FINAL REPORT

FOR

Contract NAS8-35318

"THE DESIGN AND DEVELOPMENT OF THE HUBBLE SPACE TELESCOPE NEUTRAL BUOYANCY TRAINER"

Covering the period of March 1983 - December 1990

Submitted to:

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

Submitted by:

Essex Corporation
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Huntsville AL 35806

December 31, 1990

Foreword

This document has been furnished by Essex Corporation in partial fulfillment of contract NAS8-35318. Should any questions or comments arise from review of this document, they may be directed to Alan Ware, Engineering/Design Manager, at (205) 971-2046.

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ACRONYMS AND ABBREVIATIONS

EVA	Extra Vehicular Activity
FGS	Fine Guidance Sensor
FSS	Flight Support System
FRR	Foot Restraint Receptacle
HST	Hubble Space Telescope
KLSS	Keel Latch Support Structure
LGA	Low Gain Antenna
MFR	Manipulator Foot Restraint
M&R	Maintenance and Refurbishment
MLI	Multilayer Insulation
MSFC	Marshall Space Flight Center
NB	Neutral Buoyancy
NBS	Neutral Buoyancy Simulator
ORU	Orbital Replacement Unit
ORUC	Orbital Replacement Unit Carrier
OTA	Optical Telescope Assembly
PFR	Portable Foot Restraint
RMS	Remote Manipulator System
SA	Solar Array
SI	Scientific Instrument
SSE	Space Support Equipment
SSM	Support Systems Module
WBKL	Wide Body Keel Latch
WFPC	Wide Field Planetary Camera

1.0 Introduction

This contract was awarded to Essex Corporation on March 31, 1983 for the purpose of designing and fabricating Hubble Space Telescope (HST) Extra Vehicular Activity (EVA) training hardware for zero-gravity simulations in the Marshall Space Flight Center (MSFC) Neutral Buoyancy Simulator (NBS) and the Johnson Space Center Weightless Environment Training Facility. The HST NBS hardware was also used to support flight hardware development and development of EVA crew servicing procedures.

This contract has produced deployment, and Maintenance and Refurbishment (M&R) mission trainers. These trainers reflect flight hardware fidelity in their respective areas of EVA crew interface.

The design and fabrication of simulator training and development hardware, the associated test support from utility divers, test conductors, and test subjects have all been with the common goal of enabling HST program management to use the NBS EVA data to make design and program decisions.

Essex Corporation has been supporting the MSFC HST Neutral Buoyancy Simulation effort virtually since it began back in early 1979. We have designed, fabricated, and installed into the NBS every piece of HST hardware built for NBS simulations. We have supported tests with utility divers, test conductor, and have even provided suited test subjects.

2.0 Contract History

The original contract for the HST Neutral Buoyancy (NB) support was awarded to Essex on March 31, 1983. The contract has undergone approximately 30 change orders or modifications since it was originally signed.

Modification #:	Date:
1	4/13/83
2	6/25/84
3	12/24/84
4	4/25/85
5	7/22/85
6	8/15/85
7	9/27/85
8	12/17/85
9	2/19/86
10	2/19/86
11	2/24/86
12	4/1/86
13	6/25/86

(continued)

Modification #:	Date:
14	11/3/86
15	10/27/86
16	2/3/87
17	6/15/87
18	7/10/87
19	1/29/88
20	2/20/88
21	3/21/88
22	5/2/88
23	9/9/88
25	?
26	3/31/89
27	10/24/89
28	2/23/90
29	8/20/90
30	10/9/90

3.0 Deliverables

Final Refurbishment and Upgrade of the HST Deployment Crew Trainer consisting of:

- Diode Boxes
- Aft Shroud
- Support Systems Module (SSM) Equipment Section
- Optical Telescope Assembly (OTA) Equipment Section
- OTA Forward Shell
- Light Shield
- Aperture Door
- Station 100 Mockup consisting of:
- Emergency Umbilical Disconnects
- Umbilical Retract Mechanisms
- Umbilical Tower
- High Gain Antennas
- Solar Arrays
- Astronaut Control Panel

HST Maintenance Crew Trainer consisting of:

- Aft Shroud
- Aft Shroud Orbital Replacement Units (ORUs)
- SSM¢\Equipment Section with all ORU envelopes, electrical connectors, electrical wiring, and decals and fasteners
- OTA Equipment Section, with all ORU envelopes, electrical connectors, electrical wiring, and decals and fasteners
- Diode Boxes
- Focal Plane Assembly
- Fine Guidance Sensor (FGS) - 3
- Wide Field Planetary Camera (WFPC)

- Manipulator Foot Restraint (MFR)
- Crew Aid Tools
- Portable Foot Restraint (PFR) - 2
- Orbital Replacement Unit Carrier (ORUC), several configurations, the last one consisting of:
- Spacelab Pallet - 2
- ORU Storage Shelves with Supports
- Shelf adapter plates
- Keel Latch Support Structure (KLSS)
- Wide Body Keel Latch (WBKL) Assembly
- Load Isolation System
- FGS Scientific Instrument Protective Enclosure
- Flight Support System (FSS)- Cradle A
- Solar Array Carrier (various configurations)
- Spare ORU envelopes for the ORUC
- Exterior ORUs: Low Gain Antenna,(LGA) Coarse Sun Sensors (3)

4.0 List of Tests

Date	Subject
March 1984	Evaluate Crew Accessibility of HST deployment/return electrical umbilicals, axial Scientific Instrument (SI) cryogenic vents, and SSM equipment section bays 1,4,6 and 9.
July 1984	Design Verification of ORUC Preliminary Design Review Configuration. Evaluation of ORU mechanisms on the carrier. Evaluate Remote Manipulator System (RMS) MFR as a work platform and ORU transfer medium. Evaluation of all crew aids. Evaluate temporary parking locations for old instruments. Refine instrument changeout timelines.
May 1985	Evaluate access to ORUs in Bays 1 and 7.
September 1985	Evaluate PFR, Evaluate Essex wrench and extensions with drop-proof feature. Verify use of clothesline transfer device. Verify Deployment Mission procedures. Establish an elapsed time for the Deployment Mission crew training.
October 1985	Evaluate accessibility of Block II ORUs.

November 1985	Establish end-to-end timelines for Mission Timeline Profile Analysis. Investigate ORU concepts/crew aids. Investigate work site preparation. Investigate tool/crew aid management.
February 1986	Determine if ORUC Foot Restraint Receptacle (FRR) locations are acceptable for ORU access. Define EVA umbilical operations on the station 100 mockup and a high fidelity FSS mockup. Verify crew aid placement for all FSS contingency operations. Confirm access to LGA from existing FSS FRR's.
May 1986	Determine if a crewman working off the PFR on the KLSS can reach Block II ORUs in the SSM Equipment Section while the HST is tilted down for servicing. Verify access to the HST tool box located on the KLSS. Verify access to the Frame 4 stowage boxes located on the ORUC. Verify access to the EVA interfaces on the WBKL.
February 1987	Validate the Solar Array (SA) carrier concept. Identification of Crew aid placement on the SA Carrier. Develop initial SA removal and replacement timelines.
September 1987	Determine validity of the proposed SA Carrier design.
April 1988	Verify the designs of the flat base and t-frame SA carriers. Determine if an electronic latch drive is required. Determine if two mirror image latches are required. Determine if SA-1 EVA installed handholds are required. Evaluate the design of the Multilayer Insulation (MLI) and the FGS retention device.
December 1988	Perform end-to-end timeline runs for a simulated HST M&R mission consisting of two 6-hour EVA days. Test the NiCd to NiH2 battery changeout. Test the reach and access for 12 new Block II ORUs. Test the manual translation of an SA as a contingency operation to RMS failure. Test the removal, parking, and reinstallation of the WFPC with the extended handrails. Test the EVA interface on the WBKL. Evaluate the design of the MLI blanket on the small-ORUC.

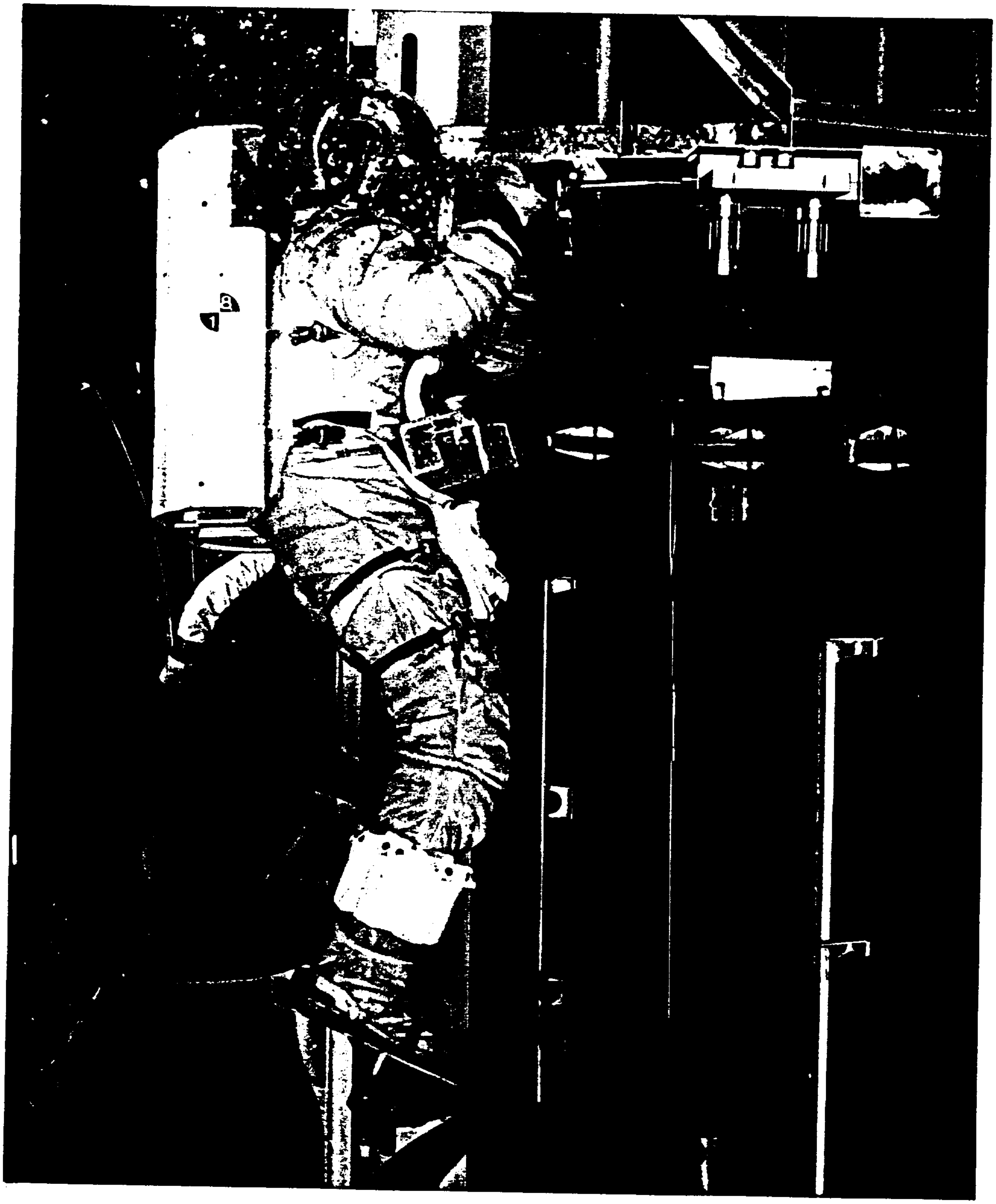

Figure 1: HST Deploy/Return Electrical Umbilical Interfaces
Here a suited subject evaluates the access and visibility of indicator markings on a first generation Umbilical Disconnect Mechanism during NB45B in February of 1984.

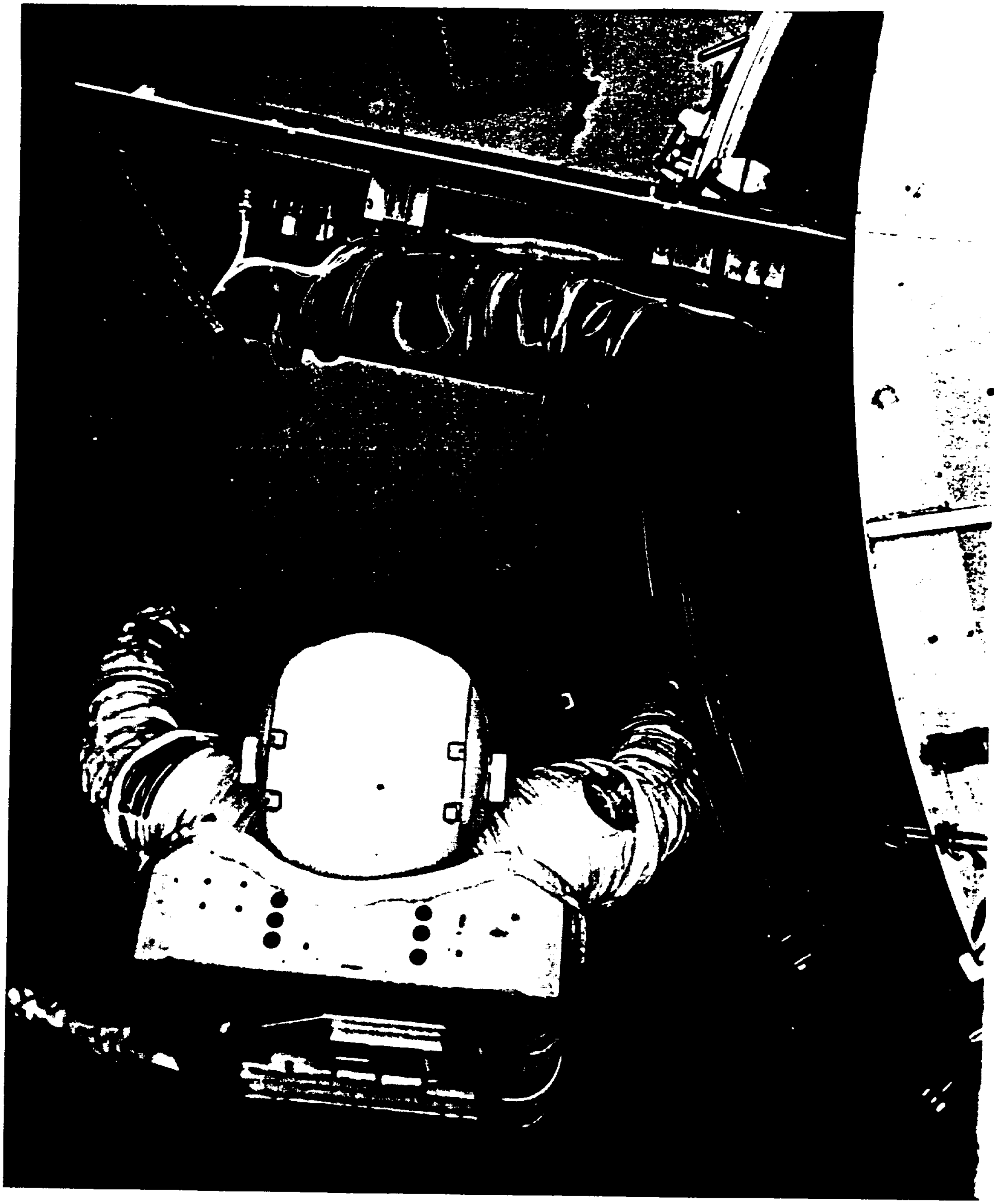

Figure 2: Bay 1, SSM Equipment Section
Suited Subject evaluates access to ORUs in Bay 1 during NB45E in May of 1984.

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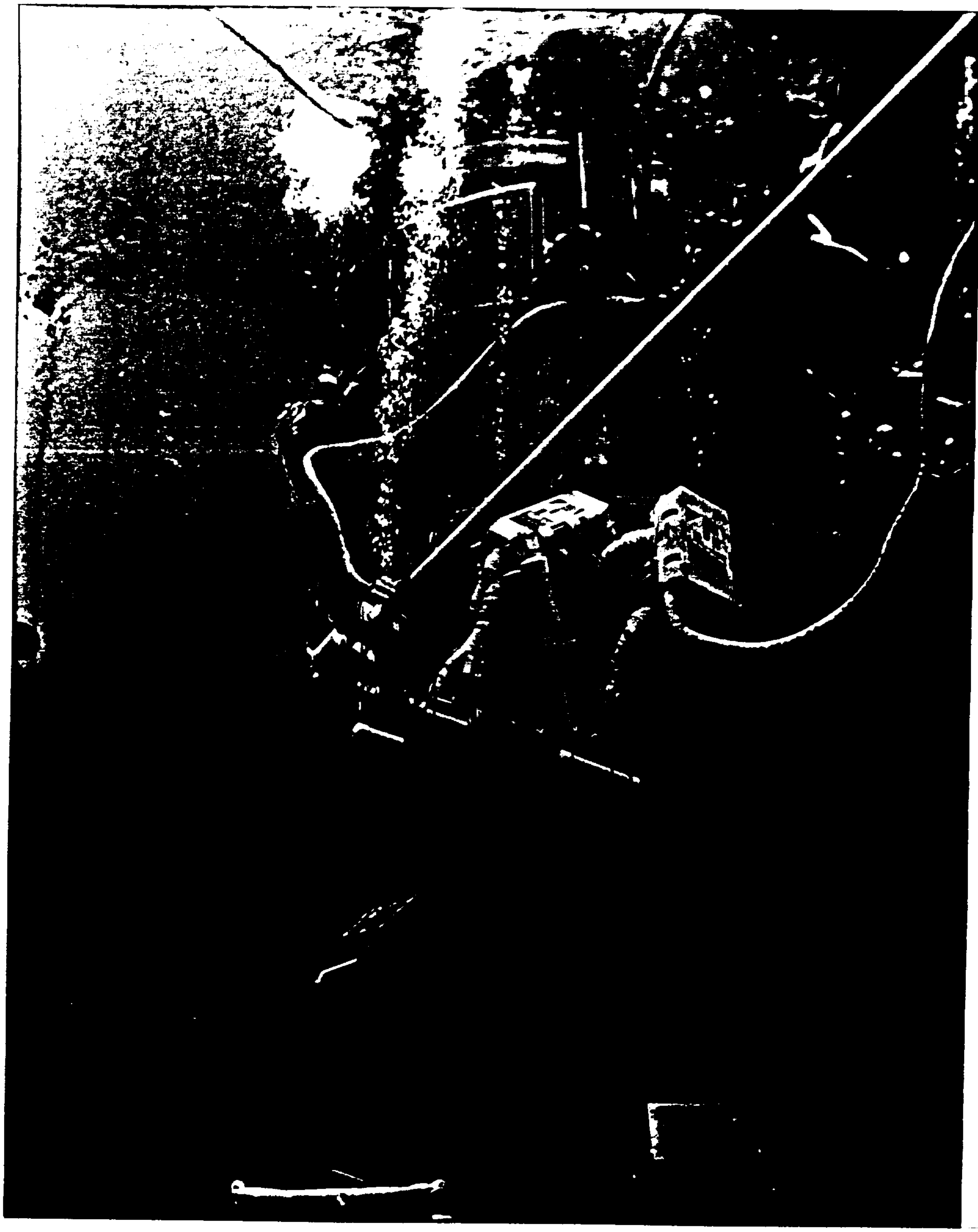

Figure 3: ORU Replacement
Astronauts McCandless and Sullivan evaluate the RMS as a method of transferring the FGS replacement ORU from the ORUC to the Aft Shroud during NB45J in November of 1985.

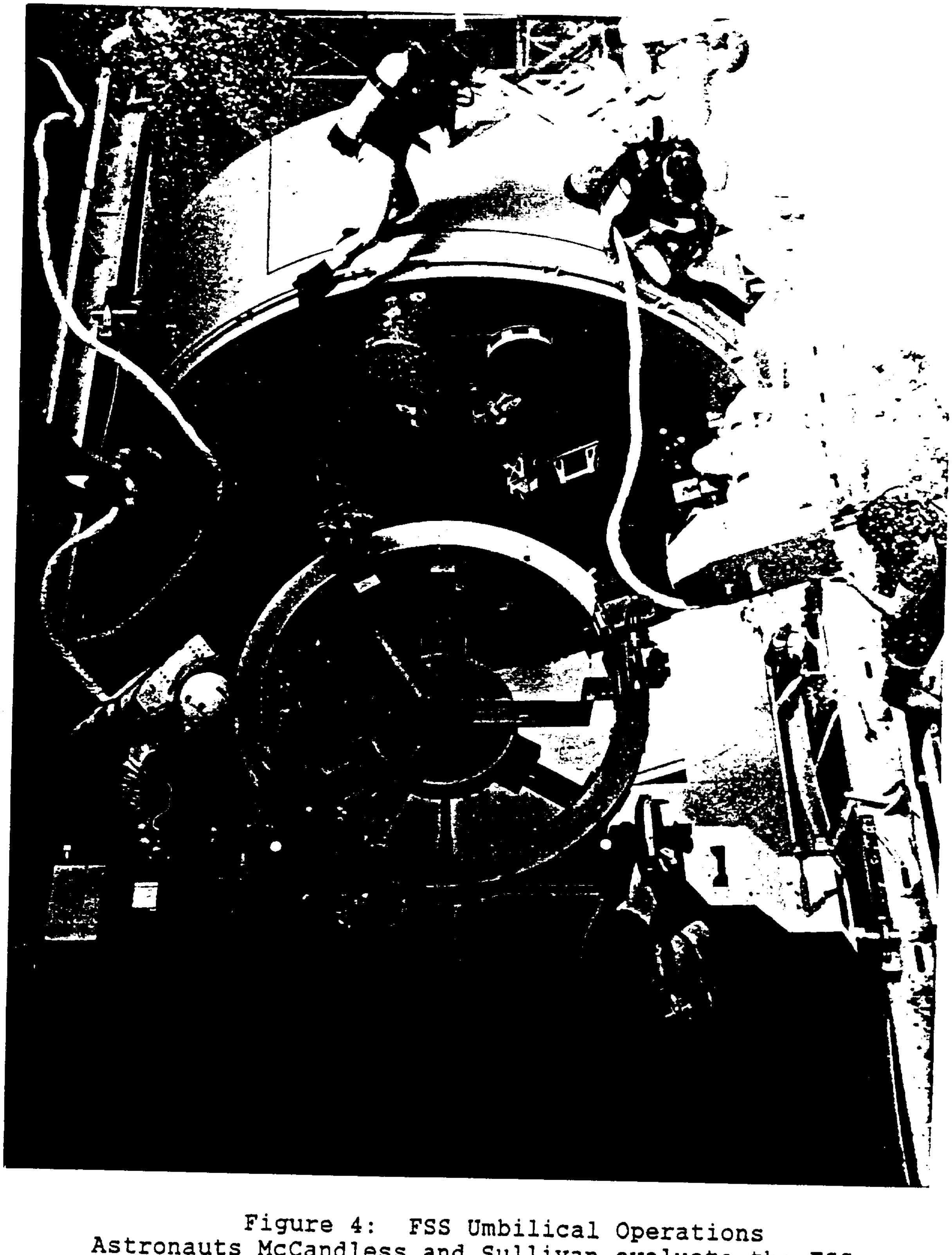

Figure 4: FSS Umbilical Operations
Astronauts McCandless and Sullivan evaluate the FSS crew aid provisions and umbilical mechanism operations using the Station 100 mockup.

5.0 Program Accomplishments

The HST NBS program has contributed significantly to the development of the flight HST article. Some of these program inputs are listed below:

- <u>Axial SI Guide Rail Spring</u> Essex built five different springs each with a different spring rate for the Axial SI guide rails. These were evaluated by the crew during NBS simulations to determine the best spring rate to retain the SI in the upper guide rail. The resulting test data was sent to Perkin Elmer Corporation to enable them to use the crews' input to determine the spring rate for the flight unit.

- <u>Flight Ratchet Wrench</u> As the servicing scenarios developed for HST, it became clear through NBS simulation that a need existed for a ratchet wrench which would adapt to the suited subjects limitations. Essex built many different wrench concepts for use during NBS simulations of HST servicing tasks. From this work the flight "Essex" Ratchet Wrench was developed.

- <u>EVA Timelines</u> The NBS HST hardware allowed both development of servicing scenarios and the actual definition of the amount of time each EVA task would take. As mission servicing objectives were finalized, the crew was able to determine complete beginning-to-end timelines.

- <u>Foot Restraint Socket Locations</u> The HST NBS hardware provided for crew confirmation of foot restraint socket locations. This input directly affected where the sockets were placed on the flight unit.

- <u>PFR Development</u> The HST NBS simulations produced a need for an articulating portable foot restraint to allow better access from foot restraint socket locations. After the design and engineering drawings were completed by Lockheed, Essex built two NB versions of the PFR before any flight ones were produced. This fabrication from Lockheed drawings revealed many errors and inconsistencies in the drawings which ultimately saved NASA money and time by correcting them before the flight units were built.

- o <u>Assorted Crew Aids Development</u> The HST NBS simulations allowed NASA engineers and astronauts to experience the HST EVA servicing environment, which generated many ideas for tools and other equipment which will ultimately make it easier for the EVA crewman servicing the HST. Among these are door stays, connector removal tools, and ratchet wrench socket extensions.

- o <u>Development of NB Paint Specifications</u> The NB environment caused Essex to research paint types to select the most durable product available. This led to the development of a process for preparing and painting NB mockups which Essex formally presented to the NBS.

6.0 Summary

The HST NBS Trainer contract has contributed significantly to the development of the flight HST. It is a prime example of how NBS activities can aid in the development of hardware development and EVA servicing scenarios.