipulator System Tie-Down Bolt
A total of eight Tie-Down bolts are used,
four at each end in the folded configuration.

2.3 PDGF Rigid Umbilical Assembly

The PDGF Rigid Umbilical Assembly (Figure 2.3-1) consists of four electrical cables mounted to a rigid structure resembling a channel measuring approximately (12.0" h x 23.2" w x 95.2" l) and will serve as an external jumper to carry power and data to the PDGF and other payload and utility services on the external surface of the ISS. Included in the PDGF Rigid Umbilical Assembly and located near each end are two stanchions which are equipped with handholds, tether points, and captive fasteners. The fasteners located in the stanchions and a central EVA bolt are used to secure the assembly to an adapter mounted on pallet trunnion interfaces. The assembly will be unstowed from the mounting adapter by loosening the three captive fasteners and translating the assembly to the ISS where it will be secured by the captive fasteners located at either end in the stanchions. The cables mounted to the Rigid Umbilical Assembly will then be demated from dummy connectors, unfolded, and mated to electrical connectors mounted to the ISS.

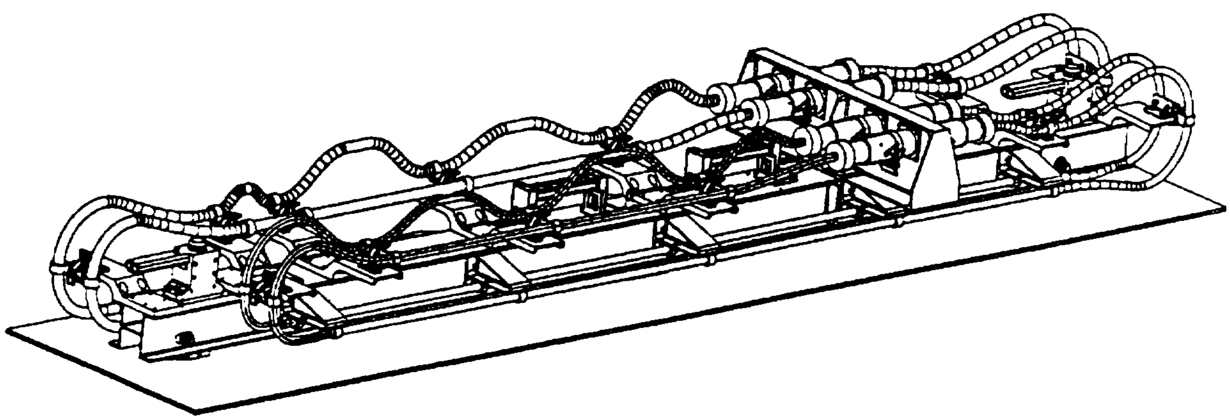

Figure 2.3-1. The PDGF Rigid Umbilical Assembly in the Stowed Position

2.4 UHF Antenna and Deployment Assembly

The UHF Antenna and Deployment Assembly (Figure 2.4-1) are a pair of high gain antennas mounted to a mast, and will deploy when the mast is rotated to the vertical position in relation to the base. The antenna assembly and boom will be secured to an adapter mounted to an SLP trunnion interface through the use of seven EVA-type captive fasteners. Four of these bolts will secure the base of the antenna to the forward end of the adapter, two more will be located near the center of gravity, and the remaining captive fastener will be located near the end of the boom. After translation to the ISS, the assembly will be bolted to the ISS, raised to a vertical position, and secured by a pip pin.

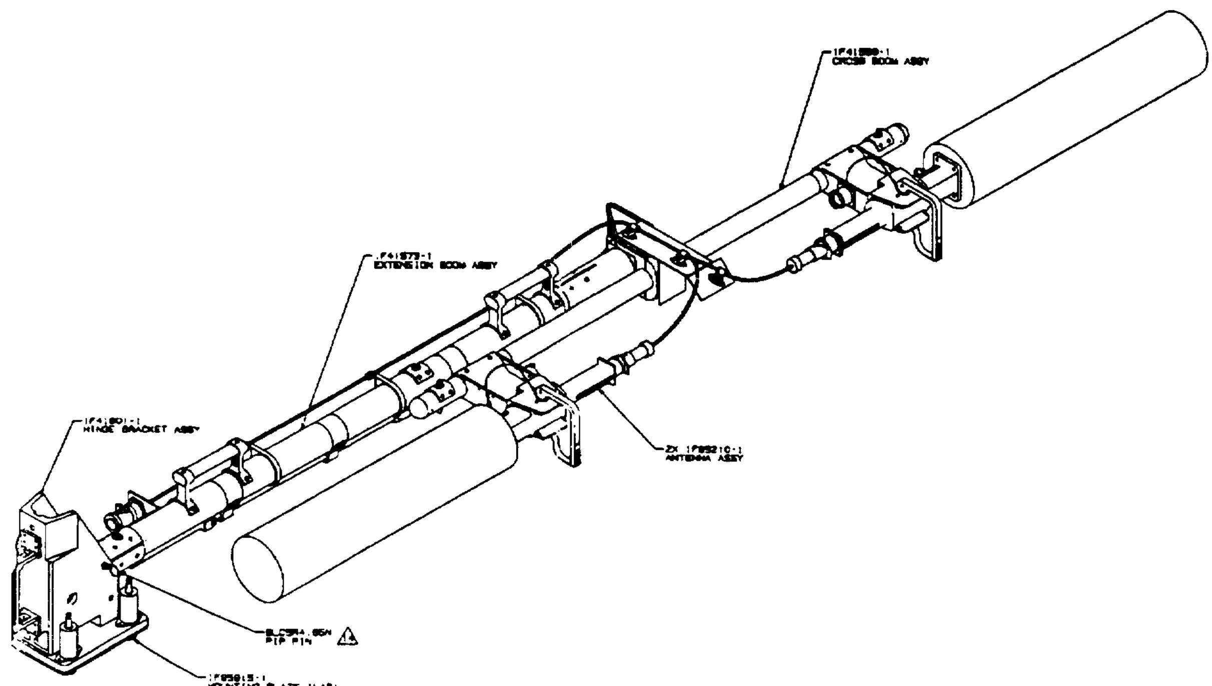

Figure 2.4-1 The UHF Antenna and Deployment Assembly in the Stowed (folded) Position

2.5 Lab Cradle Assembly

The LCA is a rectangular structure measuring approximately 40" x 40", that contains a motorized capture mechanism, structures to mount the LSA to an ISS interface, and alignment devices designed to secure the SLP and other structures to the ISS by latching to a bar on a *passive* interface (the Module to Truss Structure Attachment System-Passive; MTSAS-P). The LCA will be

secured to the forward end of the pallet by means of adapters that mount the structure to the LSA through the use of captive bolts. The LCA will be removed from the mounting adapters and translated from the cargo bay for installation on the ISS. After the LCA is mounted to the ISS, a cable attached to the LCA will be mated to connectors located on the ISS. This cable powers the latching mechanism on the LCA.

2.6 SSRMS Bolt Stowage

The SSRMS Bolt Stowage and return device is a series of eight tubes mounted under the PDGF Rigid Umbilical Assembly mounting adapter and will be used to store the tie-down bolts for return to Earth after deployment of the SSRMS. Each of the eight bolts will fit in one of the tubes and will be secured by a lid.

2.7 Utility Cable Stowage Facility

The Utility Cable Stowage Facility will stow the Utility Cable during the launch and return to Earth. The Utility Cable will be used to power the SSRMS for thermal protection prior to deployment. During stepping-off operations it will provide power for the joint motors, computers, and video equipment, as well as allow transmission of video and positional signals.

2.8 Module to Truss Support Attachment Structure-Passive

The MTSAS-P is a passive interface to the LCA and will be mounted to the Aft frame of the SLP through a series of struts mounted to the SLP Interface Points. The MTSAS-P will remain with the SLP and return to Earth at the end of the mission.

2.9 Launch Support Assembly

The LSA is a passive structural assembly that supports the SSRMS during launch and deployment operations. The LSA is considered Flight Support Equipment. The LSA will be mounted to and supported in the SLP by a series of tubular struts that mount to the standard SLP Hard Points. The LSA also provides mounting surfaces and structural support for WIFs and hand holds.

2.10 Flight Releasable Grapple Fixture

The FRGF is similar to a standard SRMS grapple fixture except that it is equipped with a method

whereby the FRGF can be demated from the SRMS End Effector by an EVA crew member in the event of failure of the SRMS End Effector. This activity is considered a contingency operation.

3.0 NEUTRAL BUOYANCY HARDWARE DESCRIPTION

3.1 Overview

The hardware used in the Neutral Buoyancy Developmental Tests of the LDA (Figure 3.1-1) consisted of class IIB mockups (see Appendix A: Table of Mockup Classes) of the SSRMS, UHF Antenna, and Rigid Umbilical. The cargo elements were mounted to a Spacelab Pallet mockup equipped with handrails and trunnions and which contained a class IIIB mockup of the LSA. The Spacelab Pallet was also equipped with class IA WIFs which had been modified to accept pip pins to secure the class IIB mockups of the two APFRs used. The FRGF and LCA were class IIIC mockups. The entire assembly was mounted in a full-scale mockup of the Space Shuttle Cargo Bay equipped with a functioning model of the SRMS arm. The aft one-fourth of the cargo bay mockup had been removed and a class IIIC mockup representing a portion of the ISS was attached using a class IIB mockup of the MTSAS-P and a second, older version of the LCA. This arrangement allowed both in-bay and out-of-bay operations to be performed without changing hardware configuration. The following is a description of each of the above-mentioned cargo items and crew aids along with a description of major deviations between the mockups and flight equipment.

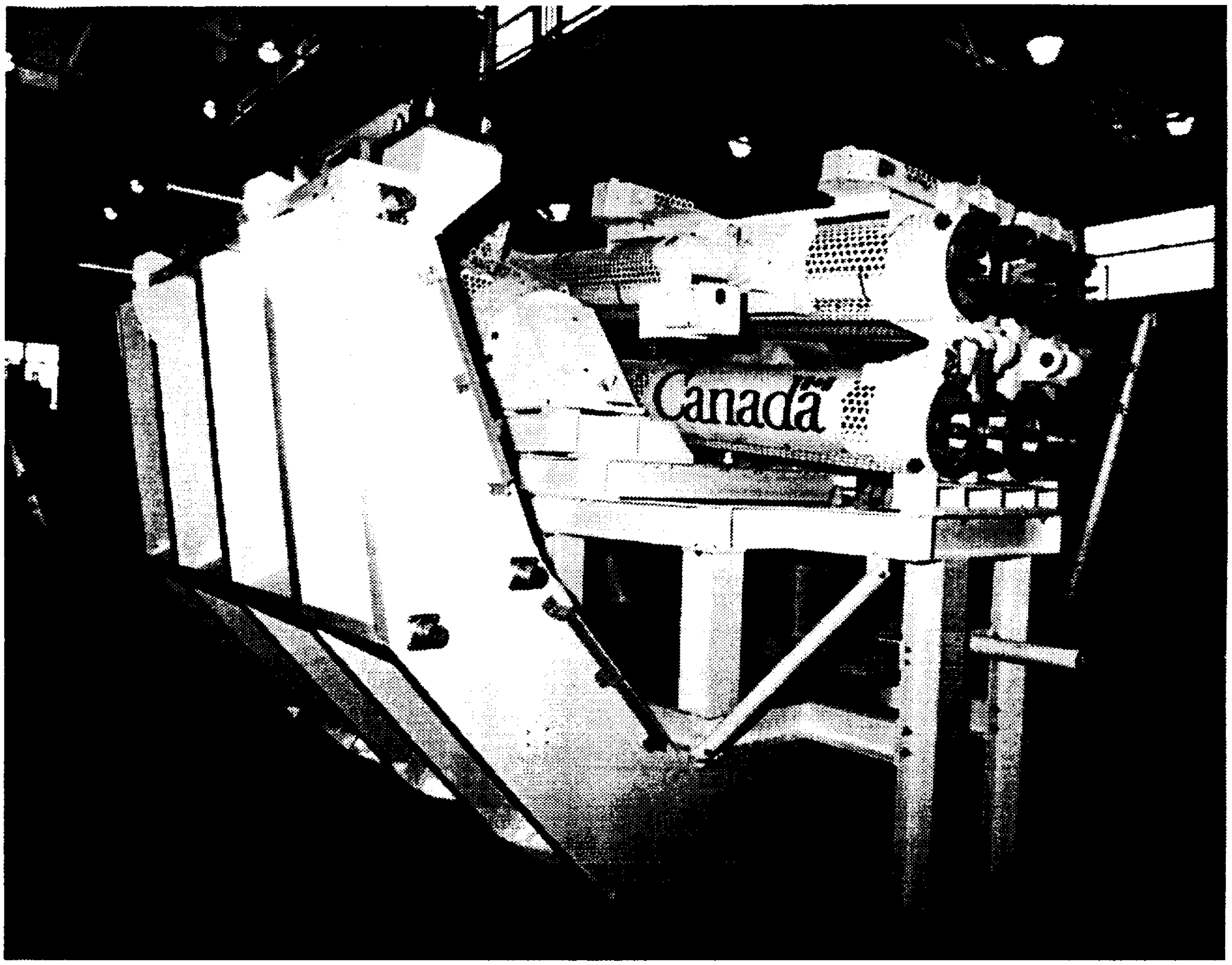

Figure 3.1-1. Neutral Buoyancy Mockup of the Launch Deployment Assembly

3.2 SSRMS Mockup

The SSRMS mockup was previously used for the verification and developmental testing of the SSRMS deployment and maintenance tasks; the tests were performed in the WETF at JSC in July and September 1992. The booms of the SSRMS mockup deployed in the same manner as the flight model and can be secured in different angles of elevation for reach envelope and geometric boundary evaluations. Orbital Replacement Unit (ORU) volumetric mockups were located on the mockup, as were non-functioning moveable clutch release levers. The tie-down bolts, which were stainless steel, were primarily used to maintain alignment of the mockup during shipping and for demonstrating access to the location of the EVA interfaces. They were not neutrally buoyant. The location of the tie-down bolts approximated those of the flight unit, although a more mature design has jackscrews (see Figure 2.2-3) to provide additional tension to the bolts. For testing hand-off feasibility, tie-down bolts were represented by volumetric mockups fabricated of polyvinyl chloride (PVC) and provided with flexible tether points. These mockups were light

weight and did not require flotation devices. The EDFs used to secure the halves of the booms on the flight unit were functional, but the mockup drive hex was 9/16" instead of 7/16" (the standard for EVA bolts). In addition, the braided-wire EDF retainers were frayed and judged hazardous to the integrity of the Extravehicular Mobility Unit (EMU) gloves and to safety divers. Therefore, the EDFs were not handled by suited subjects; access to them was examined.

3.3 PDGF Rigid Umbilical Mockup

The PDGF Rigid Umbilical mockup was a class IIB volumetric representation which was equipped with cables and realistic, though non-functional, connectors. The crew interfaces were flight-like, with the exception of the handholds on the stanchions which were located approximately two inches lower than the flight versions due to a spacer being left out of the stanchion assembly. After consultation with crew subjects, this was not considered significant, although it did result in less clearance for a gloved hand. The EVA-type bolts were high-fidelity and used the same thread series as flight. Much of the floatation for making the mockup neutral was located internally. The external flotation did not interfere with access to the bolts or handholds.

3.4 UHF Antenna Mockup

The UHF antenna mockup was a class IIB volumetric representation which had internal floatation cells. The mockup was constructed of PVC with the exception of seven realistic EVA bolts. A tubular member not found in the flight hardware was added between the antenna elements to increase structural integrity. This addition was marked as a "keep-out" zone, as were the two cylindrical antenna elements. Three handholds were added to the mockup prior to the tests. The handholds at the center of gravity and on the base were in close approximation to the flight unit. The third EVA handhold (again, not present in the current flight design) was added prior to the Crew Tests and was approximately two feet in length. The entire structure measured approximately 16.5" h x 21.3" w x 176.6" l.

3.5 LCA Mockup

The LCA mockup was provided by Boeing Huntsville as a concept and was volumetric in nature. No EVA bolts were furnished with the mockup. Two flight-like handholds were placed on the mockup prior to the test; there were no known handrails in the flight system. Two mating cylinders, approximating the size of an ISS Keel Pin, were located on the base of the LCA and the forward end of the LSA. These cylinders served to hold the LCA in the approximate position for launch. A

volumetric projection on the starboard side of the LCA mockup represented the conceptual design of a strut which would attach to a ring on the ISS module.

3.6 Bolt Stowage Facility Mockup

The Bolt Stowage Facility was represented by a series of eight aluminum tubes welded between the support structure for the PDGF Rigid Umbilical and the SLP. The tubes were volumetric representations; the design of the method for securing the tie-down bolts while in orbit or for the return to Earth was immature and not mocked up.

3.7 Utility Cable Stowage Mockup

A Utility Cable Stowage mockup was not available due to the immaturity of the design of the flight unit. However, it was expected to take the form of a series of EVA Cable Clamps terminating in four dummy bulkhead connectors. These articles are expected to be located on the aft frame of the SLP/LDA near the MTSAS-P or on the interior aft port SLP wall. Another concept has the dummy connectors located on a structural plate on the aft end of the LSA.

3.8 MTSAS-P Mockup

The MTSAS-P mockup was volumetric and was mounted to the SLP aft end frame in a realistic representation. This mockup was bolted to an older version of the LCA, supplied by McDonnell Douglas Aerospace, which was then bolted to a mockup representing a section of the ISS. The section of ISS was equipped with a bulkhead upon which was mounted six connector mockups. The effect was to provide a viable method for evaluating reach envelopes for access to the connectors located on the ISS.

3.9 LSA Mockup

The LSA mockup was a high fidelity representation of the flight unit with the exception of several vertical members which were used to mount the structure in the SLP mockup. No flight-like internal struts were provided. However strut mockups were mounted in the approximate locations on either end of the assembly as a "keep-out" barrier and for use by the subjects as translation aids.

3.10 FRGF Mockup

The FRGF mockup was a medium fidelity non-functioning representation of the flight unit which was primarily used as a physical barrier and translation aid of opportunity by the test subjects. The Neutral Buoyancy FRGF was secured to the SLP in approximately the same location as the flight unit and was equipped with a flight-like support structure. The FRGF was not equipped with EVA release interfaces.

3.11 Crew Aids

Crew Aids consisted of handrails, handholds, and WIFs. Other items such as tethers, wrenches, power tools, and cargo handling devices such as the micro handling tool were standard items or were conceptual and are expected to be available for EVA in the near future. The use of the latter crew aids was not a formal part of the test, but was treated as additional informal evaluation data.

3.11.1 Handrails

The handrails were of two types: those furnished with the Cargo Bay and SLP mockups, and those furnished by MSFC as part of the SLP/LSA mockups. The former were high fidelity representations which had been used on numerous occasions for other tests. The latter handrails and handholds were constructed in the “dog bone” style which will be used on the ISS and is defined in EVA Standard ICD SSP 30256:001E. The location of the handrails was determined prior to the tests through an analysis of EVA tasks and expected translation paths.

3.11.2 WIFs

The eight WIFs used were on loan from JSC and were high fidelity flight-like units, each of which had been drilled through the cylindrical portion to accept a .25" dia. pip pin. The pip pins were used to retain the APFRs in the sockets. A side-mount WIF was used at socket location F5; the top-mount type was used at the other socket locations. The locations of the WIFs were on the Pallet Attach Points on the SLP with the exception of F3 and F5 (see Figure 2.2-1). A3 was moved after engineering run E1 (see Results - Section 5.0).

3.11.3 APFRs

Three APFRs were used for the tests: two functional models were fully articulating, and the third was a neutrally buoyant model used only for evaluating the placement of handholds

provided for installation of the APFRs in the WIFs. Of the functional APFRs, one (APFR 43) was high fidelity and employed flight-like EVA latches to adjust the settings. The other unit (APFR 44) was not flight-like in three respects: the method for adjusting the settings was to use pip pins, the pitch labeling was reversed with respect to flight-like, and all settings were not labeled. Both APFR 43 and APFR 44 used pip pins through the stings which insert into the WIFs to secure the units rather than the retractable detents found on the flight units.

4.0 LDP DEVELOPMENTAL TEST METHODOLOGY

4.1 Test Subjects

A total of eight test subjects were used—two from MSFC for the SCUBA runs and Engineering tests, and the other six Astronauts from JSC who participated in the three crew tests. Table 4.1-1 summarizes the type of test, date of tests, and subjects.

Table 4.1-1. Summary of Test Type, Date, Conductors, and Subjects

Test Type	Date	Test Conductor	Test Subjects
SCUBA	8 Nov. 1995 (AM & PM)	Tom Loughead	Charlie Dischinger Al English
SCUBA	9 Nov. 1995 (AM & PM)	Tom Loughead	Charlie Dischinger Al English
Engineering (E1)	13 Nov. 1995	Tom Loughead	Charlie Dischinger Al English
Engineering (E2)	14 Nov. 1995	Tom Loughead	Charlie Dischinger Al English
Crew (C1)	16 Nov. 1995	Charlie Dischinger	Carl Waltz Jay Apt
Crew (C2)	17 Nov. 1995	Charlie Dischinger	Mark Lee Jim Voss
Crew (C3)	20 Nov. 1995	Charlie Dischinger	Jeff Wisoff Wendy Lawrence

4.2 Test Setting

All of the Developmental Tests were performed in the NBS, Building 4705, located at MSFC. Figure 4.2-1 and Figure 4.2-2 illustrate the setup of the mockup equipment in the facility. Figure 4.2-3 is a photograph of the test setup.

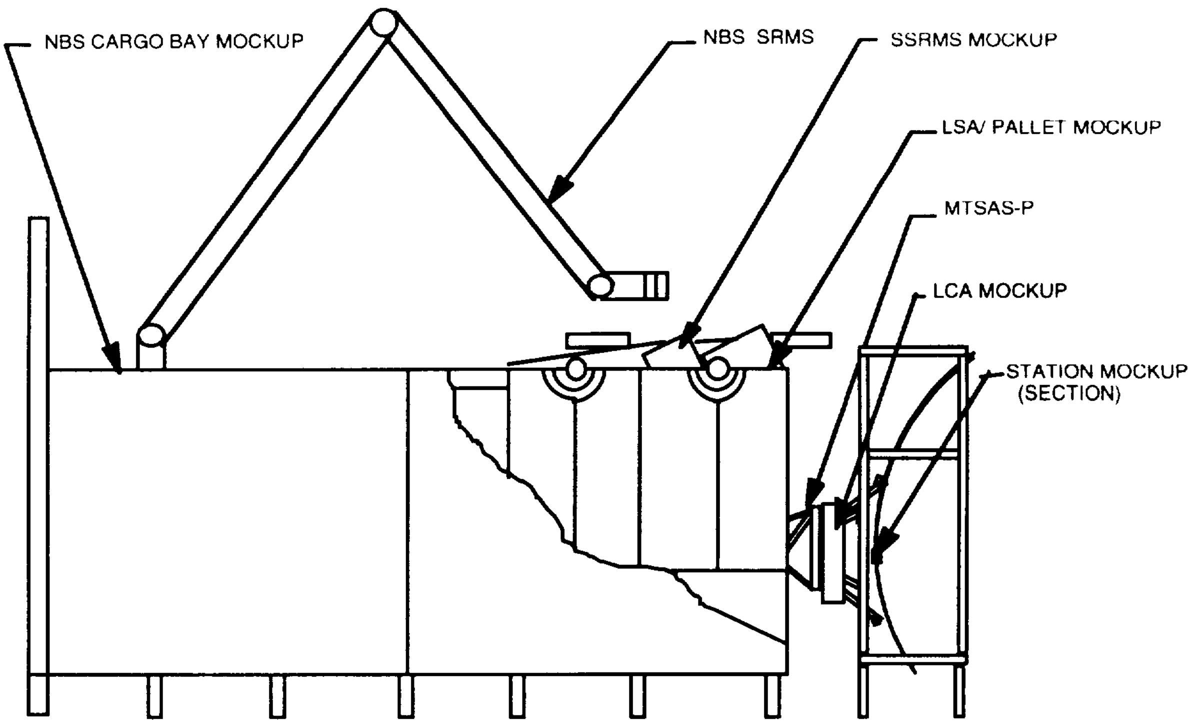

Figure 4.2-1. Configuration of the Launch Deployment Assembly and Associated Hardware in the Neutral Buoyancy Simulator–Side View

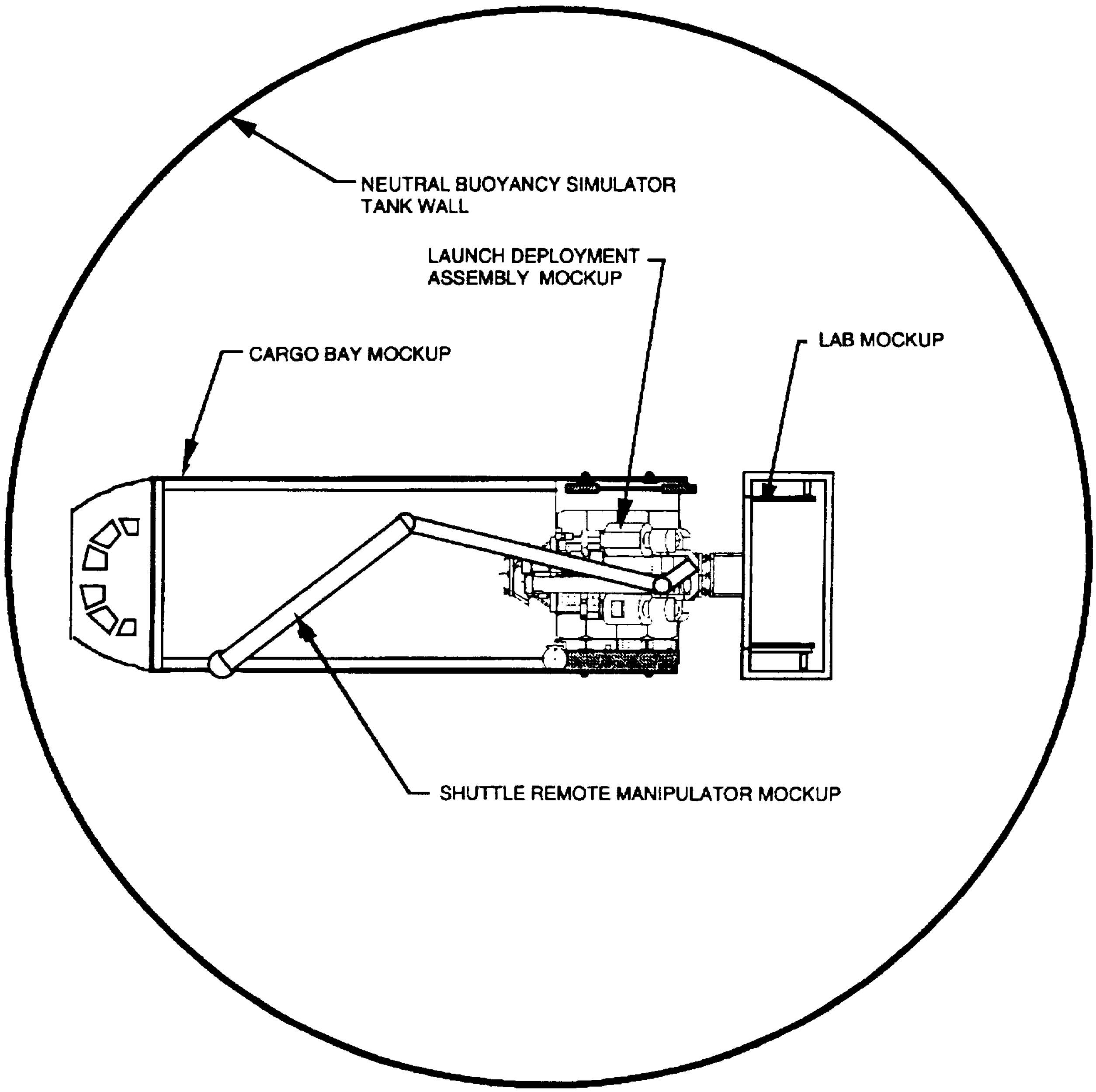

Figure 4.2-2. Configuration of the Launch Deployment Assembly and Associated Hardware in the Neutral Buoyancy Simulator–Top View

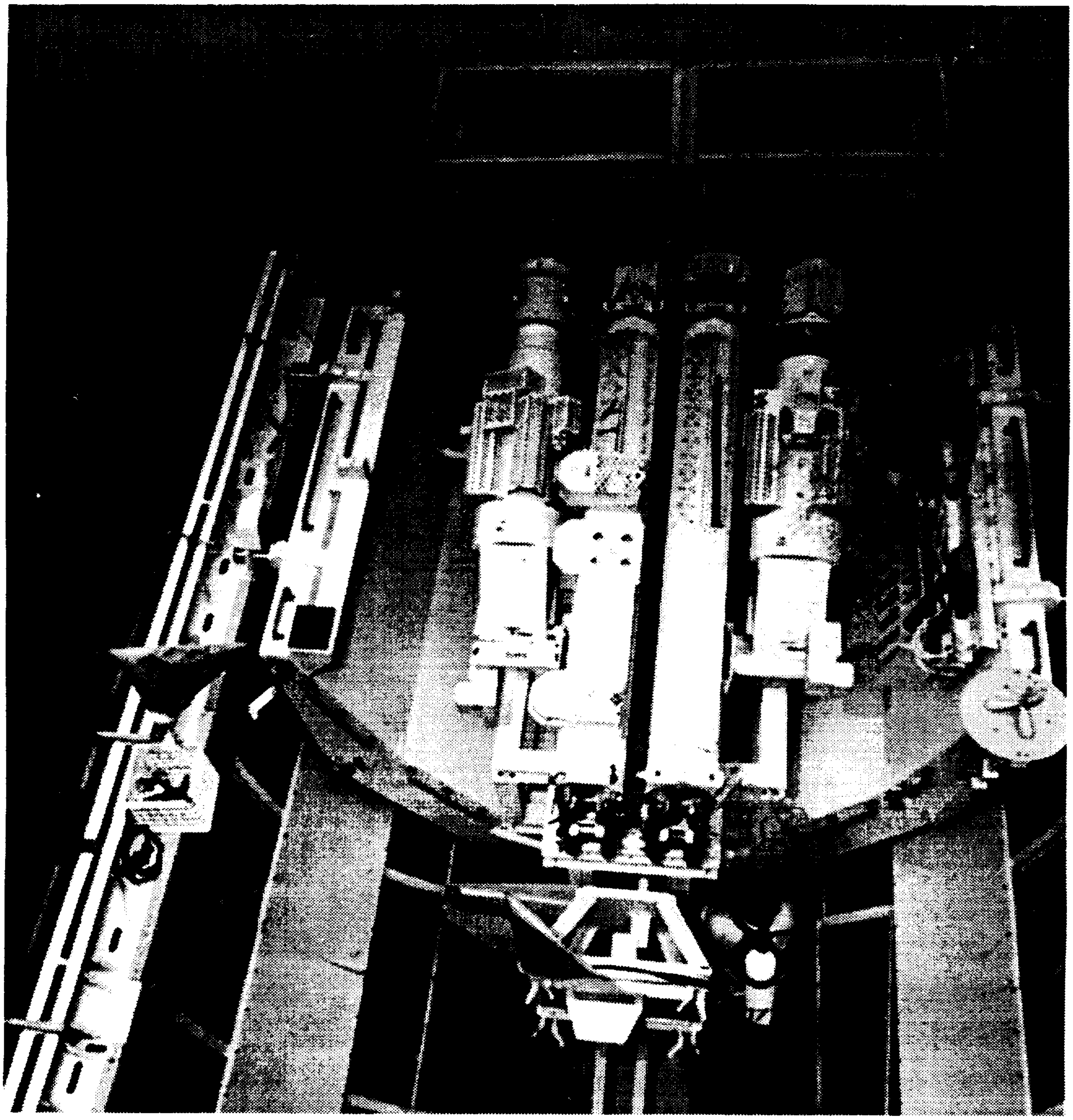

Figure 4.2-3. Neutral Buoyancy Mockup of the Launch Deployment Assembly in Cargo Bay

In this photograph, the UHF antenna assembly has been removed from its stowage position on the left side of the pallet.

4.3 Test Data

Data collection consisted of still and video images and recorded crew comments. Central Standard Time was recorded on the video images, allowing for the synchronization of events and elapsed time measurement. In addition, video images could be captured and printed by the test conductor. Two important sources of data were the crew comments captured during the debriefs (see Test Procedures, Section 4.4) and the Crew Consensus Report (see Results, Section 5.0 and Appendix D).

4.4 Test Readiness Reviews

Two Test Readiness Reviews (TRR) were held before the test series began. Neither TRR revealed any concerns which would affect the conduction of the LDA Developmental Test Series.

The first TRR was held on 31 October 1995, and was attended primarily by cargo item developers with representatives from McDonnell Douglas Aircraft Corporation (MDAC), JSC, Lockheed, and MSFC. The purpose of this TRR was to close out any issues concerning the hardware design that might impact the Neutral Buoyancy Tests. This review was chaired by the 6A SLP Chief Engineer.

A second TRR was held on 2 November 1995, which consisted primarily of those persons (chiefly from MSFC) with an interest in facility concerns (safety, structures, diver support, etc.) and test procedure preparedness. This review was chaired by the Test Director.

4.5 One-G Walk-Through

A One-G walk-through was held on 31 October 1995, to familiarize the personnel with the Neutral Buoyancy Hardware. The walk-through was held in the high bay area of Bldg. 4705 and consisted of the full assembly of the LDA mounted to the SLP.

4.6 Test Procedures

In general, the following procedures were used for all tests. The SCUBA runs were not recorded and were used to familiarize the test subjects, utility divers, and other test personnel with the hardware and procedures.

4.6.1 Pre-Test Briefing

Prior to each Test session, participants were briefed on the goals of the session. These briefings were co-chaired by the Test Conductor and Test Director. A summary of the day's activities was given and any current issues such as changes to general procedures were discussed. In addition to the Test Subjects, the Safety and Utility Divers were given an overview and any special instructions for the day's test. The Pre-Test Briefings were held at 7:00 a.m. on the day of the test.

4.6.2 Test Conduct

The Test Director was given control of the activities until the Test Subjects were neutrally buoyant and ready to perform the test activities, at which point test conduct was turned over to the Test Conductor. The Test Conductor gave instructions to the Test Subjects and divers through the Suit intercoms and/or underwater speakers. The Safety Divers could communicate with the Crew and Test Conductor through the use of Diver's Slates. The actual sequence of events generally followed the Developmental Test Procedure contained in Appendix B, which was developed to maximize the efficiency of the Neutral Buoyancy Tests and was not intended to follow a general scenario of EVA events. In actuality, the sequence of events was modified during the tests to accommodate speeds at which different Test Subjects worked, as well as to evaluate additional tasks or skip those tasks which, in the opinion of the Test Conductor and Test Subjects, did not warrant further investigation.

4.6.3 APFR Settings

The settings for the APFRs were predicted using Jack®, a computer program that displays and manipulates articulated geometric figures. Jack® was developed by the Computer Graphics Research Laboratory at the University of Pennsylvania. The predictions were made using Jack® on an SGI computer and utilized models furnished by the various cargo element developers. The predicted settings for each task to be performed at each WIF were written on PVC placards attached near each WIF. The Utility Divers moved the APFRs between positions and installed the APFRs in each WIF. Appendix C contains the predicted APFR settings by EVA Task.

4.6.4 Debriefing

After each test, a debrief was held as soon as the Test Subjects were able to change into street clothes. During the Debrief, the Test Subjects were asked for input on any aspect of the test including Crew Aids, procedures, mockup issues, etc.

4.6.5 Quick Look Test Reports

After each test a Quick Look Test Report was written which documented the results of the test and included suggested changes for the next test.

5.0 TEST RESULTS AND DISCUSSION

Refer to Figure 2.1-1 for WIF locations identified in this section.

5.1 SSRMS Related Tasks

5.1.1 SSRMS Boom Deployment

The evaluation of the LDA-provided work envelopes and crew aid locations for the SSRMS boom deployment followed the general scenario of the crew member working from the PFR on the SRMS, rotating the SSRMS booms to the straight position (Figure 5.1-1).

Two configurations were investigated regarding the initial position of the SSRMS booms prior to deployment: (1) booms in the launch (lowered) position and (2) booms raised approximately 15° prior to deployment. The first condition was investigated to determine if this would prove more efficient from the standpoint of crew time and was attempted in conjunction with tasks involving installation of the EDFs with the booms in the lowered position. The second configuration (booms raised first) proved to be the only feasible method because of the location of the WIF (F3). The F3 position was immediately under the port boom, and the booms needed to be brought within the work envelope.

The F3 position proved useful in manually raising the light end of the SSRMS booms prior to unfolding. The test subjects utilized both the micro handling tool ("Ice Cream Scoop") (Figure 5.1-2) and a wheel-shaped device similar in appearance to the ORU Handling Tool, but which was fitted with the Spar Micro fitting (Figure 5.1-3). Both tools proved useful in that the subjects were able to physically raise the SSRMS booms within the reach envelope (approximately 20°) for engaging the EDFs.

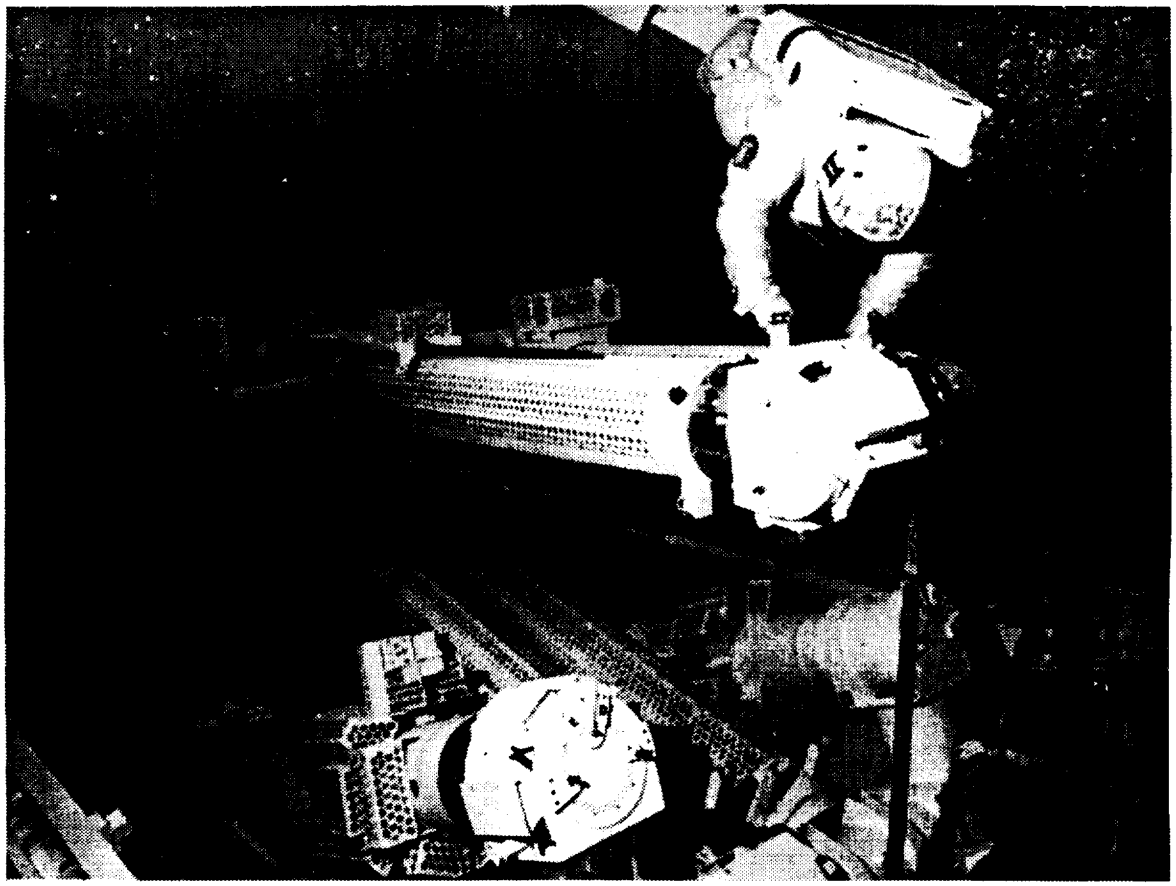

Figure 5.1-1. Rotating the SSRMS Booms by Utilizing a PFR on the SRMS

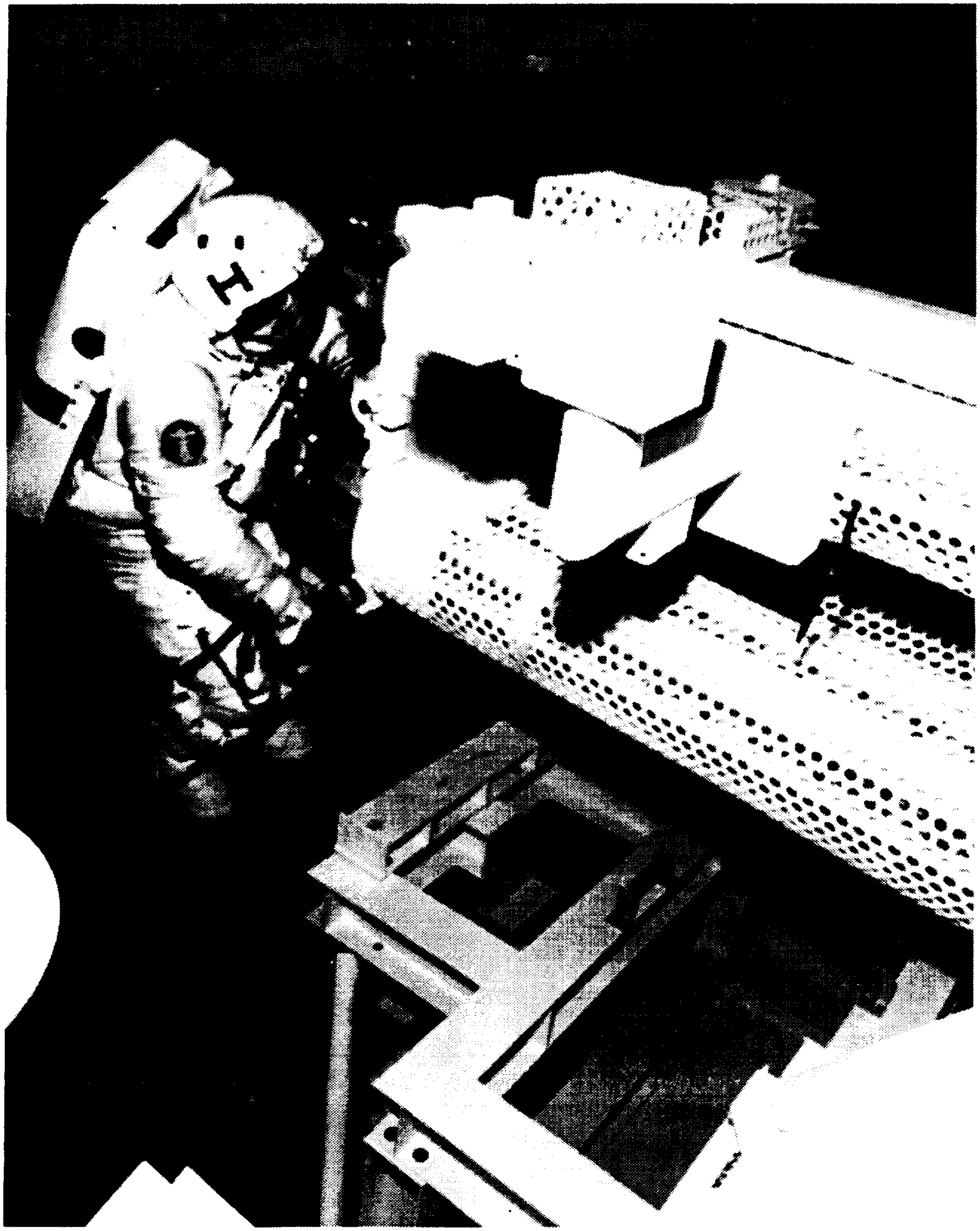

Figure 5.1-2. Manually Raising the Folded SSRMS Booms from Position F3 Using the Spar Micro Tool

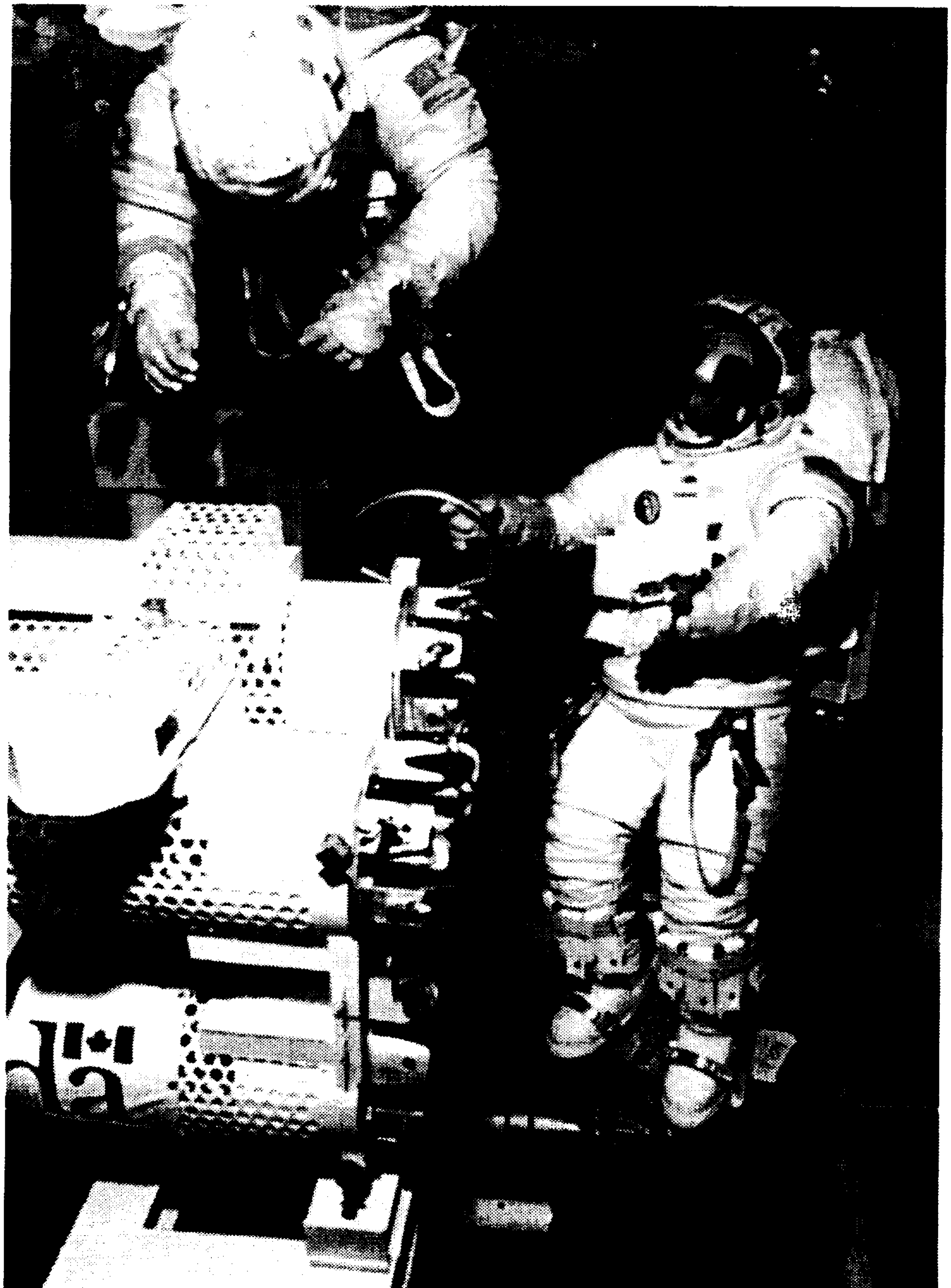

Figure 5.1-3. Manually Raising the Folded SSRMS Booms from Position F3 Using the ORU Handling Tool

The Crew Evaluation was N/A (not applicable) due to the previous evaluation performed and documented in the WETF Verification Testing and documented in Crew Consensus Report #CA3-92-106.

5.1.2 EDF Drive

Driving the EDFs was simulated through the Test Subjects placing a socket wrench on the head of each of the EDFs. This was done for four reasons:

- The retaining cables for each of the EDFs were frayed and posed a hazard to the EMU gloves.
- The EDFs were coated with a hydrocarbon-based lubricant which posed a possible fire hazard due to the oxygen-rich Nitrox breathing gas.
- The hex drive on the EDFs was a mockup-peculiar 9/16" instead of the EVA standard 7/16".
- Driving the EDFs was not considered part of the test since this had been investigated earlier in the WETF Tests.

All eight of the EDFs proved accessible from both the APFR in position F3 (Figures 5.1.2-1 and 5.1.2-2) and the PFR on the SRMS. The latter method required less orientation on the part of the Test Subjects and was deemed adequate.

The use of an APFR mounted in position F3 proved feasible, but some reorientation by the Test Subject was necessary in order to gain visual and physical access to the EDFs located on the port side. There was quite a bit of between-subject difference in the facility with which this was accomplished. These differences could be attributed to differing levels of experience in related tasks as well as physical limitations such as flexibility.

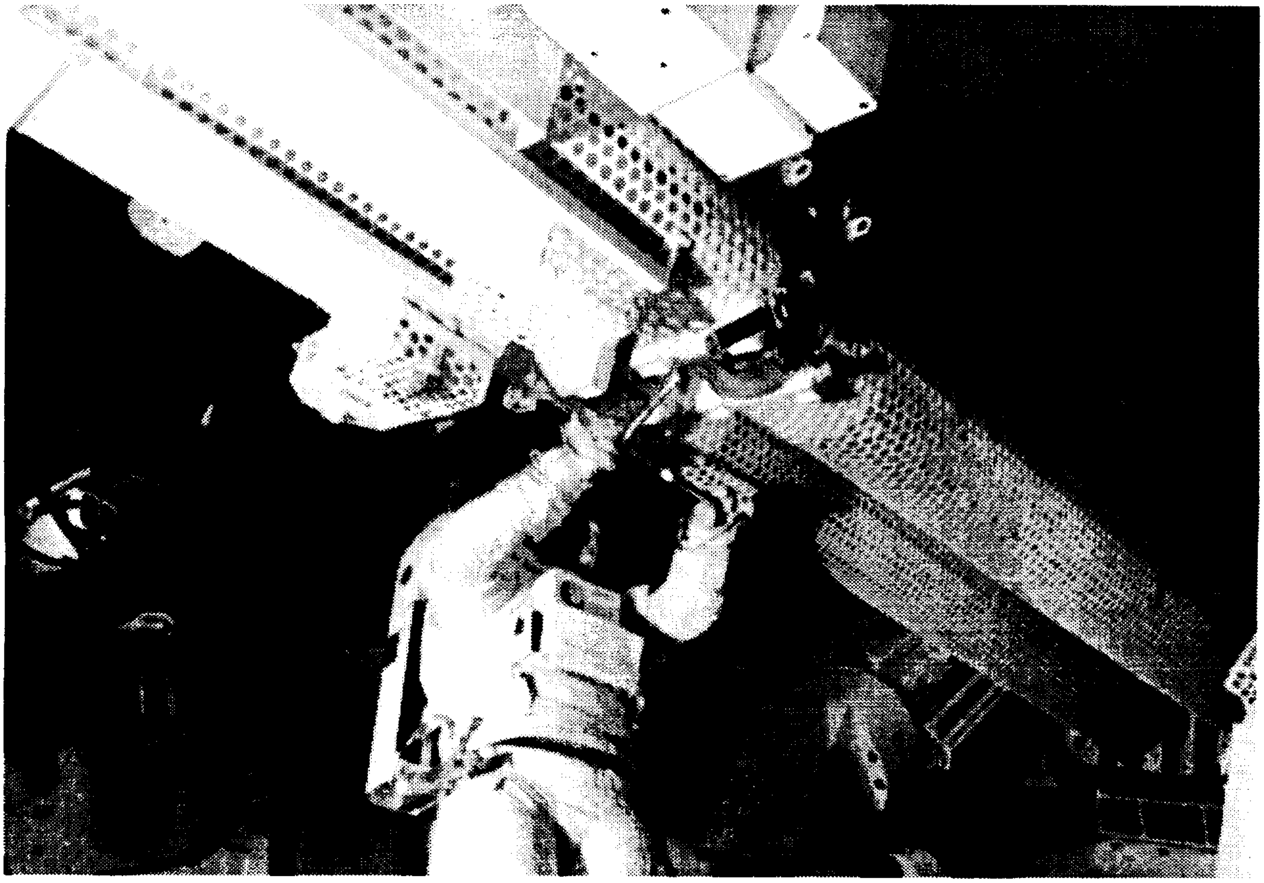

Figure 5.1.2-1. Accessing the Lower Starboard EDFs using Position F3

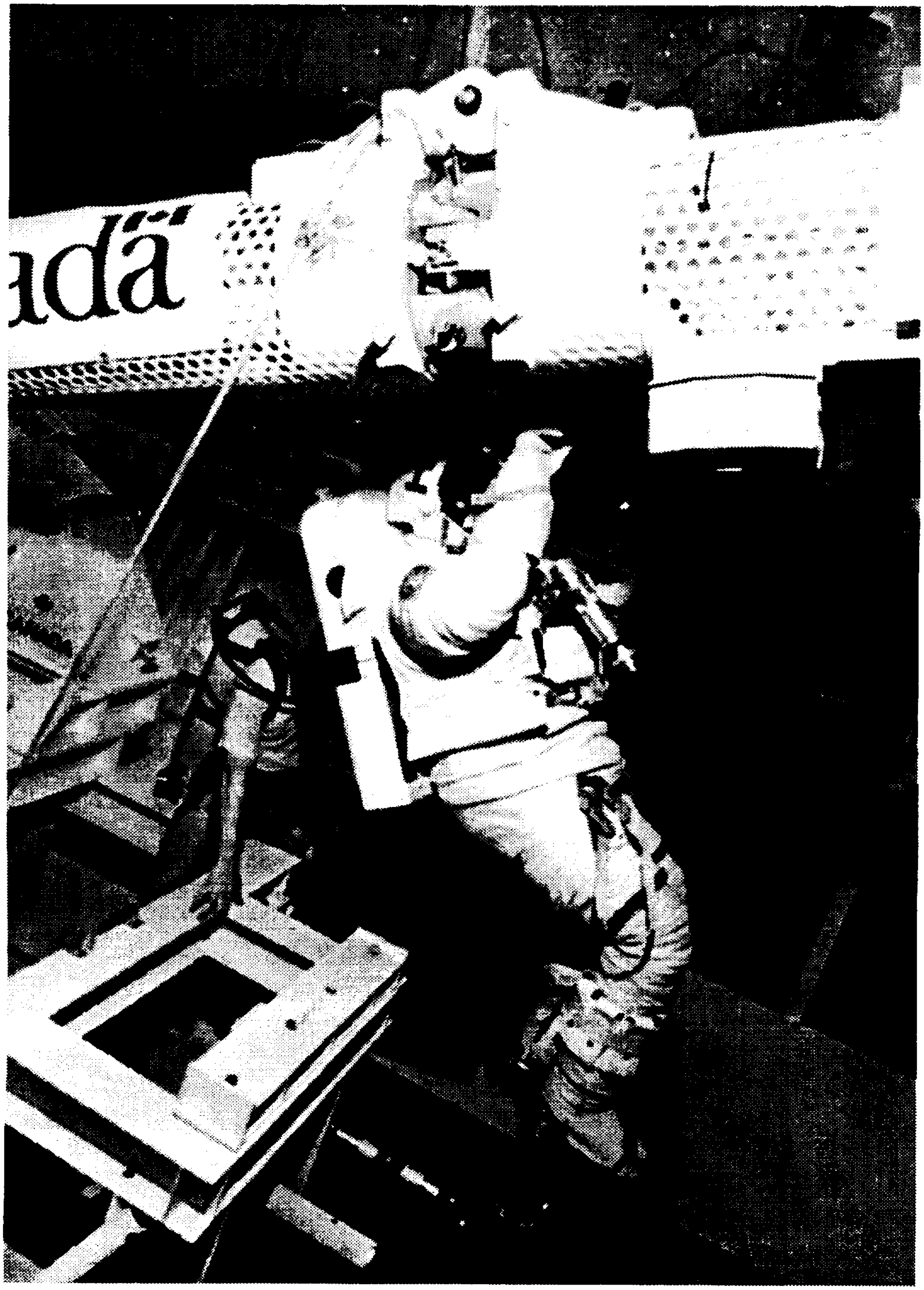

Figure 5.1.2-2 Accessing the Lower Port EDFs using Position F3 with the APFR Footplate Rotated 180°

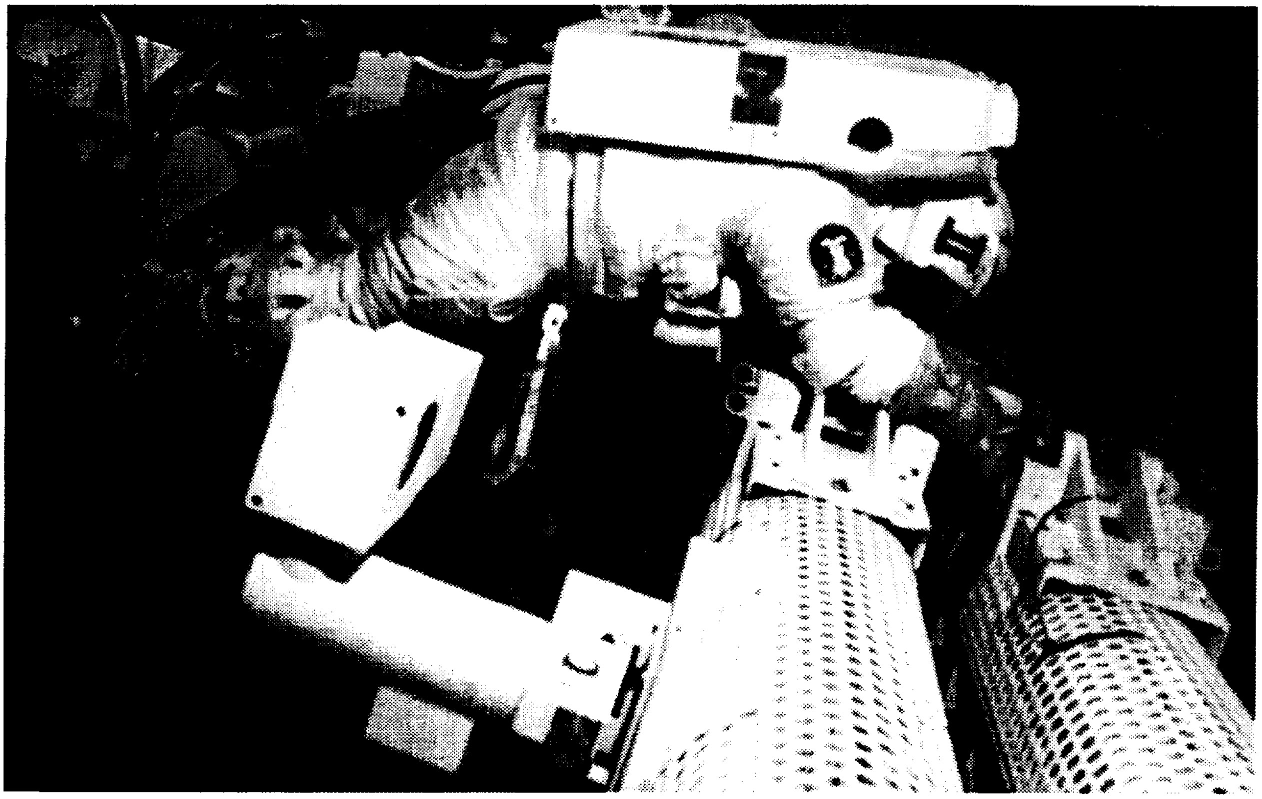

Figure 5.1.2-3. Accessing the Upper EDFs from Position F1

Driving the EDFs with the Test Subject using position F1 was difficult with the shorter Test Subject, although it was accomplished using a right angle drive on the power tool (Figure 5.1.2-3). The addition of the right angle drive extended the reach envelope to the point where the Starboard EDFs could be reached easily, but the inside upper EDF on the port side was only marginally accessible.

The Crew Evaluation was **Acceptable - A.** It was recommended that the Crew member yaw the APFR boot plate 180° to face the EDFs looking forward in the cargo bay.

5.1.3 Clutch Manipulation

Manipulation of the SSRMS joint clutches located at the wrist and shoulder joints was successfully attempted by Test Subjects using the RMS/PFR combination (Figure 5.1.3-1) in free float, and using an APFR in position A1. All three methods were successful and were deemed acceptable by the Test Subjects.

The Crew Evaluation was **Acceptable - A**.

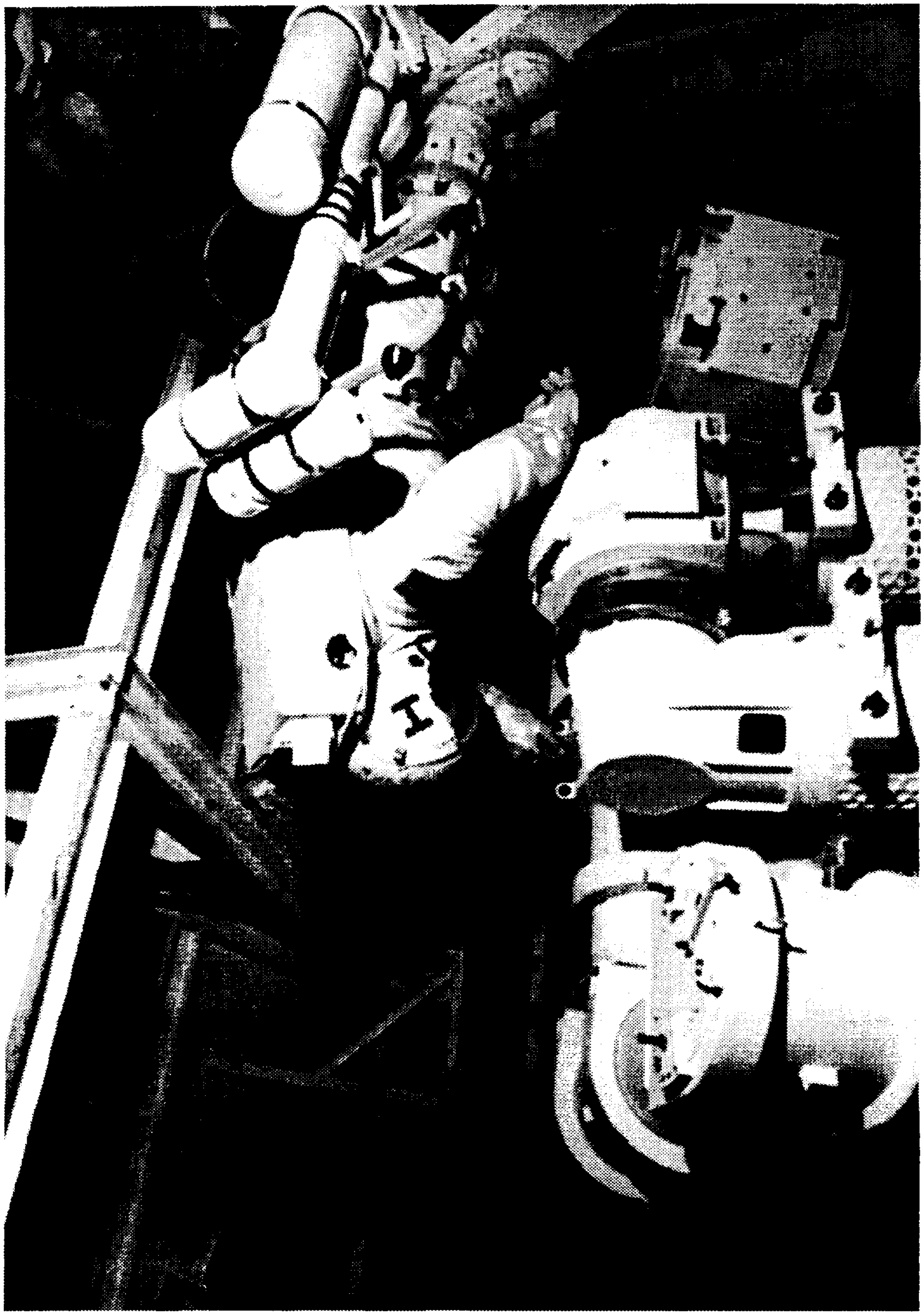

Figure 5.1.3-1. Manipulating the Joint Clutches on the SSRMS Utilizing a PFR on the SRMS

5.1.4 FSEGF Operations

Tasks which involved driving the EVA release for the hook-links in the FSEGF proved successful from the APFR in position F5. Initial trials at these tasks were marginalized by a conflict between a micro fitting on the SSRMS mockup and another portion of the mockup which prevented the booms from being raised to a full 60° to 90°. This condition severely restricted the Test Subject's work envelope. During the first Crew run, the micro fitting was sheared off when the booms were rotated, allowing the booms to be raised fully. The expanded work envelope allowed the Test Subjects to access all four EVA interfaces with the Essex wrench (Figure 5.1.4-1) and the power tool (Figure 5.1.4-2).

The Crew Evaluation for FSEGF operations was **Acceptable - A**. Recommendation was that the two handholds provided on the upper surface of the LSA structure were not needed due to ample handholds of opportunity afforded by the LSA structure itself.

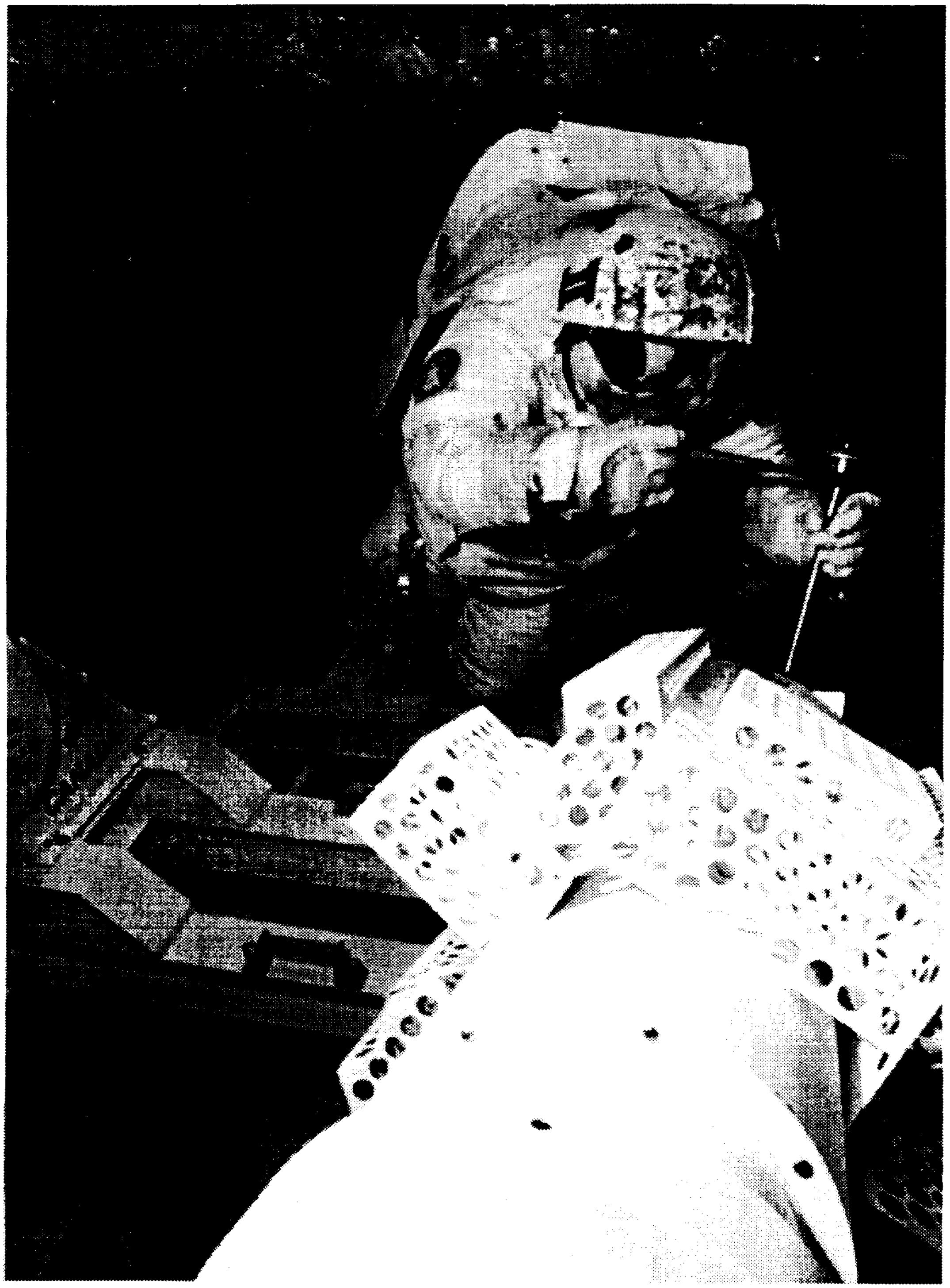

Figure 5.1.4-1. Accessing the FSEGF Upper Starboard Hook-Link Using an Essex Wrench

Figure 5.1.4-2. Accessing the FSEGF Inner Port Hook-Link Using a Power Tool

5.2 Payload Element Removal Tasks

5.2.1 SSRMS Utility Cable Deployment and Stowage

The tasks involving unstowing the Utility Cable, translating with the Utility Cable to the ISS, and Mating the connectors to the ISS were partially evaluated due to the lack of a dummy connector panel and a method for securing the cable during launch. However, an attempt by Test Subjects to place the connectors in the position to mate with the ISS connectors was difficult from an APFR position (A1 and A2) and it was the suggestion of the crew to use an RBT attached to one of the handrails on the aft frame of the SLP.

The Crew Evaluation was not available due to lack of mockup hardware. The recommendation was that a dummy connector panel be located vertically facing aft and clear of the handrails. It was also recommended that the Crew Office table-top review the final connector panel location, that the cable be sized to allow for adequate connector mating, and that Space Station EVA line clamps be used to attach the cable(s).

5.2.2 Removal and Stowage of the SSRMS Launch Restraint Bolt Assemblies

Removal, hand-off, and stowage of the Launch Restraint Bolts (tie-down bolts) was accomplished with Test Subjects using forward and aft APFRs at position F3 (forward) and A1 (aft) as well as the SRMS (Figure 5.2.2-1 and Figure 5.2.2-2) for removal of the bolts and the second subject in free-float.

Position F3 afforded good access to all four forward Launch Restraint Bolts (Figure 5.2.2-3) and provided an adequate reach envelope to hand the bolts off to the other crew member through the use of a retractable tether (Figure 5.2.2-4).

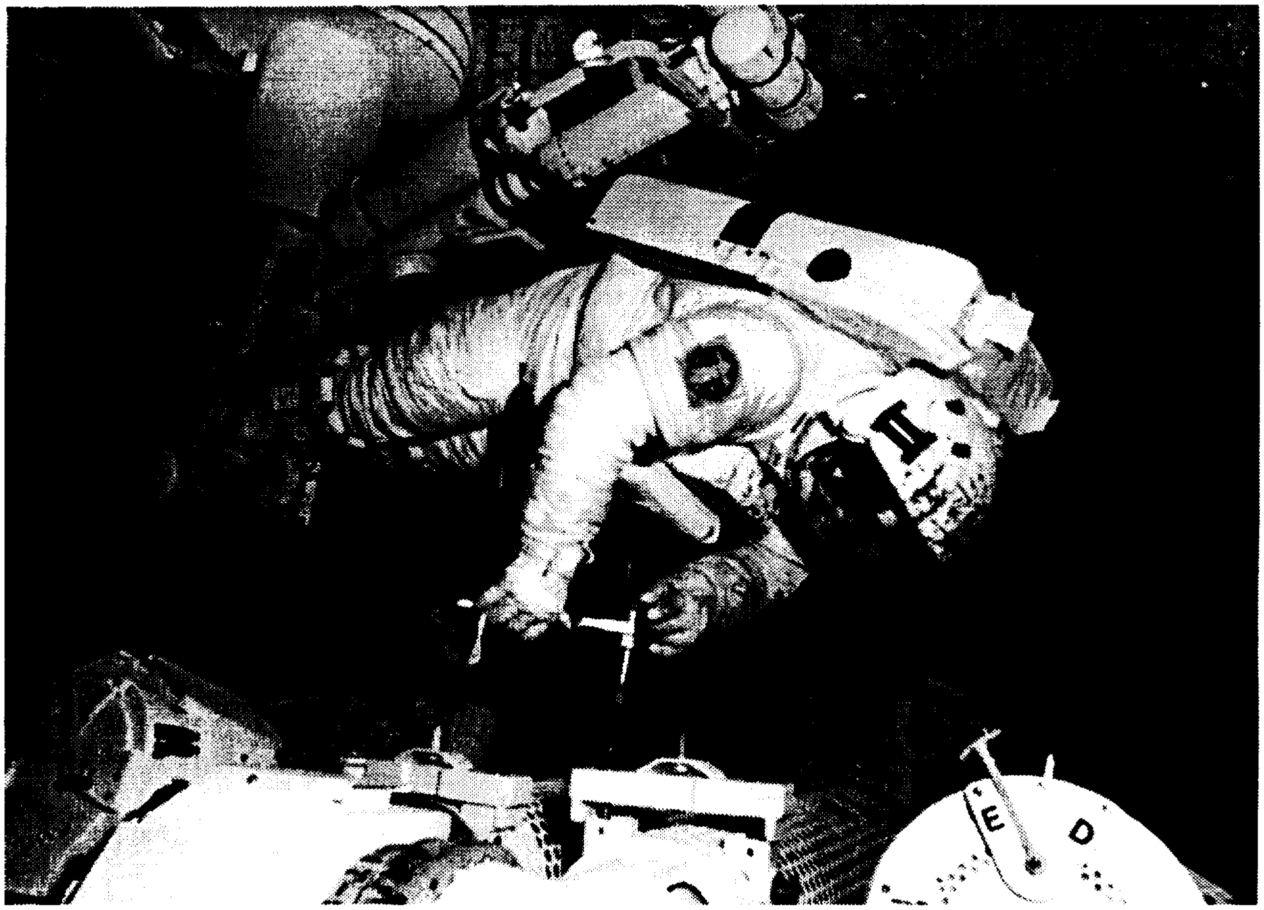

Figure 5.2.2-1. Loosening the Tie-Down Bolts from the APFR on the SRMS

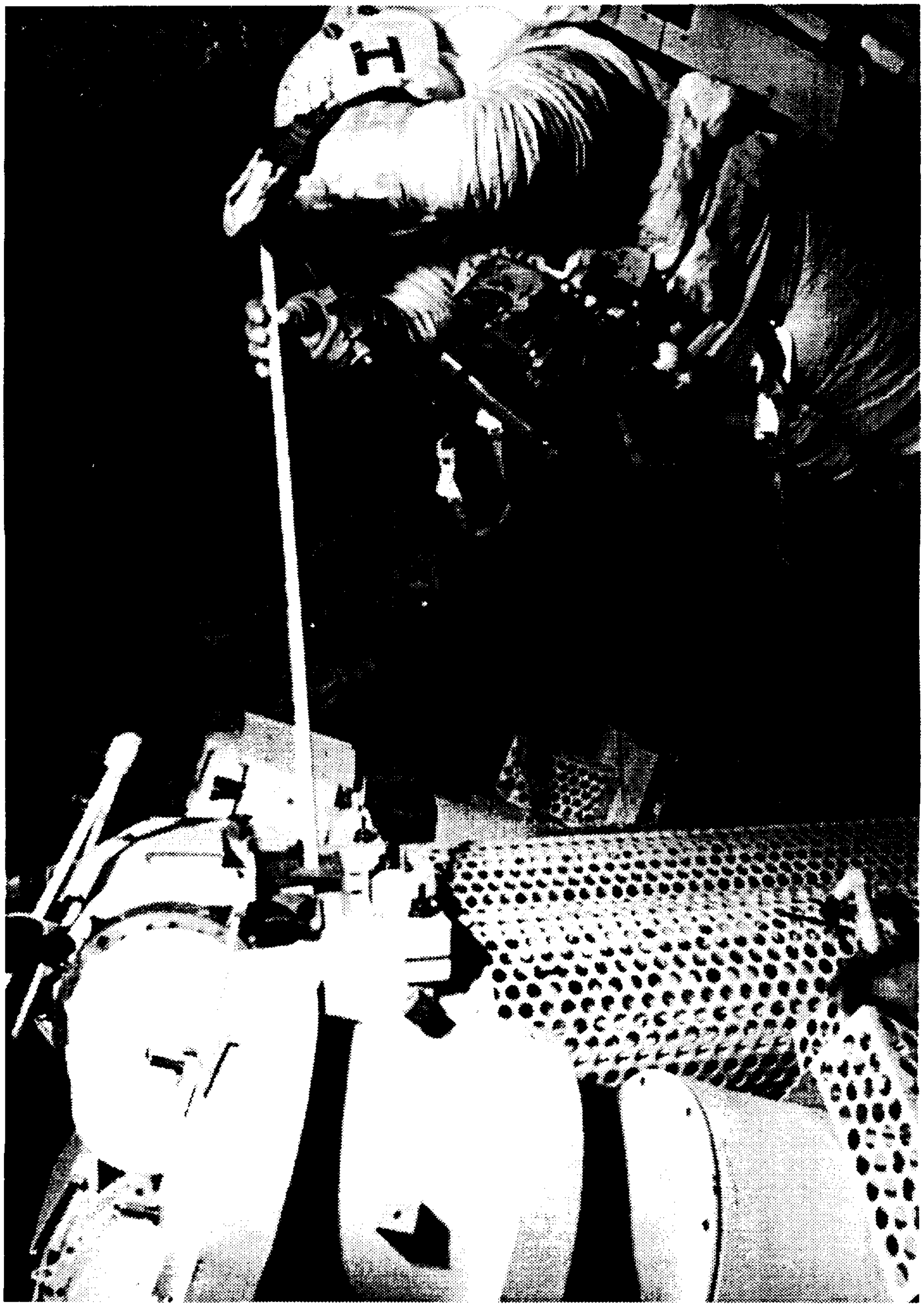

Figure 5.2.2-2. Removal of the Tie-Down Bolts from the APFR on the SRMS

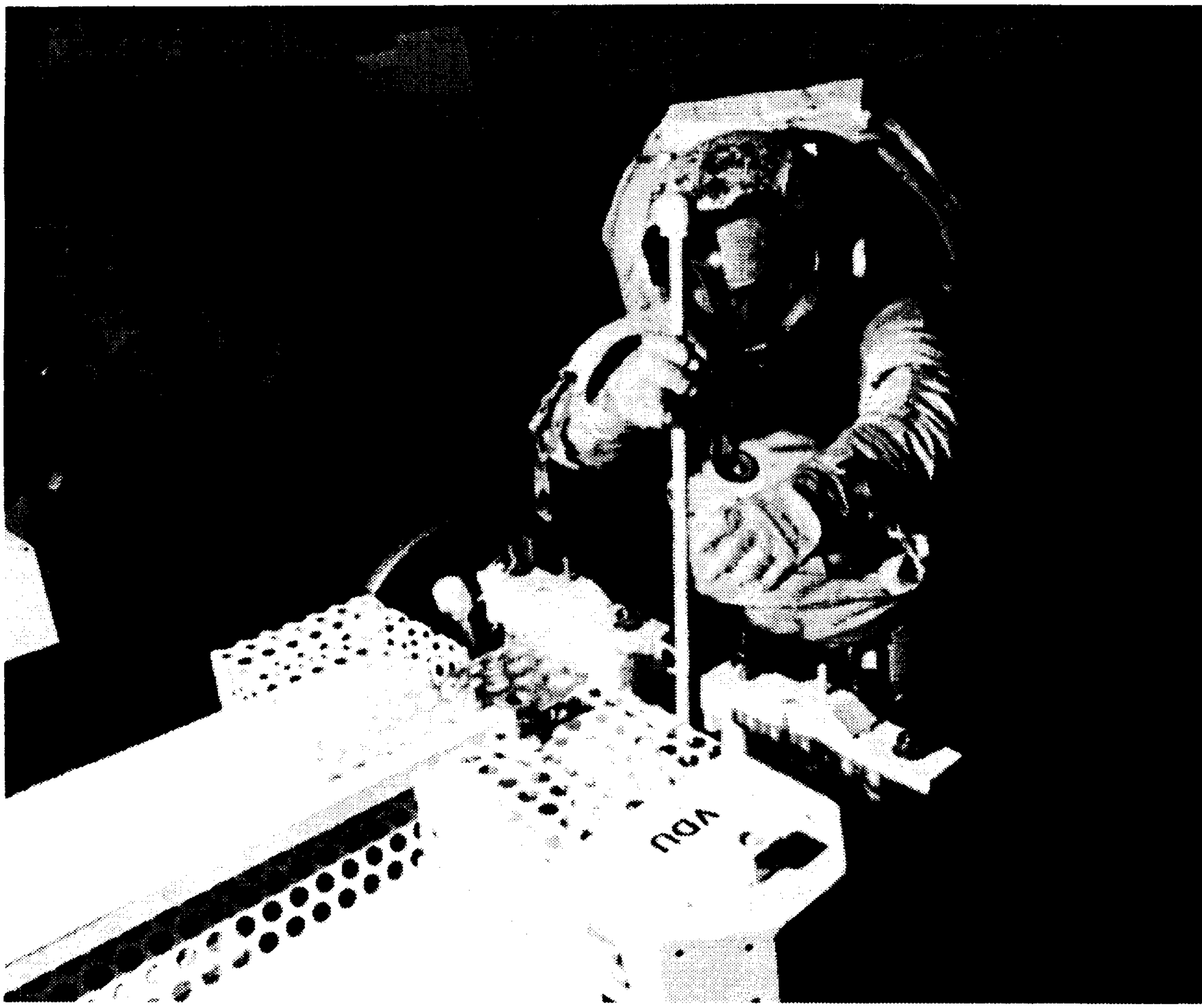

Figure 5.2.2-3. Removal of the Tie-Down Bolts from Position F3

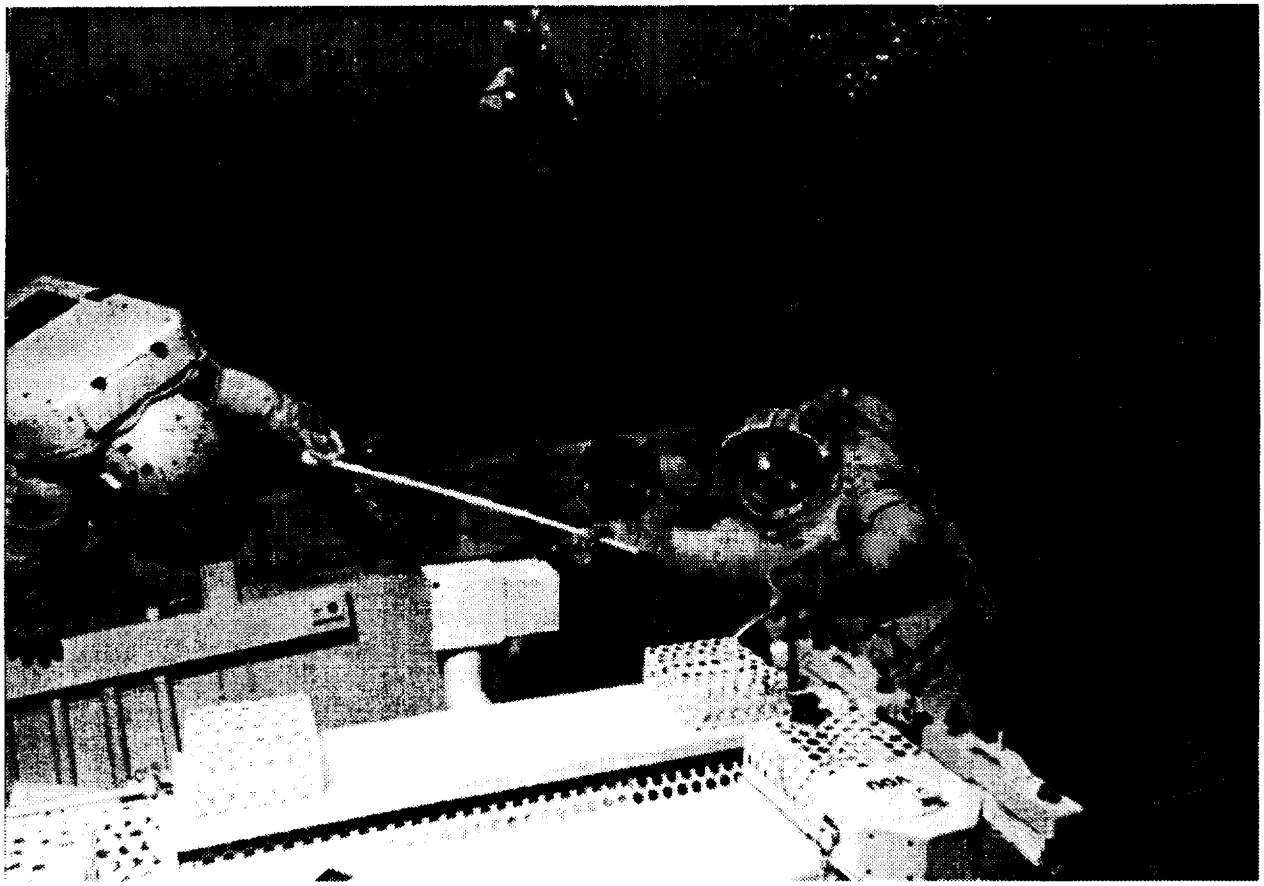

Figure 5.2.2-4. Hand-off of the Tie-Down Bolts from Position F3

Position A1 provided good access to the two port tie-down bolts, but the starboard bolts could only be reached by using a right angle drive (Figure 5.2.2-5). The WIF at position A4 would provide the same reach as A1 because they are mirror images in regard to the SSRMS. The Mini Work Station may have to be temporarily removed from the front of the suit in order to avoid contact with the joint drive if this task is performed using the APFRs at position A1 and A4.

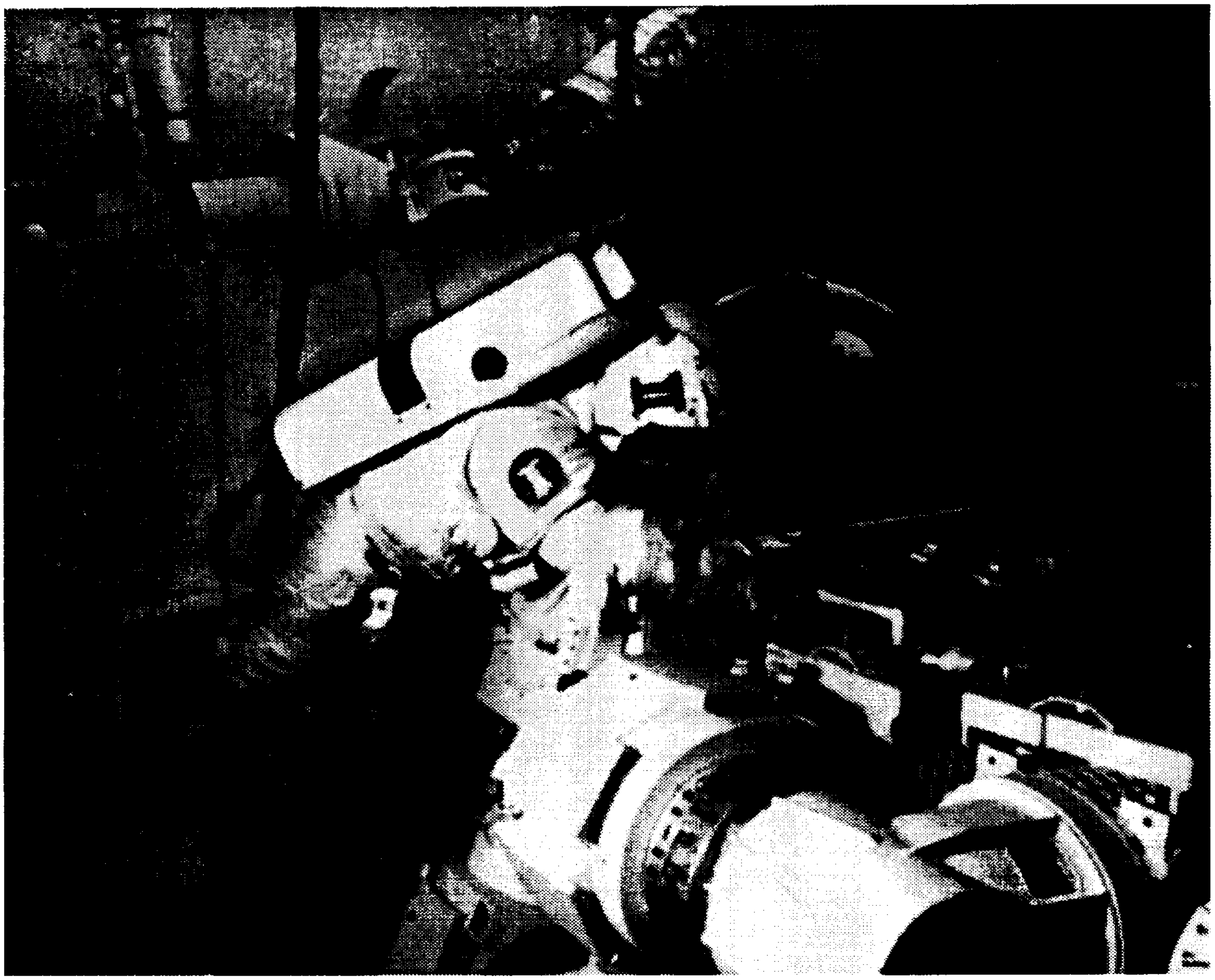

Figure 5.2.2-5. Loosening the Tie-Down Bolts from Positon A1 Using a Power Tool and Right Angle Drive

Location and access of the Bolt Stowage location was satisfactory both with subjects in a free-float or SRMS mode, however, it was not acceptable with the subject in an APFR at location A1 because the forward stowage location was outside the Test Subject's reach envelope.

- The Crew Evaluation for removal and stowage of the SSRMS tie-down bolts using the SRMS as well as APFRs in positions F3 and A1 was **Acceptable - A**.

- The Crew Evaluation for stowage of the tie-down bolts using free-float, SRMS, or an RBT was **Acceptable - A.** It was recommended that the Crew Office review the final design of the tie-down bolt stowage.

- The Crew Evaluation for using an APFR in position A1 to stow the tie-down bolts was **Unacceptable - U1** due to an inadequate reach envelope for the forward bolt. It was also noted that an APFR was not required to perform the task.

5.2.3 UHF Antenna and Deployment Assembly Removal

Access to the seven EVA-type bolts securing the UHF antenna and deployment assembly could easily be reached by the Test Subjects in APFRs located at position F2 (Figure 5.2.3-1), A3 (Figure 5.2.3-2), and F1 (Figure 5.2.3-3), and was evaluated as **Acceptable - A** by the Crew.

The handhold configuration on the UHF antenna and deployment assembly was evaluated as **Unacceptable- U1** because the hand holds were too far apart.

Figure 5.2.3-1. Loosening the Bolts on the UHF Antenna and Deployment Assembly from Position F2

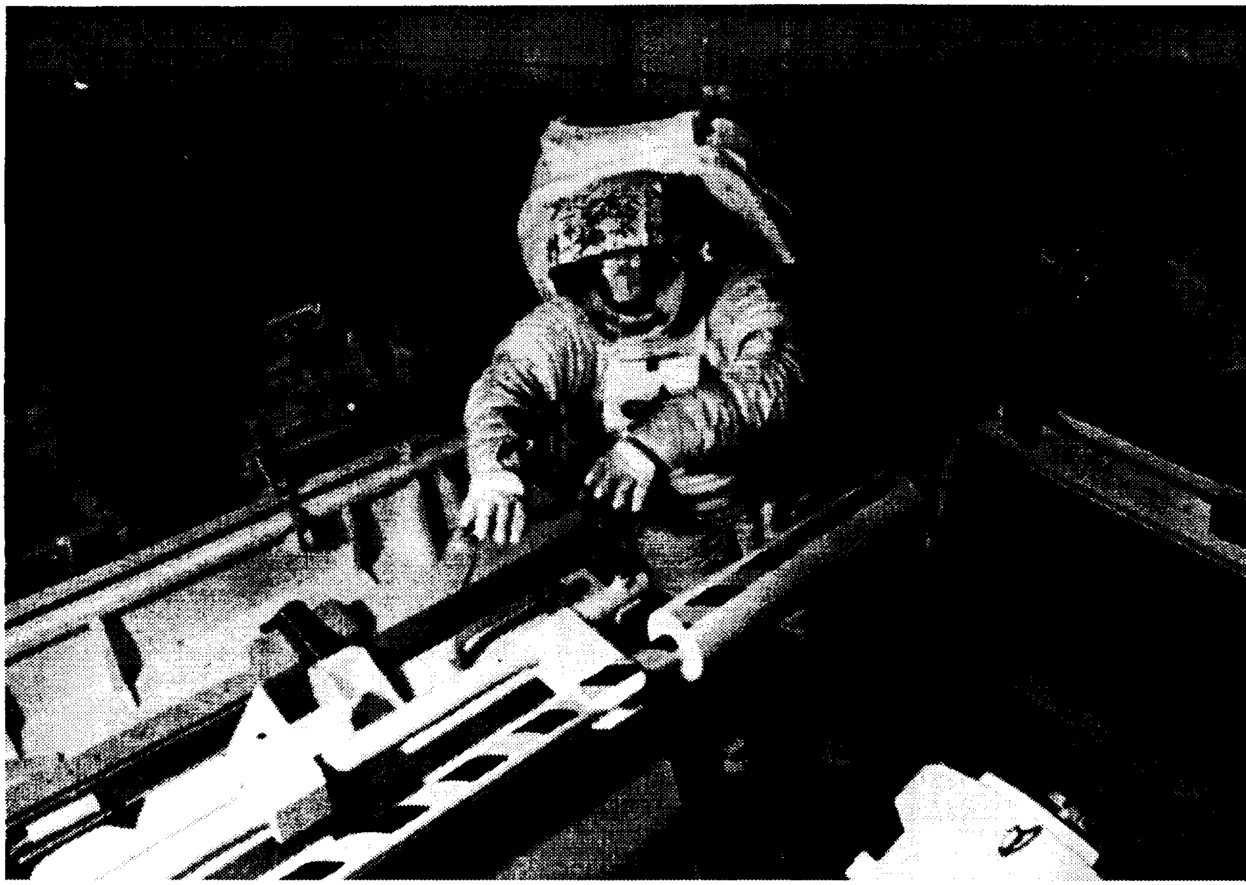

Figure 5.2.3-2. Loosening the Aft Bolt on the UHF Antenna and Deployment Assembly from Position A3

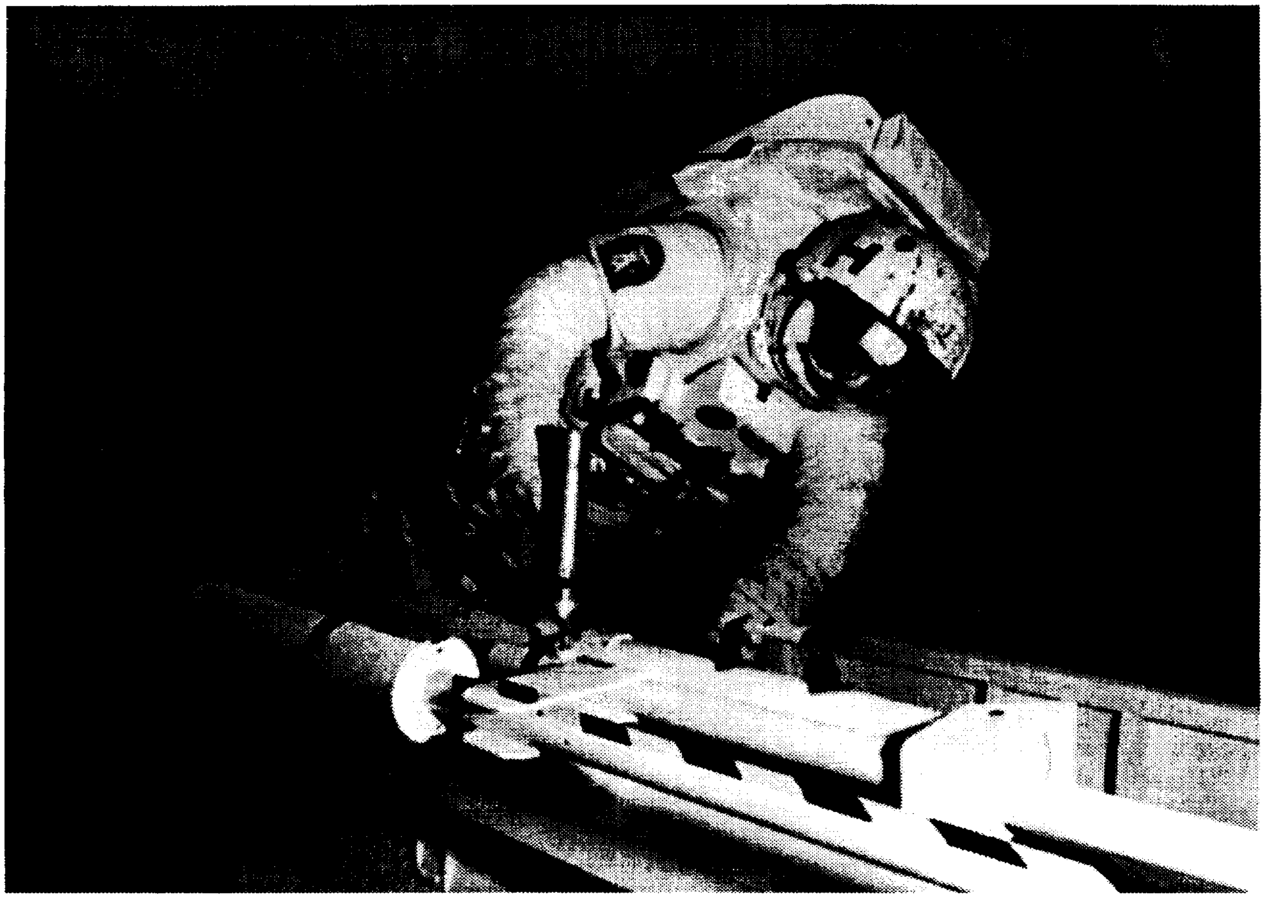

Figure 5.2.3-3. Loosening the Bolts on the UHF Antenna and Deployment Assembly from Position F1

5.2.4 PDGF Rigid Umbilical Removal

Removal of the PDGF Rigid Umbilical was easily accomplished by Test Subjects using the APFR locations provided (Figure 5.2.4-1 through 4) as well as the SRMS. Some interference was encountered with the camera mockup on the SSRMS mockup while loosening the forward EVA bolt from the APFR position F4 (Figure 5.2.4-1) This was not considered a problem and may not be relevant due to a redesign of the camera and light assembly by Spar Aerospace which has resulted in a more compact assembly. The main recommendation from the conversations during the tests and from the debriefs was that it would be desirable to provide a positive indication of disengagement from the bolts located in the stanchions at either end of the PDGF Rigid Umbilical. This could be accomplished by using a pin that protrudes from the stanchion when the threads are disengaged.

Removal of the PDGF Rigid Umbilical by using both APFRs and the SRMS was evaluated as **Acceptable - A** by the Crew.

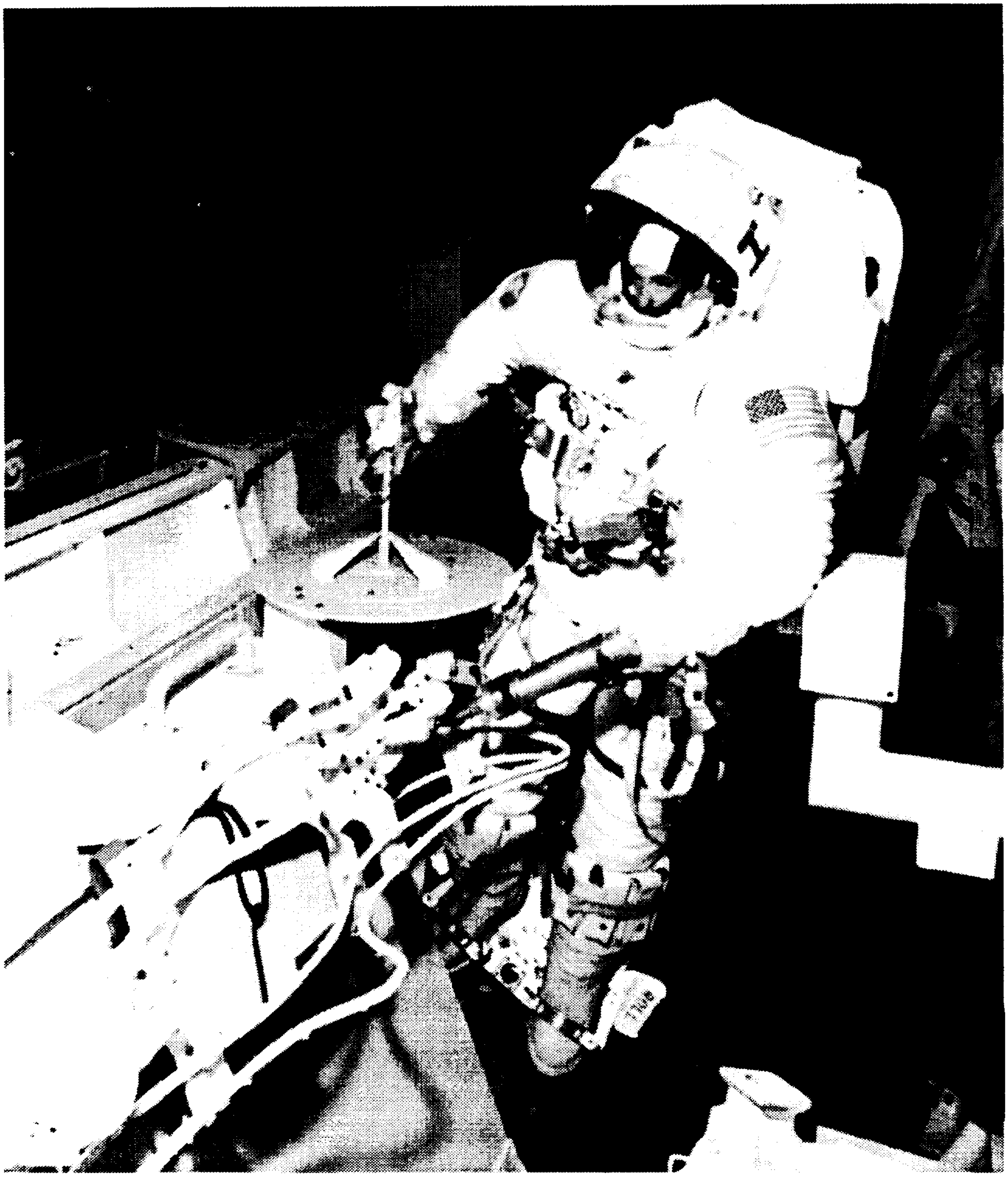

Figure 5.2.4-1. Loosening the Forward EVA Bolt on the PDGF Rigid Umbilical from Position F4

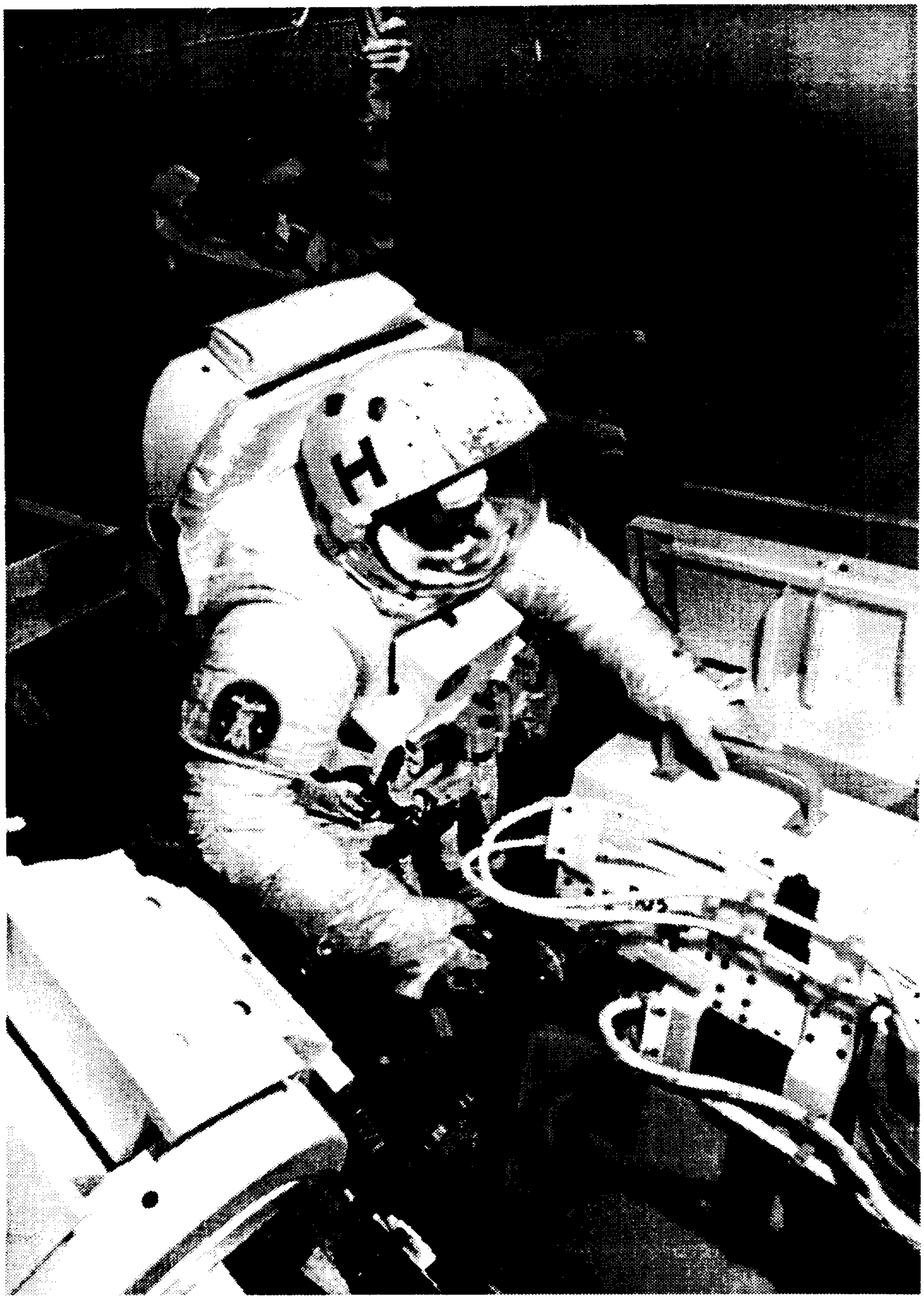

Figure 5.2.4-2. Loosening the Aft EVA Bolt on the PDGF Rigid Umbilical from Position A2

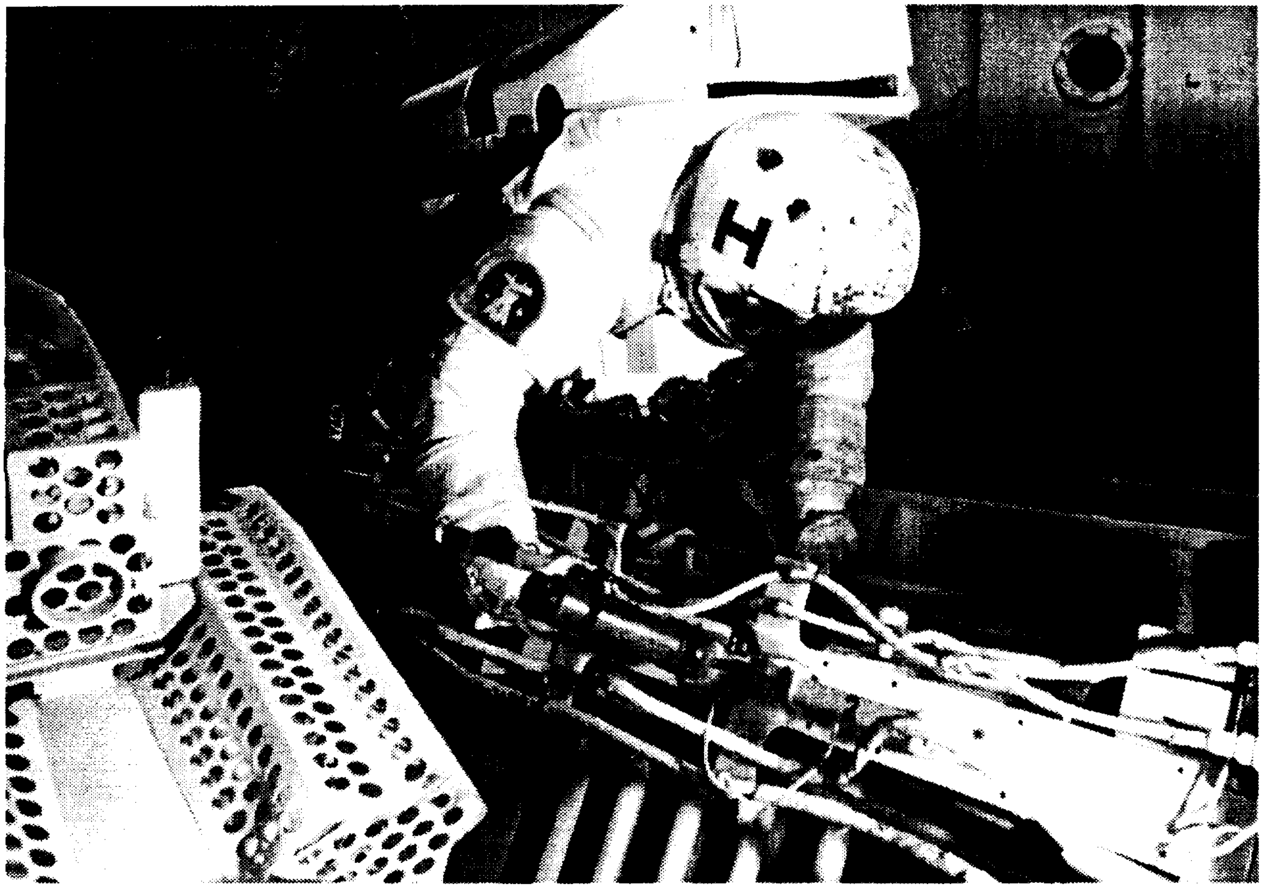

Figure 5.2.4-3 Loosening the Center EVA Bolt on the PDGF Rigid Umbilical from Position A1

Figure 5.2.4-4. Unstowing the PDGF Rigid Umbilical from Position A1

5.2.5 LDA-Provided Translation Envelopes

The translation envelopes provided by the LDA and SLP consisted of handrails provided on the vertical surfaces of the forward and aft frames of the SLP and handholds of opportunity in the LDA structure. Other translation paths were derived from the handrails provided by the SLP as standard equipment and the handrails on the Cargo Bay sill. These translation paths were considered adequate and afforded good paths transversely between port and starboard sides as well as longitudinally along the standard handrails.

The Crew Evaluation for the translation paths provided on the LDA and SLP was **Acceptable - A.**

5.2.6 Use of SRMS Support as Mobile Platform for Primary Test Objectives

The use of the SRMS as a mobile platform was considered effective and resulted in an efficient use of crew time. The most difficult task involved the removal of the LCA from its forward stowage position on the LSA, but this was accomplished in several orientations (e.g.,

Crew member vertical, head -Z or supine, head -X) with good communication between the EVA and Intravehicular Activity (IVA) crew members.

The Crew Evaluation for using the SRMS as a mobile platform was **Acceptable - A.**

5.2.7 Laboratory Cradle Assembly (LCA) Access

Due to the immaturity of the LCA design, a full evaluation was not possible and was considered a secondary objective. However, several associated tasks were evaluated; these included (1) removal of the LCA by two crew members, one on the SRMS and the other in an APFR in positions F1 and/or F2 (see Figure 5.2.7-1) , and (2) ingress into the APFR at positions F1 and F2 using the LDA structure. The removal tasks were successfully accomplished, although this may best be accomplished by the crew member on the SRMS, with the other Crew member providing visual assistance and guidance. Likewise, ingress into the APFRs located at positions F1 and F2 was easily accomplished using the LSA structural members as handholds.

The general recommendation for securing the LCA in the stowage position was for captive fasteners to be located along the top or port side of the structure.

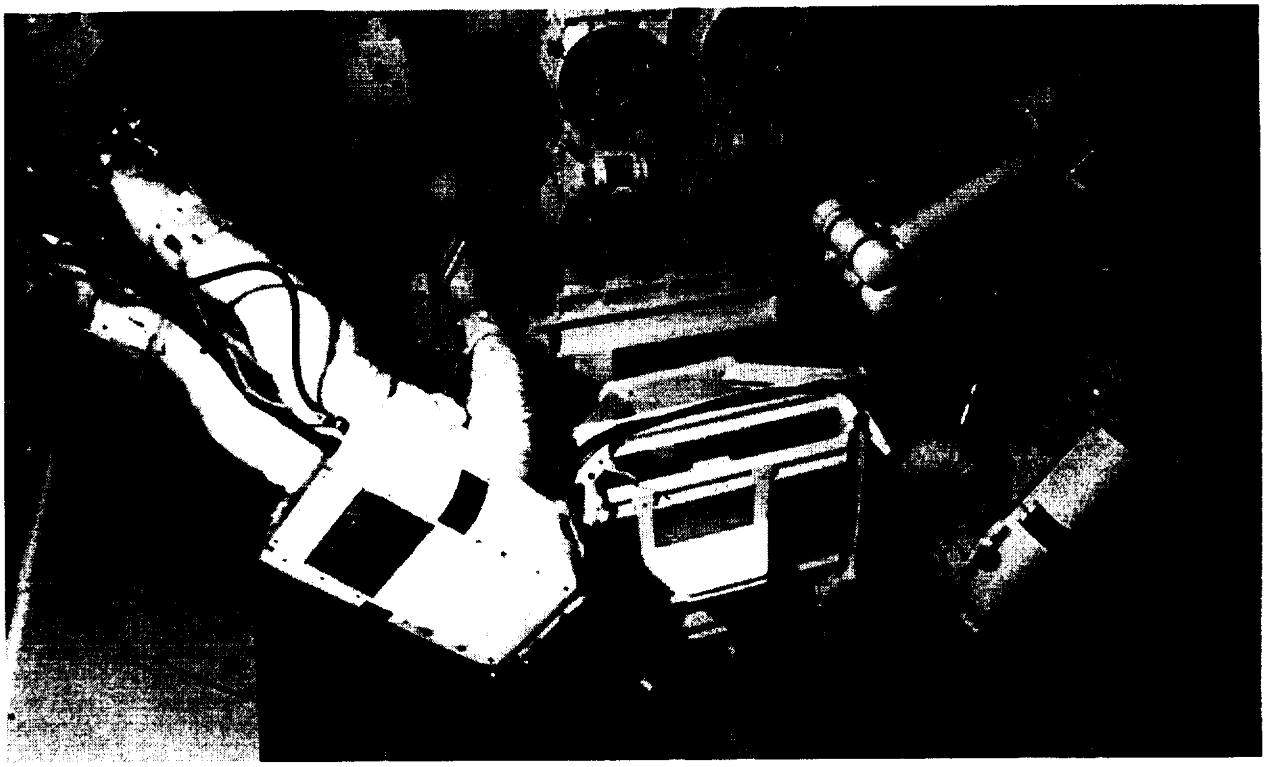

Figure 5.2.7-1. Removal of a Candidate Lab Cradle Assembly by Two Crew Members

- The Crew evaluation for removal of the LCA launch bolts was not applicable due to immaturity of design and mockup furnished.

- The Crew evaluation of using two crew members for LCA removal was **Acceptable-A.**
- The Crew evaluation for ingressing an APFR at positions F1 and F2 was **Acceptable-A.**

5.2.8 EDF Drive Operations With SSRMS Booms Stowed

Due to the geometry of the LSA/SSRMS interface there was inadequate clearance for the APFR from position F3 with the SSRMS booms in a lowered position. This was not presented to the Crew Members for evaluation as determination was made during the first Engineering Test.

5.2.9 APFR Installation at WIF locations

Installation of APFRs at all nine WIF locations was accomplished with no difficulty using a neutrally buoyant APFR mockup and provided translation paths. The handrails provided on the SLP frames (Figure 5.2.9-1) were in good position and the LSA structure provided handholds of opportunity for the locations numbered F3 and F5. Two handrails had been provided on top of the LSA structure for translation and APFR installation purposes. However, the Crew Members suggested that these crew aids were unnecessary if LSA structure could be used for handholds.

The Crew evaluation for APFR installation at WIF locations was **Acceptable-A.**

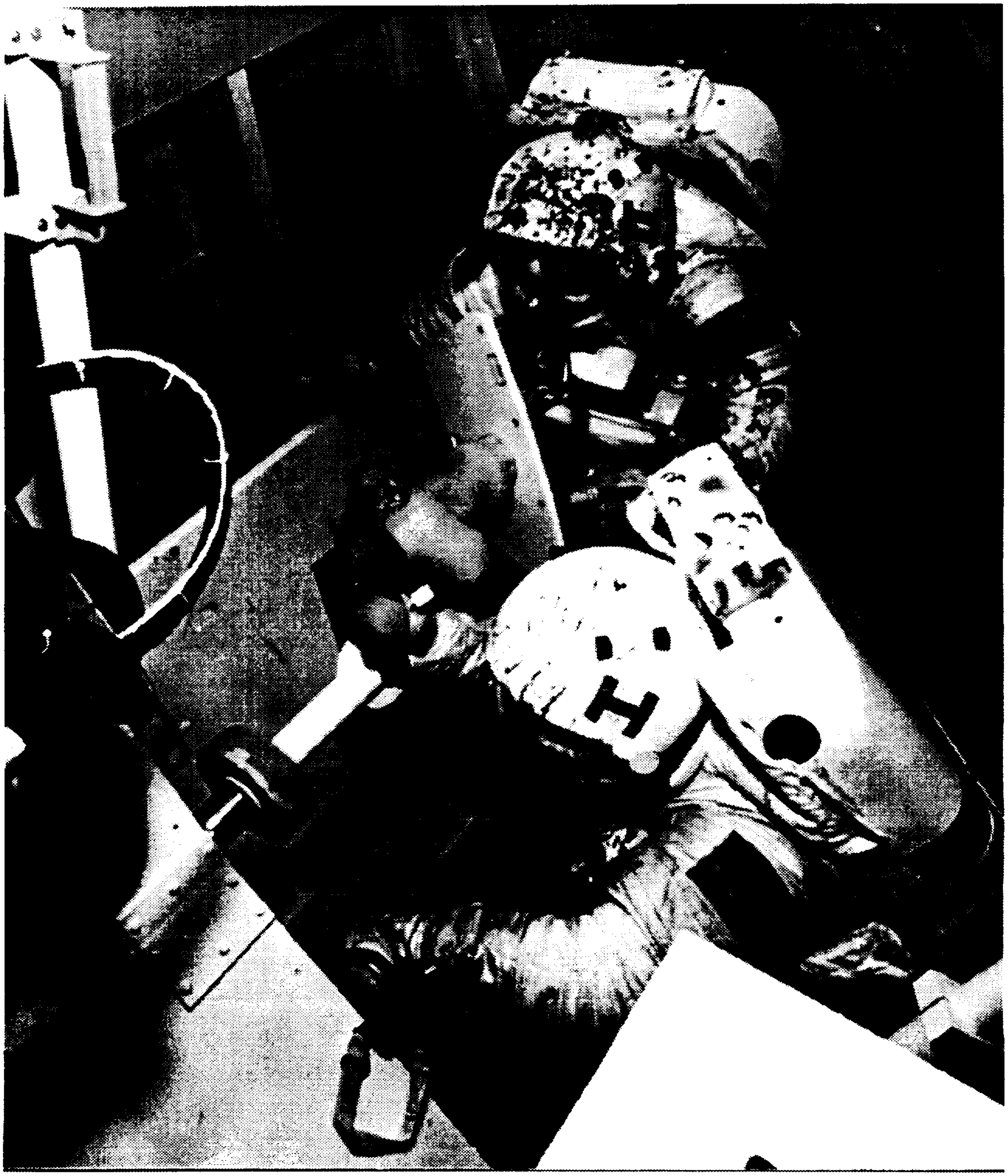

Figure 5.2.9-1. Installing APFR in Position F4 Using Provided Handrail

Appendix A

Table of Mockup Classes

MOCKUP CLASSIFICATION

PHYSICAL \ FUNCTIONAL	A. FUNCTIONALLY ACTIVE	B. OPERABLE	C. STATIC
I. FLIGHT ASSY. TOLERANCE SIMILAR MATERIAL EXACT CONFIGURATION	I.A.	I.B.	I.C.
II. RELAXED ASSY. TOLERANCE MIXED MATERIAL APPROX. CONFIGURATION	II.A.	II.B.	II.C.
III. APPROXIMATE DIMENSIONS OPTIONAL MATERIALS CANDIDATE CONFIGURATION	III.A.	III.B.	III.C.

DEFINITIONS

PHYSICAL:

CLASS I: CLASS I Mockups are typically used to support Crew training and engineering verification.

Flight Assembly Tolerance: Built to Flight Dimensional Specifications.

Similar Material: Materials used are of the same family and are characteristic of the flight material, but not necessarily of the same grade or specification. (e.g., metals-metal, plastics-plastic, fabrics-fabric).

Exact Configuration: Appearance is like flight in all aspects (e.g., size, shape, color, orientation, location, etc.).

CLASS II: CLASS II Mockups are typically used for Crew familiarization and design development.

Relaxed Assembly Tolerance: Not held to Flight Dimensional specifications. Margins to be specified by Program.

Mixed Materials: Materials will be generally characteristic of flight, but not necessarily of the same family, grade, or specification.

Approximate Configuration: Appearance is similar to flight in most aspects (e.g., size, shape, color, orientation, location, etc.).

CLASS III: CLASS III Mockups are typically used for concept formulation and preliminary layout.

Approximate Dimensions: Anticipated volumetric approximation.

Optional Materials: Appropriate material to support mockup objective.

Candidate Configuration: Appearance appropriate to depict concept.

FUNCTIONAL

A. FUNCTIONALLY ACTIVE: Operates like flight and system response is like flight.

B. OPERABLE: Operates like flight, but response may or may not be like flight (e.g., switch can be thrown, door can be opened).

C. STATIC: Does not operate (e.g., graphics, dummy switches).

NOTE: Particular applications (e.g., neutral buoyancy mockups designed for underwater applications) will overlay unique requirements.

Appendix B
Launch Deployment Assembly Developmental Test Procedures

LAUNCH DEPLOYMENT ASSY. NEUTRAL BUOYANCY DEVELOPMENT TEST PROCEDURE
Crew Evaluation Sequence C 1 (15 Nov. 1995)

Test Director/Test Conductor	(IV) RMS Operator Utility Divers Safety Divers	EV1	EV2
PRETEST ACTIVITIES			
TD: Instruct lift personnel to lower EV1 into water & SDs to Trim Out	SD: Trim Out EV1		
TC: Announce test start: date, time, test number; etc. Instruct SDs to transport EV1 to Manip. Foot Restraint on RMS.	SD: transport EV1 to MFR on RMS - Ingress MFR (facing 0˚), rotate stanchion to 180˚ UD: Ensure FR in socket F4 is set to RU1 orientation		
TEST BEGINS			
TD: Instruct lift personnel to lower EV2 into water & SDs to Trim Out	SD: Trim Out EV2		
TC: Instruct UD: Verify F 4 in orientation : RU1; also obtain power tool w/ 6" socket for EV2	SD: Transport EV2 to F4, aid EV2 ingress F4. UD verify APFR in position : RU 1		Evaluate ingress aids, socket F4. Assess FR orientation : RU1
TC: Instruct UD to install APFR in A2; also obtain Essex wrench w/ 2" socket for EV1	UD: pass power tool to EV2		Loosen 1 EVA Bolt in handle of stancheon toward forward end of Rigid Umbilical with power tool.
TC: instruct RMS operator to move EV1 to UHF Antenna Forward Position.	UD: install APFR in socket A 2; adjust to position RU 2. UD: pass wrench to EV1.	Position Essex wrench over 4 Forward EVA bolts of UHF Ant.	Egress APFR Xlate via pallet handrails to aft of pallet to A2.
TC: Instruct UD to move APFR from F4 to A1	SD assist EV2 ingress APFR at A2.	Loosen 4 EVA Bolts (2 turns ea.) at base of UHF Antenna. KEEP CLEAR OF OTHER ANT. ELEMENTS.	Evaluate ingress aids. Assess FR position: RU2 Loosen 1 EVA Bolt in handle of stancheon toward aft end of Rigid Umbilical with power tool.

Test Director/Test Conductor	(IV) RMS Operator Utility Divers Safety Divers	EV1	EV2
TC: Instruct IV to position EV1 over aft end of UHF Ant. TC: Give SD heads up to assist EV2 when egresses APFR. Instruct UD to install APFR in A1.	IV: position EV1 at Aft end of UHF Ant. UD : move APFR from F4 to A1 SD: assist EV1 in roll	Loosen 1 EVA bolt (2 turns) at Aft end of UHF Ant. KEEP CLEAR OF OTHER ANT. ELEMENTS.	Reorient APFR (Roll to Right) to access 2 clutches at shoulder joints of SSRMS.
TC: instructions IV to position EV1 to center EVA bolts of UHF Ant. WARN of DAMAGE TO ANTENNA ELEMENTS.	IV: position EV1 at Center Pos. of UHF Ant. UD: Move APFR to socket A1. UD: Adjust APFR to position RU3	Remove 2 center EVA bolts (2 turns ea.) Lift UHF Ant. 12" (+z), then 12" to starboard (+y) by EVA Handhold. KEEP CLEAR OF OTHER ANT. ELEMENTS.	Egress APFR Stay clear of UD as APFR is moved to socket A1
TC: Request 2 UD replace UHF Ant. in position, lighty tighten EVA Bolts	UD: (2 UDs) replace UHF Ant SD: Assist EV2 Ingress APFR at A1.	Hand UHF Ant to UDs	Ingress APFR at A1 with assistance from SDs. Assess ingress aids.
TC: request IV position EV1 at forward stancheon of Rigid Um. after reinstallation. Instruct UD to move APFR from A2 to A3.	IV: reposition EV1 to forward position of Rigid Umb.		Loosen center EVA bolt in Rigid Umbilical (2 turns) with power tool. Lift Rigid Umb 6" (+y), then 12" (+z) using EVA Handhold(s)..
TC: Request UDs replace Rigid Umb. in position on mount. TC: Instruct UD to postion APFR to UH 1.	UDs (2 UDs) receive Rigid Umb from EV2. Reinstall Rigid Umbil in position on mount. UD: install APFR in A3. Pos UH 1		Hand off Rigid Umb. to UDs.
	SDs: Assist EV2 xlation to position A3 as needed.	Loosen 1 EVA Bolt in handle of stancheon toward forward end of Rigid Umbilical with Essex wrench.	Egress APFR, Xlate to APFR at A3 (NOTE: this is not anticipated xlation path in flight).
TC: Instruct EV 1 in removal of RU -- Caution EV 2 not to contact UHF Ant Elements.	SDs: Assist EV2 ingress APFR IV: Position EV1 at Aft end of Rigid Umbilical.	Loosen 1 EVA Bolt in handle of stancheon (2 turns) toward aft end of Rigid Umbilical with Essex wrench.	Ingress APFR at A3 with assistance from SDs. AVOID CONTACT WITH ANT. ELEMENTS.

Test Director/Test Conductor	(IV) RMS Operator Utility Divers Safety Divers	EV1	EV2
	IV: Position EV1 at center of Rigid Umbilical. UD: install APFR in F2 & configure.	Loosen center EVA bolt in Rigid Umbilical (2 turns) with Essex Wrench Lift Rigid Umb 6" (+y), then 12" (+z).	Loosen 1 EVA bolt (2 turns) at UHF Ant aft end with power tool.
TC: warn EV2 to avoid contact w/ antenna TC: instruct UD to move APFR from A1 to F2. pos to UH 2	UDs (2 UDs) receive Rigid Umb from EV2 . Stow Rigid Umbilical outside test area. UD move APFR to F2- UH 2	Hand off Rigid Umb. to UDs.	Egress APFR, xlate to APFR at F2 via Orbiter handrails. AVOID CONTACT WITH ANT. ELEMENTS.
TC: instruct UD to move APFR from A 3 to F2.	SDs: Assist EV2 ingress APFR at F2. IV: Position EV1 to access 2 clutches at shoulder joints of SSRMS.	Access 2 clutches at shoulder joints of SSRMS.	Ingress APFR at F2 with assistance from SDs.
	IV: Position EV1 to release Utility Cable from Dummy connectors at aft end of pallet. UD: Move APFR to socket F1 & configure.	Release connectors for Utility Cable from Dummy Connectors. Tether cable loose end with wrist tether.	Loosen 4 EVA Bolts (2 turns ea.) at base of UHF Antenna with power tool. KEEP CLEAR OF OTHER ANT. ELEMENTS.
TC: instruct UD to move APFR from A3 to F1- Position to UH 3	IV: Maneuver EV1 -Z to release Utility Cable from clamps. UD: Ad just APFR to position UH 3	Coordinate positioning w/ IV; remove cable from clamps.	Egress APFR Stay clear of UD as APFR is moved to socket F1 and reconfigured.
	IV: Xlate EV1 -X to position near Lab Mockup to mate 4 EVA Connectors to corresponding Connectors on Lab. near LCA.	Coordinate with IV to position near Lab Mockup to connect 4 EVA Connectors to corresponding Connectors on Lab. near LCA.	Ingress APFR at F1 with assistance from SDs. KEEP CLEAR OF OTHER ANT. ELEMENTS.

Test Director/Test Conductor	(IV) RMS Operator Utility Divers Safety Divers	EV1	EV2
		Mate 4 EVA Connectors., relaease tether.	Remove 2 center EVA bolts (2 turns ea.) with power tool. Lift UHF Ant. Clear of mount (~12") by EVA Handhold. KEEP CLEAR OF OTHER ANT. ELEMENTS.
		Demate 4 EVA Conectors Tether cable loose end with wrist tether.	
	IV: Xlate EV1 +Z and +Y to return to Utility Cable stowage.	Coordinate with IV to Xlate back to Dummy Connector Panel to stow 4 EVA Connectors on Aft end of Pallet.	Hand UHF Ant to UDs (SIMULATE)
	UDs: Receive antenna & Stow outside test area.	Mate 4 EVA Connectors in Dummy Panel Release Tether	
	IV: Xlate EV1 to forward (+X) end of pallet for LCA Removal operations.		Egress APFR at socket F1 Stay clear of UD as APFR is reconfigured.
	IV: Position EV1 head down forward , port side to access Lab Cradle Assy.		
TC: Instruct UD to move position APFR at F 1 to position LC 1	UD: Adjust APFR (F1) to position LC 1.		
	SDs: Assist EV2 ingress APFR		Ingress APFR at socket F1; assess ingress aids
TC: Advise EV1 that we are assessing *potential* Cradle attachment		Place wrench in area of potential bolt location on base of Cradle Ass'y; assess access for removal of "pip pin"	Grasp LCA-- assist EV1 in removing LCA from stowage position.

Test Director/Test Conductor	(IV) RMS Operator Utility Divers Safety Divers	EV1	EV2
	IV: Raise EV1 (+Z) to remove Lab Cradle Assy. UD: receive LCA from EV1, EV2 Stow outside test area.	Grasp LCA-- removing LCA from stowage position by pulling forward (+X) 12" and then lifting up 24" (+Z). Hand off LCA to UDs.	Grasp LCA-- assist EV1 in removing LCA in vertical (+Z) from stowage position.
TC: instruct EV2 to translate aft & across pallet Frame 4 to free-float position over forward bolt-stowage position	IV: position EV1 over hinge end tie-down bolts. UD: remove 4 bolts from SSRMS-stow out of way. UD: hand PVC bolts to EV1	Place wrenchon each tiedown bolt and drive (release); pull plastic mockup	Translate to Fwd bolt-stowage position; assess translation path
TC: instruct UD to move APFR from F1 to F3 and position to SB 1 setting	UD: move ft.restr. from F1 to F3 and set to SB1 setting	Pass plastic mockup to EV2 (if necessary, coordinate reposition w/ IV)	Receive bolt from EV1 and install in stow tube
TC: instruct IV to position EV1 over joint end tie-down bolts	IV: position EV1 over joint end (Aft End) tie-down bolts. UD: remove 4 bolts from SSRMS-stow out of way. UD: hand PVC bolts to EV1	Place wrenchon each tiedown bolt and drive (release); pull plastic mockup	Translate to Aft bolt-stowage position;
TC: (*SAFETY CAUTION)* alert UDs to clear bay & SDs to stay above robot for arm unfolding. SD for EV2 should remove EV2 from bay	IV: position EV1 to grasp (w/ micro handling tool) joint end booms SD: remove EV2 from bay	Apply micro tool to joint end fitting and lift booms.	Stay Clear of Boom unfolding operation.
TC: remind EV1 &2 that they should not touch exp. diam. fasteners or retainers (dirty, burrs)	IV: maneuver EV1 to raise & rotate booms into unfolded position	Coordinate with IV movement of booms unfolding.	
TC: *After booms fully unfolded,* instruct SD to move EV2 to F3; IV to above booms, accessing exp. diam. fast.; UD to install pip pin in EDF holes.	SDs: position EV2 to ingress F3; assist ingress. IV: maneuver EV1 to above booms, accessing exp. diam. fast.;		

Test Director/Test Conductor	(IV) RMS Operator Utility Divers Safety Divers	EV1	EV2
TC: caution subjects to not touch EDFs due to HC contamination.	UD: place pip pin in EDF holes to secure booms.		
TC: Instruct IV to raise EV1(+Z) to raise booms ~15°.	IV xlate EV1 to hinge portion of booms- xlate in +Z direction to lift booms ~15°.	Grasp Booms with micro fitting tool. Raise deployed booms ~ 15°	Ingress F3 when booms are raised ~15°. Assess ingress aids
TC: Instruct EV2 to access Port EDFs-- Caution not to touch.	SD: Aid EV 2 to ingress F 3 if necessary.		Simulate Driving lower EDFs on Port side.
TC: Instruct EV1 to access upper EDFs-- Caution not to touch.		Simulate Driving upper EDFs Drive upper exp. diam. fasteners	Reorient APFR to position ED 2
TC: Instruct EV2 to access lower Sbd EDFs-- Caution not to touch.			Simulate Driving lower EDFs on Starboard side.
TC: Instruct IV to assist EV 1 in raising deployed booms to ~60°	UD:s raise booms to 60 º and secure	Grasp Booms with micro fitting tool. Simulate raising deployed booms ~ 60°	Egress F3
TC: Caution SDs about position of EV 2	SD: Make sure EV 2 does not become entrappped. SD: Move EV 1 to forward of LDA UD: move APFR to F5 & set for HL1	Egress MFR on SRMS	Ingress F5 Assess hand holds. Access top EVA HL bolt on Port FSEGF- simulate release.
TC: instruct UD to obtain micro handling tool, & instruct another to pull exp. diam. fasten. out of boom flanges	UD: obtain micro handling tool; pass to EV1 UD: move APFR to F3 position ED 1	Pass plastic mockup to EV2 (if necessary, coordinate reposition w/ IV)	Receive bolt from EV1 and install in stow tube.
TC: Instruct EV 2 to reorient to access inboard Port Hook Link. TC: Instruct EV 1 to xlate around pallet and try APFR installation.	UD: Give Neutrally Buoyant APFR to EV 1 for evaluation of xlation paths and crew aids	Obtain Nuetrally Buoyant APFR from UD. Xlate around pallet with APFR and install in WIFs.	Reorient APFR- access inner EVA HL bolt on FSEGF- release.

Test Director/Test Conductor	(IV) RMS Operator Utility Divers Safety Divers	EV1	EV2
TC: Instruct EV 2 to reorient to access inboard STBD Hook Link.			Reorient APFR YAW left - access inner EVA HL bolt on STBD FSEGF- release.
TC: Instruct EV 2 to reorient to access upper STBD Hook Link.			Reorient APFR- access upper EVA HL bolt on STBD FSEGF- release.
			Egress F5
TC: obtain feedback from EV 1 and EV 2 re Xlation paths and crew aids. Remind of Debrief.		After assessing Xlation paths, pass off APFR to EV 2	Obtain Nuetrally Buoyant APFR from EV 1. Xlate around pallet with APFR and install in WIFs.
		EV 2 Finished	EV 1 FINISHED

Appendix C
APFR Settings Listed by Task and Foot Restraint Position

* Suggested Preliminary Settings - EVA can modify while in APFR
** Settings are for Medium Fidelity APFR used on aft frame of Pallet --(): settings on Hi FI APFR
^ Changed from Test run on 11-15-95

APFR Settings by EVA Task
For Crew Evaluation Sequence C 1 (16 Nov 1995)

TASK	FR#	Posi-tion	Hand Rail #	APFR ORIENT. In WIF	Pitch Dial	ROLL* Dial	YAW* Dial	NOTE
Loosen Forward EVA Bolt From Rigid Umbilical Assembly	F4	RU1	FRGF brace	12:00 O'Clock 0°	RR -18°	G L 18°	1 R 30°	
Loosen AFT EVA Bolt From Rigid Umbilical Assembly	A2**	RU2	Pallet H.R.	1:00 O'Clock 30°	RR -18°	C R 40°	12 0°	
Loosen Center EVA Bolt From Rigid Umbilical Assembly	A1**	RU3	HR on RU	12:00 O'Clock 0°	W W -63°	E R 18°	12 0°	
Loosen AFT Retaining Bolts fromUHF Antenna Assy.	A3**	UH1	Pallet H.R.	12:00 O'Clock 0°	Q Q -9°	F 0°	11 L 30°	
Loosen Forward Retaining Bolts fromUHF Antenna Assy.	F2	UH2	Upper SBD.	12:00 O'Clock 0°	P P 0°	F 0°	12 0°	
Loosen Center EVA Bolts fromUHF Antenna Assy, remove Antenna	F1	UH3	Pallet H.R.	11:00 O'Clock ^ 30°	UU -45°	F 0°	12 0°	
Remove LCA (Assist EV on SRMS)	F1	LC1	LCA H.R.	5:00 O'Clock 150°	M M 27°	F 0°	1 R 30°	
Remove Super Bolts from SSRMS Light End	F3	SB1	M.F.-SSRMS	12:00 O'Clock 0°	P P 0°	F 0°	12 0°	
Tighten Lower Exp. Diameter Bolts—SSRMS Light End - Port Side	F3	ED1	M.F.-SSRMS	12:00 O'Clock 0°	P P 0°	F 0°	10 L 60°	
Tighten Lower Exp. Diameter Bolts—SSRMS Light End - Starboard Side	F3	ED2	M.F.-SSRMS	12:00 O'Clock 0°	P P 0°	J L 54°	3 R 90°	
Release Hook-Link top EVA bolt on FSEGF Port Upper	F5	HL1	HR on LSA	1:00 O'Clock 30°	NN ^ 18°	E R 18°	2 R 0°	
Release Hook-Link top EVA bolt on FSEGF Port Inner	F5	HL2	HR on LSA	1:00 O'Clock 30°	NN ^ 18°	H ^ L 36°	12 ^ 0°	
Release Hook-Link top EVA bolt on FSEGF Starboard Upper	F5	HL3	HR on LSA	1:00 O'Clock 30°	NN ^ 18°	H ^ L 36°	12 ^ 0°	
Release Hook-Link top EVA bolt on FSEGF Starboard Inner	F5	HL4	HR on LSA	1:00 O'Clock 30°	NN ^ 18°	F 0°	10 L 60°	
Mate Connectors from Utility Cable to Lab. Module	A2**	UC1	Pallet H.R.	5:00 O'Clock 150°	P P 0°	E 0°	10 L 90°	
Remove Super Bolts from SSRMS Heavy End (Port)	A1**	SB2		3:00 O'Clock 90°	P P 0°	C (F) 0°	1 R 30°	
Remove Super Bolts from SSRMS Heavy End (Starboard)	A4**	SB3		10:00 O'Clock 300°	P P 0°	E (F) 0°	11 L 30°	

* Suggested Preliminary Settings - EVA can modify while in APFR
** Settings are for Medium Fidelity APFR used on aft frame of Pallet --(): settings on Hi FI APFR
^ Changed from Test run on 11-15-95

Appendix D
6A Launch Deployment Assembly Crew Consensus Report

Crew Consensus Report

Flight 6A Launch Deployment Assembly (LDA) Neutral Buoyancy Simulation (NBS) Extravehicular Activities (EVA) Development Test November 16-20, 1995

On November 16 - 20, 1995, NASA MSFC conducted an NBS EVA development test of assembly tasks to be performed on the International Space Station (ISS) flight 6A Spacelab Pallet (SLP) and LDA. The Astronaut Office provided the following crew test participants: Jerome Apt, Wendy B. Lawrence, Mark C. Lee, James S. Voss, Carl E. Walz, and Peter J. K. Wisoff.

The primary objective of the test was to evaluate SLP and LDA flight 6A EVA tasks, hardware interfaces, and worksite provisions for each of the following:

- Ultra-High Frequency (UHF) Antenna Unstow
- Laboratory (Lab) External PDGF Rigid Umbilical Unstow
- Space Station Remote Manipulator System (SSRMS) Unstow and Deploy
- Lab Cradle Assembly (LCA) Unstow
- LCA to Lab Umbilical Connections
- SLP and LDA Crew Translation Paths
- SLP and LDA Articulating Portable Foot Restraint (APFR) Worksite Interface (WIF) Locations

This test utilized a SLP mockup outfitted with mockups of the flight 6A cargo elements consisting of: LDA, SSRMS, LCA, UHF Antenna, and Lab External PDGF Rigid Umbilical. Each of the cargo elements were configured in their launch configuration. For evaluation of the UHF Antenna, Lab External PDGF Rigid Umbilical, and LCA unstow operations, the SLP mockup was configured to represent its Shuttle payload bay stowed configuration. To evaluate SSRMS unstow and deployment, and LCA to Lab umbilical connections, the aft end of the SLP mockup was outfitted with an LCA and Lab simulator to replicate the SLP to Lab mated configuration. The test also evaluated SLP and LDA crew translation paths and WIF locations. WIFs were evaluated relative to crew worksite access and positioning, and APFR installation and ingress.

The crew used the station APFR and facility Shuttle Remote Manipulator System (SRMS) simulator to provide crew worksite positioning. The station compliment of tools were used to evaluate tool access to hardware interfaces.

The test did not and was not planned to evaluate cargo element installation at their on-orbit use locations since that aspect of the task is to be demonstrated by the hardware truss segment or pressurized module interfacing with the cargo element.

The crew used the following evaluation ratings to assess the EVA hardware and tasks in this test:

Category	Description	Evaluation Rating - Criteria
ACCEPTABLE (A)	Design changes are not required. Hardware configuration and associated operations for the defined task are acceptable as tested.	**A** - Crew is able to accomplish the task as defined within an acceptable workload. **B** - Crew is able to accomplish the task with small compensation.
UNACCEPTABLE 1 (U1)	Design changes are required, however, changes will not impact testing results. No retesting required. 1-G verification is adequate.	**C** - Crew is able to accomplish the task as defined, but with difficulty. Design modifications are required.
UNACCEPTABLE 2 (U2)	Design changes are required and will significantly impact testing results to warrant retesting. Retesting required.	**D** - Crew is barely able to accomplish the task as defined either due to excessive workload or design deficiency. **E** - Crew is unable to accomplish the task as defined.
INCONCLUSIVE (I)	No crew consensus can be reached due to inadequate hardware fidelity or insufficient number of test subjects used to establish a crew consensus.	**I** - Crew is not able to fully evaluate the task due to the limited test environment, test objectives, hardware fidelity, or number of test subjects.

Crew Consensus Report
Flight 6A LDA NBS EVA Development Test (11/16-20/95)

Evaluation Results	Rating*	Recommendations

* A = Acceptable, U1 = Unacceptable but retesting not needed, U2 = Unacceptable and requires retest, I = Inconclusive

1. UHF Antenna Unstow		
a. APFR ingress at WIF locations #A3, F1, and F2 are **ACCEPTABLE** for UHF Antenna unstow from the SLP.	**A**	
b. Tool access and crew positioning to bolt interfaces # UHF1 (1 bolt), UHF2 (4 bolts), and UHF3 (2 bolts) are **ACCEPTABLE** using an APFR at WIF locations #A3, F2, and F1, respectively, or the SRMS.	**A**	
c. UHF Antenna handhold locations are **UNACCEPTABLE 1** because they are spaced too far apart for SRMS and APFR unstow and manipulation.	**U1**	A third handhold needs to be added between the two baseline handholds to afford the same antenna handling capabilities noted during testing for all crew members, regardless of height and arm length.
d. UHF Antenna unstow from SLP is **ACCEPTABLE** using the SRMS or an APFR at WIF location #F1.	**A**	

2. Lab External PDGF Rigid Umbilical Unstow		
a. APFR ingress at WIF locations #F4, A1, and A2 are **ACCEPTABLE** for Lab External PDGF Rigid Umbilical unstow from the SLP.	**A**	The configuration of the SSRMS boom camera tested did interfere with APFR ingress at F4, but it is understood that the camera or configuration has been changed would not effect ingress.
b. Tool access and crew positioning to bolt interfaces (1 bolt each) #RU1, RU2, and RU3 are **ACCEPTABLE** using an APFR at WIF locations #F4, A2, and A1, respectively, or the SRMS.	**A**	
c. Lab External PDGF Rigid Umbilical unstow from SLP is **ACCEPTABLE** using the SRMS or an APFR at WIF location #A1.	**A**	

3. SSRMS Unstow and Deploy		
a. Tool access and crew positioning to each of eight tie-down/super bolt interfaces (two per boom segment) on the SSRMS light and heavy ends using the SRMS is **ACCEPTABLE**.	**A**	
b. Tool access and crew positioning to the four aft tie-down/super bolt interfaces on the SSRMS heavy end untorquing and removal is **ACCEPTABLE** using an APFR at WIF location #A1 and either/or both the right angle drive and an APFR at WIF location #A4.	**A**	WIF #A1 provided access to the two port bolts. To access the the two starboard bolts required the use of either/or both the right angle drive and use of APFR at WIF #4, all dependent on size of crew member. Although not tested, APFR WIF #A4 is a mirror image location of #A1 and should work since the SSRMS is centered on the SPL. The Mini-Workstation (MWS) for some crew members might need to be temporarily removed for this task, if it interferes with bolt access operations.
c. Tool access and crew positioning to the four forward tie-down/super bolt interfaces on the SSRMS heavy end using an APFR at WIF location #F3 is **ACCEPTABLE**.	**A**	
d. Tie-down/super bolt removal and hand-off from both the heavy and light ends of the SSRMS is **ACCEPTABLE** using a retractable tether while the crew member is restrained on an APFR or on the SRMS.	**A**	
e. Tie-down/super bolt stowage location access is **ACCEPTABLE** while on the SRMS or in free-float mode.	**A**	It is assumed that the bolt stowage accommodations (soft-dock and latching) will be EVA friendly to allow free-float operations. It should be noted that the final bolt stowage design was not evaluated. Another option would be to use the Body Restraint Tether (BRT) off of the top SLP handrails (assuming a dog-done handrail design) should the SRMS not be available and two-hands are required. Any one of these three ways (SRMS, free-float, or BRT) of performing this task is recommended.
f. Tie-down/super bolt stowage location access is **UNACCEPTABLE 1** while on an APFR at WIF location #A1 because the forward-most bolt locations could not be accessed from the APFR without having to go into a free-float mode.	**U1**	An APFR is not required for this task. The recommended method of performing this task is to use the SRMS, free-float, or BRT. It is further recommended that the final bolt stowage accommodations design be, as a minimum, reviewed by the crew in a table-top review.

3. **SSRMS Unstow and Deploy - Continued**		
g. APFR ingress at WIF location #F3 is **ACCEPTABLE** using the Micro ORU Handling Tool (OHT) mounted to upper-most micro on the port side SSRMS boom.	**A**	The task will require the Micro OHT, so that in this particular case it is acceptable to not require an additional handrail for APFR ingress.
h. SSRMS joint clutch lever (2) access and actuation on the heavy end is **ACCEPTABLE** using an APFR at WIF location #A1 or the SRMS.	**A**	For low torque mechanism actuation, such as that required by the joint clutch lever mechanisms, can be performed via free-float, assuming adequate crew restraint aids are provided. Although not tested, tool access to the SSRMS joint manual drive bolt interface would not have been a problem as it is located at same clutch lever location.
i. Micro "D-handle" OHT and "Ice Cream Scoop" installations on port side SSRMS boom (light end) micro interfaces and lifting of booms using an APFR at WIF location #F3 is **ACCEPTABLE**.	**A**	It is recommended that two Micro OHT handles be used for this boom elevation task.
j. With SSRMS booms folded and elevated approximately 15 to 20 degrees, access to the lower two Expandable Diameter Fasteners (EDF) on each boom hinge is **ACCEPTABLE** using an APFR at WIF location #F3.	**A**	It is recommended that the crew member roll the APFR boot plate 180 degrees to face the bolts looking forward as the SLP sits in the payload bay.
k. With SSRMS booms unfolded and elevated approximately 10 to 20 degrees (depending on APFR WIF location used), access to the upper two EDFs on each boom hinge is **ACCEPTABLE** using the SRMS or an APFR at WIF locations #F3 and, if necessary, #F1.	**A**	The F1 WIF APFR location allowed access to the upper EDFs and can be used as alternate location or as a supplementary location for smaller sized crew members having difficulty to the starboard-most EDFs should #F3 be a problem. As before, if the MWS interferes with access, it can be temporarily removed for this task.
l. Tool access and crew positioning to the four Flight Support Equipment Grapple Fixture (FSEGF) bolt interface locations (top and inboard of each FSEGF) is **ACCEPTABLE** using an APFR at WIF location #F5.	**A**	

3. **SSRMS Unstow and Deploy - Continued**		
m. APFR ingress at WIF location #F5 is **ACCEPTABLE** using the LDA truss members.	A	The two LDA handrails located on top of the LDA and aft of WIF #F5 are not required since the LDA truss provides a convenient handhold for ingress. Assuming the mockup LDA truss design replicates the flight LDA truss and is available as a crew restraint surface, then these two LDA handrails can be deleted.
n. Manual EVA boom elevation and unfolding were not evaluated during this test as they were performed in July '92 Canadian Space Agency (CSA) Weightless Environment Training Facility (WETF) verification testing (Crew Consensus Report #CA3-92-106).	N/A	

4. **Lab Cradle Assembly (LCA) Unstow**		
a. LCA removal task is **INCONCLUSIVE** due to the low fidelity of the mockup and unknown flight configuration.	I	When the flight configuration is established and a higher fidelity mockup can be provided, the removal operations will need to be retested in neutral buoyancy.
b. Use of two crew members to perform the task of LCA removal, one on the SRMS and one on an APFR located at SLP WIF #F1 or possibly #F2, depending on LCA configuration and crew member size, is **ACCEPTABLE**.	A	The primary task of LCA removal should be performed by the crew member on the SRMS and the second crew member should assist with handling of LCA or simply provide visual assistance and guidance. WIF #F1 is the preferred APFR location for the second crew member; however, WIF #F2 might be another option.
c. Ingress into APFR WIF #F1 and #F2 is **ACCEPTABLE** using the LDA structure.	A	APFR WIF #F1 is the preferred crew restraint location for the second crew member in the LCA unstow task. The LDA structure should provide convenient handholds for APFR ingress assuming the LDA structure tested replicates the flight LDA structure design and is available as a crew restraint aid.

3. **SSRMS Unstow and Deploy - Continued**		
m. APFR ingress at WIF location #F5 is **ACCEPTABLE** using the LDA truss members.	**A**	The two LDA handrails located on top of the LDA and aft of WIF #F5 are not required since the LDA truss provides a convenient handhold for ingress. Assuming the mockup LDA truss design replicates the flight LDA truss and is available as a crew restraint surface, then these two LDA handrails can be deleted.
n. Manual EVA boom elevation and unfolding were not evaluated during this test as they were performed in July ô92 Canadian Space Agency (CSA) Weightless Environment Training Facility (WETF) verification testing (Crew Consensus Report #CA3-92-106).	**N/A**	

4. **Lab Cradle Assembly (LCA) Unstow**		
a. LCA removal task is **INCONCLUSIVE** due to the low fidelity of the mockup and unknown flight configuration.	**I**	When the flight configuration is established and a higher fidelity mockup can be provided, the removal operations will need to be retested in neutral buoyancy.
b. Use of two crew members to perform the task of LCA removal, one on the SRMS and one on an APFR located at SLP WIF #F1 or possibly #F2, depending on LCA configuration and crew member size, is **ACCEPTABLE**.	**A**	The primary task of LCA removal should be performed by the crew member on the SRMS and the second crew member should assist with handling of LCA or simply provide visual assistance and guidance. WIF #F1 is the preferred APFR location for the second crew member; however, WIF #F2 might be another option.
c. Ingress into APFR WIF #F1 and #F2 is **ACCEPTABLE** using the LDA structure.	**A**	APFR WIF #F1 is the preferred crew restraint location for the second crew member in the LCA unstow task. The LDA structure should provide convenient handholds for APFR ingress assuming the LDA structure tested replicates the flight LDA structure design and is available as a crew restraint aid.

4. Lab Cradle Assembly (LCA) Unstow - Continued		
d. Handling of the LCA during removal by both crew members is **UNACCEPTABLE 2** due to the lack of handrails and overall hardware design immaturity.	**U2**	The design of the LCA has been modified from what was previously tested on July ô95 (Crew Consensus Report #CB1-95-055) and the maturity of the design and configuration of the mockup was inadequate to evaluate the handling characteristics and aids required. LCA hardware and operations retest in neutral buoyancy is mandatory.
e. Access to LCA to LDA launch bolts can best be achieved by placement of bolts along the port vertical side and/or the horizontal upper side of the LCA structure (as it sits in the payload bay). Placement of the bolts on the upper and port sides of the inboard face of the LCA to LDA interface may be accessible depending on final location, torque, and type of bolt. As noted during the test, some bolt locationsmay require the use of the right angle drive. If high torque bolts are used, the torque multiplier might be required; however, torque multiplier and power tool access was not evaluated.	**N/A**	It is recommended that final LCA to LDA bolt access be evaluated in neutral buoyancy.

5. LCA to Lab Umbilical Connections		
a. Placement of a dummy connector panel for the LCA to Lab umbilical should be vertically on the port, aft side of the SLP face clear of the handrails or on the port side of the LCA structure.	**N/A**	A crew table-top review of the final connector panel location and configuration or inspection of high fidelity or flight hardware should be conducted.
b. The recommended method of LCA to Lab umbilical connections should be by use of the BRT on existing SLP handrails (assuming a dog-bone handrail design). The APFR method is not recommended because of the APFR set-up overhead and limited access.	**N/A**	

5. **LCA to Lab Umbilical Connections - Continued**		
c. Umbilical connector unstow and installation should follow a logical sequence to preclude lines having to cross over and under each other and reduce entanglement possibilities.	**N/A**	The length of free cable should be sized to allow adequate connector mating and, if necessary, standard Space Station EVA line clamps should be used. A crew table-top review of the final umbilical routing and connector sequencing should be conducted. A crew table-top review of the final umbilical routing and connector mating sequencing should be conducted.
d. The length of free umbilical cable should be sized to allow adequate connector mating/demating and, if necessary, standard Space Station EVA line clamps should be used along the length of lines to be manipulated by the crew.	**N/A**	

6. **SLP and LDA Crew Translation Paths**		
a. Crew translation paths on the SLP and LDA (top, forward, and aft sides) is **ACCEPTABLE**. This includes transitions between the port and starboard sides of the SLP across the forward LDA and aft LCA passive half structure.	**A**	

7. **SLP and LDA APFR Installation**		
a. APFR installation at WIF locations #A1 through #A4 and #F1 through #F5 are **ACCEPTABLE**.	**A**	APFR installation at WIF locations #F3 and #F5 can be easily accomplished using the LDA structure. Assuming the mockup LDA truss replicates the flight LDA truss design and is available as a crew restraint surface, no handrails are required. Therefore, the two LDA handrails located on top of the LDA and aft of WIF #F5 can be deleted.