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REPORT FOR NEUTRAL BUOYANCY SIMULATIONS OF TRANSFER ORBIT STAGE CONTINGENCY EXTRAVEHICULAR ACTIVITIES

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Science and Engineering Directorate

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The transfer orbit stage (TOS) will propel the advanced communications technology satellite (ACTS) from the space shuttle to an Earth geosynchronous transfer orbit. Two neutral buoyancy test series were conducted at MSFC to validate the extravehicular activities (EVA) contingency operations for the ACTS/TOS/ mission. This report delineates the results of the neutral buoyancy tests and gives a brief history of the TOS EVA program. Test numbers are: NBS–TOS–90.1 and NBS–TOS–91.1.

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FOREWORD

The transfer orbit stage (TOS) is an orbit transfer vehicle that will fly aboard the space shuttle *Discovery* in February 1993 (STS-51). TOS will propel the advanced communications technology satellite (ACTS) from low-Earth orbit into an Earth geosynchronous transfer orbit. TOS interfaces with the shuttle via the TOS airborne support equipment (ASE) which secures ACTS/TOS in the shuttle cargo bay. In preparation for the deployment of ACTS/TOS, the ASE opens and tilts the payload up 45°. After the deployment of ACTS/TOS the ASE would then be closed and latched allowing the shuttle cargo bay doors to be closed for Earth return. However, if the primary and redundant electrical systems fail, then a contingency extravehicular activity (EVA) would be employed to close and secure the TOS ASE. If ACTS/TOS is not deployed and the primary and redundant electrical systems fail, then it would also be necessary to detilt the payload to allow the cargo bay doors to close.

Two series of neutral buoyancy (NB) simulations were conducted to test the contingency EVA scenarios. The first series was conducted in October 1990 and the second in July 1991. The simulations tested the ability to detilt, close, and latch the ASE with ACTS/TOS still in the shuttle cargo bay. This report presents the results of these simulations and a brief background on the TOS EVA program.

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LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Continued)

ACRONYMS

ACTS	Advanced communications technology satellite
ASE	Airborne support equipment
EPP	EVA pin puller
EVA	Extravehicular activity
JSC	Johnson Space Center
LAW	Latch arm wrench
MSFC	Marshall Space Flight Center
NB	Neutral buoyancy
NBS	Neutral buoyancy simulator
PFR	Portable foot restraint
PRD	Payload retention device
RD	Rotation device
RMS	Remote manipulator system
STS	Space transporation system
TL	Trunnion link
TnD	Tension device
TOS	Transfer orbit stage

TECHNICAL MEMORANDUM

REPORT FOR NEUTRAL BUOYANCY SIMULATIONS OF TRANSFER ORBIT STAGE CONTINGENCY EXTRAVEHICULAR ACTIVITIES

I. INTRODUCTION

A. Purpose

The purpose of this report is to delineate the results of the neutral buoyancy (NB) simulations conducted at Marshall Space Flight Center (MSFC) for the advanced communications technology satellite (ACTS)/transfer orbit stage (TOS) mission. These simulations were conducted to determine the extravehicular activity (EVA) compatibility of the TOS EVA tools with the TOS airborne support equipment (ASE) and their associated contingency operations. This report is written in addition to the published action item list that was written to inform the chief engineer's office of the results/actions for a successful TOS EVA program.

B. Scope

This report will present the results of the contingency EVA NB simulations and how they affect the ACTS/TOS mission and mission hardware. Three EVA scenarios were tested: (1) aft ASE detilt, (2) upper forward ASE rotation closed, and (3) latching of the forward ASE. Any or all of these scenarios may be needed during the mission. However, during the simulations, all three scenarios were tested as a worst case condition (ACTS/TOS not deployed).

Each EVA task and each TOS EVA tool were thoroughly evaluated for reach, access, visibility, restraint, and worksite. These simulations were the cornerstone in developing and verifying the ACTS/TOS EVA operations.

C. Summary of Significant Results

The biggest mission impact that resulted from the NB simulations is the necessity to add longeron bridge fittings. The addition of longeron bridge fittings allows the EVA crewman to use the portable foot restraint (PFR) for the necessary restraint to perform the EVA tasks. Assuming the current location of the TOS ASE in the orbiter cargo does not change, the longeron bridge fittings that must be added are number 10 on port and starboard, and number 12 on the port side.

It is highly recommended that for future TOS missions aboard the shuttle that may require EVA, PFR sockets be added to the TOS ASE. This will eliminate the need for additional longeron bridge fittings.

D. Background

There are three contingency EVA tasks for the ACT/TOS mission: (1) detilt of the aft ASE cradle, (2) rotation closed of the upper forward ASE, and (3) latching of the forward ASE. During nominal operations the latch, the upper forward ASE, and the aft ASE cradle are

driven by electromechanical actuators. Each operation has a primary and secondary (redundant) actuator. If both actuators are disabled on any one operation, then an EVA would be employed to restore the payload.

Each actuator freely telescopes unless an integral pin is used to place the actuator in the structural load path. The actuator remains in the load path as long as the pin is engaged. In order for a failed actuator to be removed from the load path, the pin must be retracted. The primary actuators have a pyrotechnic pin puller which would retract the pin if the primary actuator failed. This would allow the secondary actuator to drive the ASE without resistance from the primary actuator. The secondary actuators do not have a pyrotechnic pin puller; therefore, in the case of a failed secondary actuator or in the case of a failed primary actuator and a failed pyrotechnic pin puller, the EVA crewman would have to manually pull the actuator pin. An EVA manual pin pull is a part of each EVA scenario.

The design, testing, and manufacturing control of the EVA tools is being done in-house at MSFC. One significant ground rule to this undertaking was that modifications to the existing flight ASE were discouraged because the cost to modify the hardware was unreasonably high.

The mechanical systems development branch (EP63) was asked to take existing conceptual designs of EVA tools that were designed for these tasks and produce flight tool designs. As of September 1990 much of this work had been done and the first TOS EVA tools were tested in the neutral buoyancy simulator (NBS) tank in October 1990. After the first series of NB tests several changes were made to the EVA tools. By the July 1991 NB test series, the NB tools represented flight designs.

II. DISCUSSION

A. Changes from October 1990 to July 1991 NB Testing

Described here are some of the changes that took place between the October 1990 test series and the July 1991 test series. Some of the changes were a result of the first test series, especially tool changes, and others were the result of program changes. One test subject was used for each test in October and two test subjects were used for each test in July. Most of the tool changes are part of the action item list which is shown in appendix A and appendix B.

1. Detilt

In the first test series a tilt device was tested for the detilt operation. The device was an enclosed ACME ball screw which attached to the ASE via an aft cradle flange bracket or "whistle" (because it looked like a basketball referee's whistle) and a window frame bracket. Several problems were encountered with the tilt device in the October test series (as noted in the action item list appendix A action numbers 027 through 045) and the design was later discontinued. By the time of the July 1991 test series, a good concept for the detilt of the aft ASE had been incorporated into the program.

The new concept utilizes a "tilt bracket" which is permanently mounted to the aft ASE flange. One end of the STS payload retention device (PRD) attaches to the forward end of the tilt bracket and the other end attaches to an orbiter port sill handrail. The PRD is then used to pull the aft ASE down into its stowed position. As a safety feature to control the aft ASE detilt, the aft bulkhead EVA winch is attached to the aft end of the tilt bracket. One crewman attends the aft bulkhead EVA winch and gradually lets out slack in the line while the second crewman operates the PRD. By keeping tension in both lines, ACTS/TOS can be gently stowed.

2. EVA Pin Pull Operations

Longeron bridge fittings 11 and 13 on the port and starboard sides are currently manifested for the ACTS/TOS mission. These bridge fittings are used to hold the trunnion carriers which in turn carry the payload. This configuration represents the aft-most location in the cargo bay. The PFR bridge clamp is an EVA tool that allows the PFR to interface with the bridge fittings. Bridge fittings 11 port and 11 starboard have room to accept the PFR bridge clamp, but bridge fittings 13 port and 13 starboard do not.

In the October 1990 tests all EVA tasks were first tried from a PFR which was mounted to bridge 11. If PFR access to the task was not sufficient, then the task was tried free-floating. After all the tasks were evaluated from a bridge 11 PFR position and/or a free-floating position, the tasks were attempted from longeron bridge fittings 10 and 12 port and 10 and 12 starboard. This was attempted in order to determine if more bridge fittings might give better access to some tasks; and they did. However, by the end of the test series in October 1990, it was decided that additional bridge fittings would not be required. This issue was reopened in the July test series due to the redesign of the EVA pin puller (EPP).

The possibility of high side loads on the actuator pin caused the EPP to be redesigned. The original EPP design used a handle with an integrated cam to pull the pin. Once the EPP was screwed on to the pyrotechnic pin puller housing and the pin tail was engaged, the crewman swung the handle from one side to the other 180° and the cam lifted the pin. With the old pin puller the crewman could pull a linear force on the pin of about 100 lb.

The redesigned EPP, which was tested in the July NB simulations, is designed to pull a linear force of 1,230 lb (the linear force on the mockup was only 640 lb). To accomplish this the new EPP uses the concept of thread advantage. The crewman installs the EPP on the housing and engages the pin tail and then screws a left-handed ACME thread to generate the pull on the pin. The new EPP requires the EVA crewman to generate a torque up to 40 ft-lb with a 1-ft lever arm. This amount of force can only be applied if adequate force reacting restraint is available; therefore, a reassessment for adding longeron bridge fittings for the manual EPP operation was done in the July 1991 NB simulations. The result of this reassessment was to add bridge fittings 10 port and starboard and 12 port. The availability and cost to add these bridge fittings is still a question that must be answered.

3. Latch Operation

The next biggest change between the October and July test series was the latch operation. There were two changes for the latch operation: (1) redesign of the latch arm wrench (LAW) and (2) deletion of the overcenter latch lock.

In the October test a telescoping LAW handle was used. The handle was 2-ft long and telescoped to 4-ft long. A much beefier nontelescoping 5-ft handle was built to replace the telescoping LAW because the calculated worst case torque required to close the same latch increased from 161 ft-lb in October 1990 to 320 ft-lb in July 1991.

The overcenter latch lock was an EVA-installed device that was wedged between the overcenter latch linkage and adjacent ASE structure. The purpose was to prevent any inadvertant movement of the latch linkage from the overcenter/locked position. During the time between the two test series, it was determined that under certain conditions the latch actuator may not hold the latch arm in the overcenter/locked position. Therefore, the tension on the latch turnbuckle member was increased to a much higher value to insure the latch arm would stay in the overcenter/locked position. Thus, the force to close the latch went up to 320 ft-lb and the need for the overcenter latch lock went away. The device was then deleted from the program. The overcenter latch lock was tested only in the October test series and not the July test series.

In the July 1991 tests series a high fidelity part task mockup of the latch was tested which required 320 ft-lb to operate. The latch was operated with ease each time it was tested.

Other changes were: (1) the addition of EVA graphics/nomenclature, tether points, and bayonet pins to the tools, (2) the addition of a nozzle to TOS, (3) the addition of the permanently mounted tilt bracket, (4) the ACTS/TOS interface adapter and the first 2 ft of an ACTS volume, and (5) the testing of the cargo bay tool stowage carrier.

B. Testing Facility

The NB simulations were conducted at the MSFC NBS. The cylindrical water tank is 75 ft in diameter by 40 ft deep and provides a close approximation of zero-gravity conditions. For TOS the NBS supported one pressurized test subject for each test in October 1990 and two test subjects for each test in July 1991. MSFC engineers and Johnson Space Center (JSC) astronauts served as test subjects in both test series.

An audio system at the NBS provides real time two-way communications with the main control room, the topside control room, and the test subjects. Test subject comments are recorded along with underwater video on 1-in magnetic and 1/2-in VHS tapes.

Underwater still photography was also provided. The audio, video, and photographic data from the TOS NB tests is located at MSFC with the Manned/Systems Integration Branch.

C. Mockups and Support Equipment

The mockup hardware was configured in the NBS shuttle cargo bay mockup. Before each test day the mockup hardware was set up in the following manner (figs. 1 through 3):

- the aft ASE cradle tilted up out of the cargo bay 45°

- the upper forward ASE in its full open position (102° from horizontal)

the pyrotechnic pin puller housing attached to the actuator with the dust cap on. (There were only two actuators and one pyrotechnic pin puller housing, but the utility divers were able to move these pieces of hardware from worksite to worksite always staying ahead of the test subjects.)

The NB tests in October 1990 included full scale mockups of:

- aft ASE cradle
- upper and lower forward ASE cradles
- pyrotechnic pin puller housing and pin with a linear force resistance of ≈100 lb
- dust cap removal tool
- ASE actuators
- TOS volumetric mockup
- latch arm interface for the LAW
- EVA pin puller
- tilt device and brackets
- rotation device (RD) and brackets
- tension device (TnD)
- trunnion link (TL)
- latch arm wrench
- latch arm wrench socket
- overcenter latch lock.

The second series of NB tests in July 1991 included full- scale mockups of:

- aft ASE cradle with mounted tilt bracket
- upper and lower forward ASE cradles
- pyrotechnic pin puller housing and pin with a linear force resistance of ≈640 lb
- dust cap removal tool
- ASE actuators
- TOS volumetric mockup

- TOS nozzle
- ACT/TOS interface adapter
- the first 2 ft of ACTS (volume plus a grapple fixture)
- latch arm interface for the LAW on forward ASE
- part task high fidelity latch
- redesigned EVA pin puller
- rotation device and brackets
- tension device
- trunnion link
- redesigned latch arm wrench
- latch arm wrench socket
- tool stowage carrier adapter plate with latches
- multilayer insulation around the pin puller
- electrical cable over the latch arm
- remote manipulator system (RMS) envelope in stowed and deployed positions.

Note: A complete list of Space Transportation System (STS) tools that were used in the test series can be found in their respective test plans: NBS-TOS-TCP-90.1 and NBS-TOS-TCP-91.1.

D. Test Subjects and Test Dates

MSFC engineers served as test subjects October 18 and 19, 1990, and July 23, 25, and 26, 1991. JSC astronauts served as test subjects during all other tests.

Date	Test Subject 1	Test Subject 2
10-18-90	Jeff Sexton	
10-19-90	Jeff Sexton	
10-23-90	Mark Lee	
10-24-90	Mark Lee	
7-23-91	Fred Sanders	Jeff Sexton
7-25-91	Fred Sanders	Jeff Sexton
7-26-91	Fred Sanders	Jeff Sexton
8-1-91	Mark Lee	Rich Clifford
8-2-91	Mark Lee	Rich Clifford

E. Contingency EVA NB Test Results

1. Aft ASE Detilt

The results of the detilt operation from the July tests are listed below:

- The PRD must be handed off from one crewman to the next while routing the PRD line under the RMS (fig. 10).

- The snatch block cannot be installed any lower than the third tether loop down on the uppermost vertical handrail on the aft bulkhead. Tether loop orbiter coordinates are approximately x = 1,307, y = 0, z = 435 (fig. 7).

- PFR's are not needed to operate the PRD or the aft bulkhead EVA winch.

- The EVA winch line should be routed as shown in figure 8. The EVA winch line contacts the handrail standoff as shown in figure 9. This slight contact is not a concern.

- Caution should be taken when translating from the orbiter port sill to the aft bulkhead due to interference from the RMS and payload bay cameras.

- The translation route from the tilt bracket to the orbiter sill for routing the PRD needs to be carefully assessed during crew training. In the NB tests the subject could translate along the aft bulkhead to the port sill and then translate with one arm along the port sill while carrying the PRD over the RMS with the other arm.

- A PFR is required to do the port and starboard side tilt actuator EVA pin pull operations. Good PFR access is available from bridge fitting 11 for the starboard actuator. PFR access from bridge fitting 11 on the port side is acceptable if and only if the RMS is in its rolled-out (deployed) position.

- When the crewman installs the EPP onto the pyrotechnic pin puller housing, the first few threads should be engaged by hand (manually turn the EPP by hand, not with tools). This helps to reduce the chances of cross-threading.

- Actions on the old EPP are in appendix A (action items 001 through 012). Obviously when the old design was discontinued none of these actions would be addressed except where they may apply to the new EPP design. Actions for the new EPP design are in appendix B (action items 070 and 081).

2. Rotation of Upper Forward ASE

The procedures for this task are as follows: install the upper and lower rotation device brackets, install the rotation device into the brackets and pin in place, pull the actuator pin (could be either primary or secondary), and turn the rotation device screw until the upper forward ASE is closed.

Action items 074 and 078 in appendix B list the actions for the rotation task. Other comments are listed below:

- The RD yokes should be pinned in place from the outboard side. This is from the bottom for the upper bracket when the upper forward ASE is open. This will assure good access to the pip pins for removal once the upper ASE is closed.

- It appeared that one PFR position (mounted on bridge 10) could accommodate the crewman while turning the RD screw from the full open position to the closed position.

- Once the upper ASE is closed and it is time to remove the RD brackets, the upper bracket should be removed first. This allows better access to the lower bracket. The brackets can be removed by using the wrist tether to tether to each bracket and then pulling the tether to overcome the bracket spring force.

- The PFR mounted on bridge fitting 10 starboard is required to pull the primary actuator pin. The PFR mounted on this bridge fitting also greatly eases the rotation operation.

- The EVA pin pull operation for the secondary rotation actuator on the aft face of the forward ASE can be done without a PFR. However, bridge 12 starboard should be added for optimum restraint and flexibility.

- Restraint for the RD yokes during translation of the RD has not been resolved but is addressed in the action item list.

3. Latching of the Forward ASE

Once the payload has been tilted down into the lower forward cradle and the upper forward ASE has been rotated closed, then the forward ASE must be latched. (The aft ASE does not require detilt if the payload has been deployed. Only if the payload did not deploy and remains in the shuttle cargo bay will it require detilt into the forward ASE). Before the RD is removed, the upper and lower forward cradles must be secured together. This is done using the TnD and TL. The TnD is installed onto the upper cradle where it is pinned in place. The TL is hooked around the forward port trunnion and then pinned to the TnD. This secures the upper and lower forward cradle and then the RD and RD brackets can be removed.

By operating the TnD EVA interface, the upper and lower forward cradles are pulled together. When the pads on the forward ASE are compressed around the payload, the latch should be within its capture range. The crewman then pulls the actuator pin and the latch is ready for closure. Listed below are the results of this operation in the NBS.

- It appeared that the TL could get slightly cocked on the trunnion. It should be noted in crew training and in annex 11 for one crewman to operate the TnD and the other crewman to assure the TL is not misaligned.

- It may be easier to attach the LAW socket to the LAW while the LAW is stowed. This needs to be worked out in training and noted in annex 11.

- There was concern that the LAW was too long to carry on the miniworkstation; therefore, a lightweight LAW and socket were built for a translation study, but no translation problems were encountered.

- Access to the latch actuators, installation and operation of the TnD and TL, and latch closure all require the RMS to be in its rolled out (deployed) position. This condition must be added to annex 11 and any other flight operations documents that may be applicable.

F. Tool Stowage

Most of the EVA tools will be stowed in the middeck lockers and the remaining tools will be stowed on a tool carrier in the cargo bay. During the evaluation of the tool carrier in July, the only tools that were being stowed on the carrier were the LAW and RD. After testing it was determined that too many tools were being stowed in the middeck and that the TnD and TL should be stowed on the tool carrier instead of in the middeck. Since all EVA tools stowed in the middeck need to go through the airlock with the crew, the number and size of these tools must be limited. As a result the TL and TnD will be stowed in the cargo bay on the tool carrier adapter plate. Comments on the tool carrier evaluation are recorded in the action item list numbers 071 through 073 and 079.

III. CONCLUSION

The TOS EVA NB simulations have proven to be a successful undertaking. With two NB simulations the program was able to build on the data from the first test series and also allow designs to mature in between test series. During the July 1991 test series the EVA tools, task procedures, and new concepts had matured greatly. After the testing in July had ended, it was clear that all the NB development work was not only finished, but was finished with completeness. Refurbishment and only a few modifications remain to be done before EVA training for the ACT/TOS mission can begin.

The TOS NB tests have also proven to be enlightening in areas not associated with TOS. Some of the lessons learned from TOS should be applied to all manned missions. For example, every manned mission should factor in contingency EVA operations during the development of the preliminary requirements. Incorporating simple design features into the hardware early in a program can greatly enhance mission success capabilities with little or no cost and schedule impacts.

The NBS continues to serve the Agency with a means of testing and verifying on-orbit EVA operations. With the success of the TOS EVA NB development simulations a smooth transition into training can occur. This report is dedicated to the safety and success of STS-51 and the TOS EVA program.

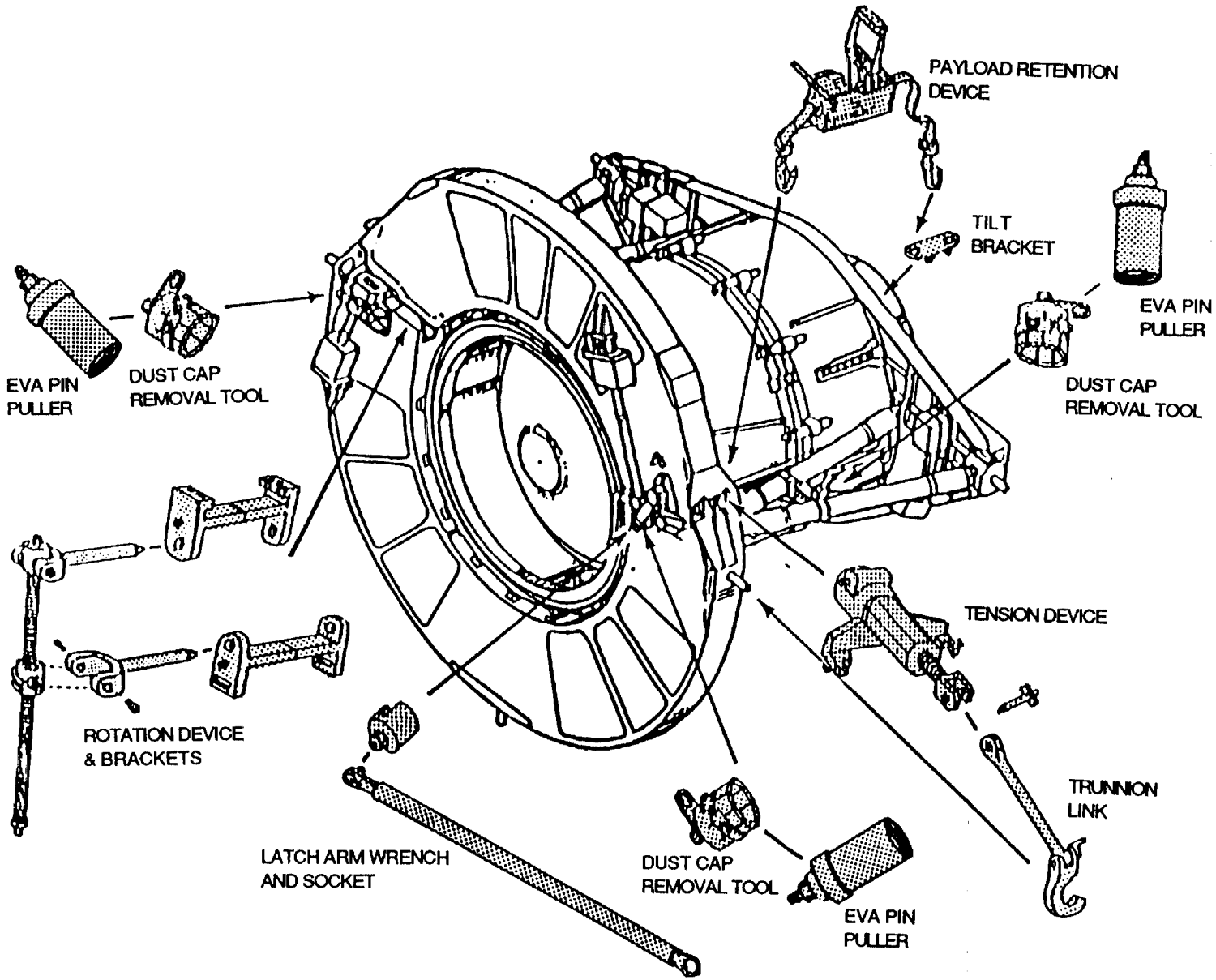

Figure 1. TOS EVA hardware schematic.

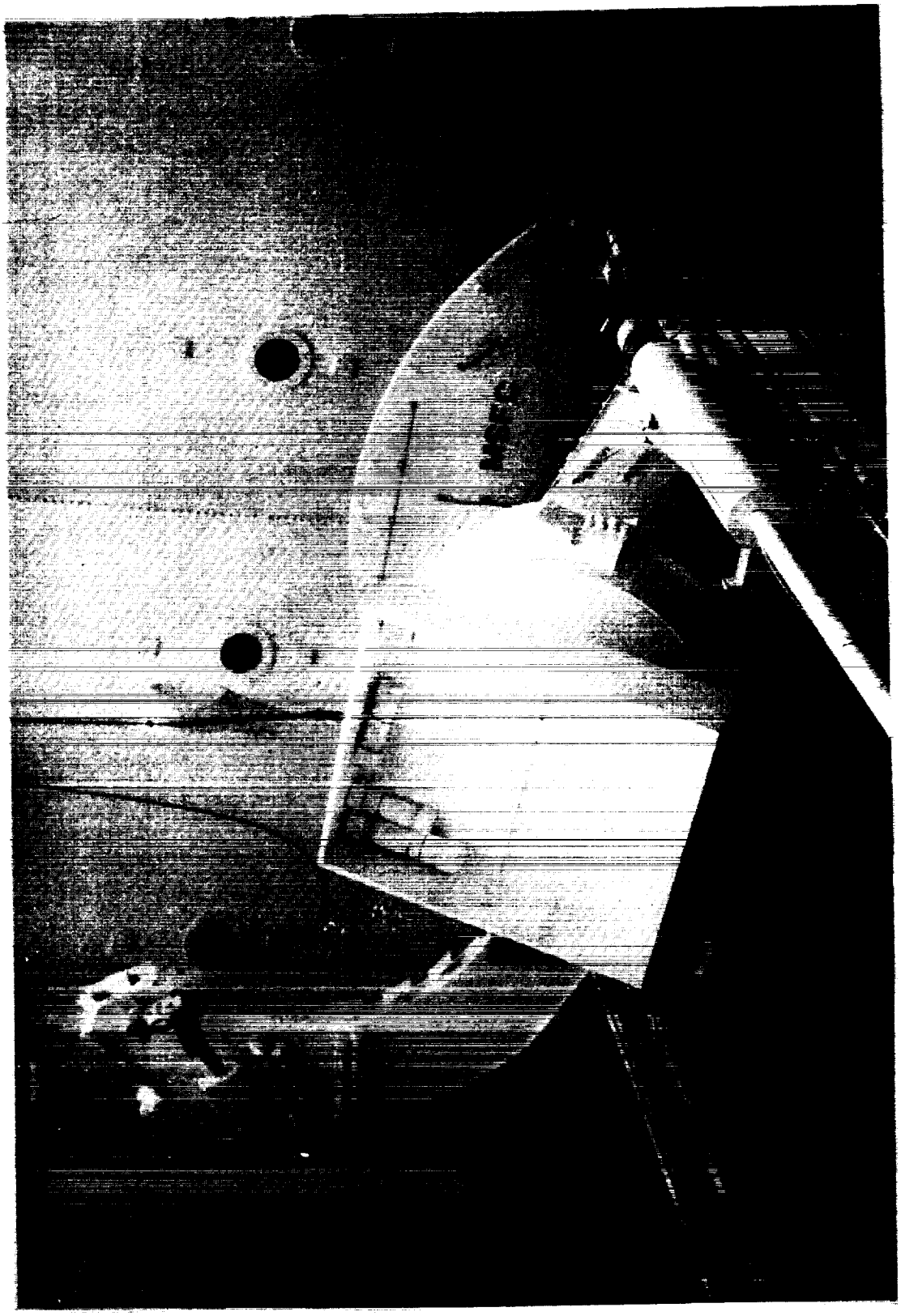

Figure 2. July 1991 test configuration front view.

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Figure 3. July 1991 test configuration side view.

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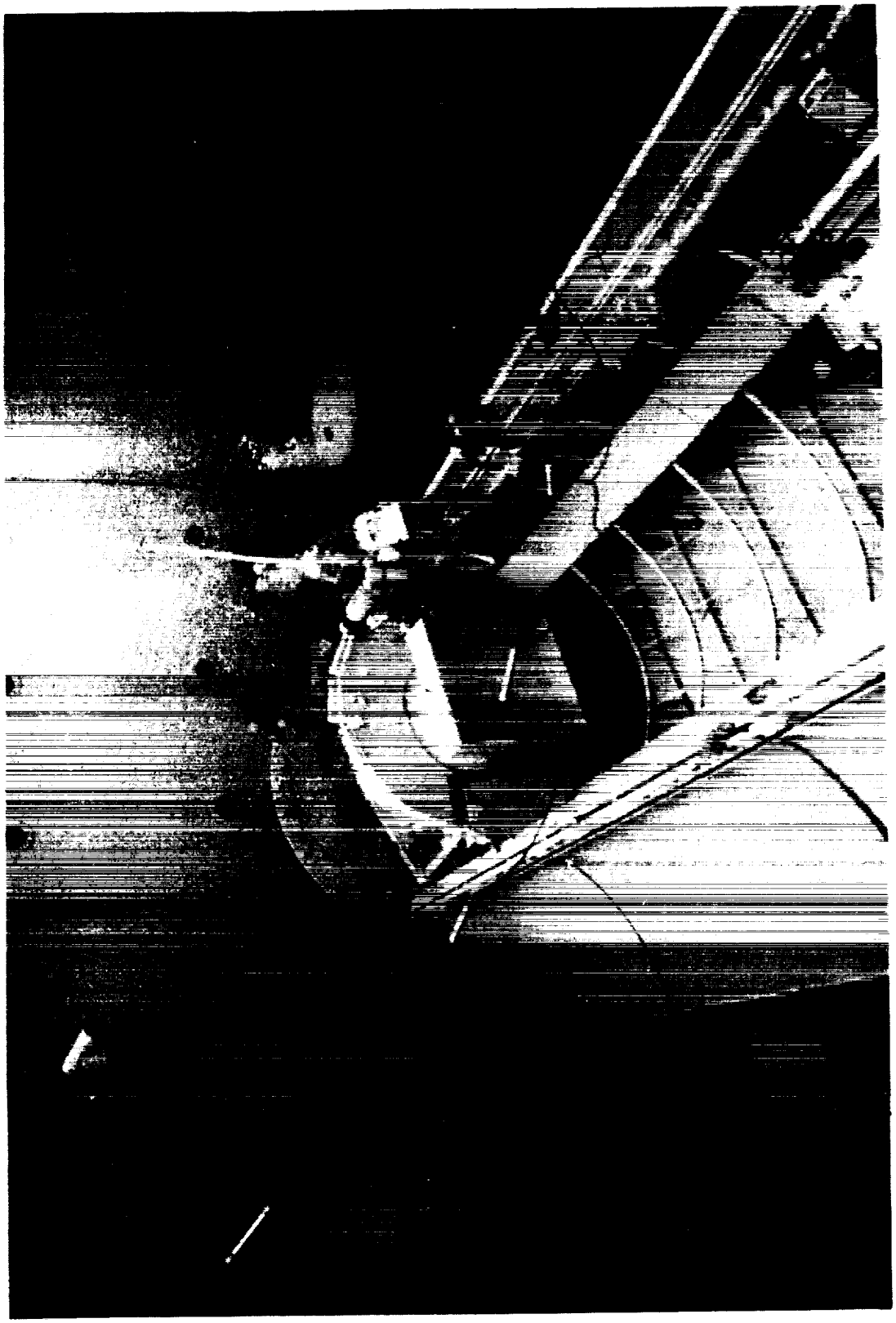

Figure 4. ASE and ACTS/TOS in its stowed position.

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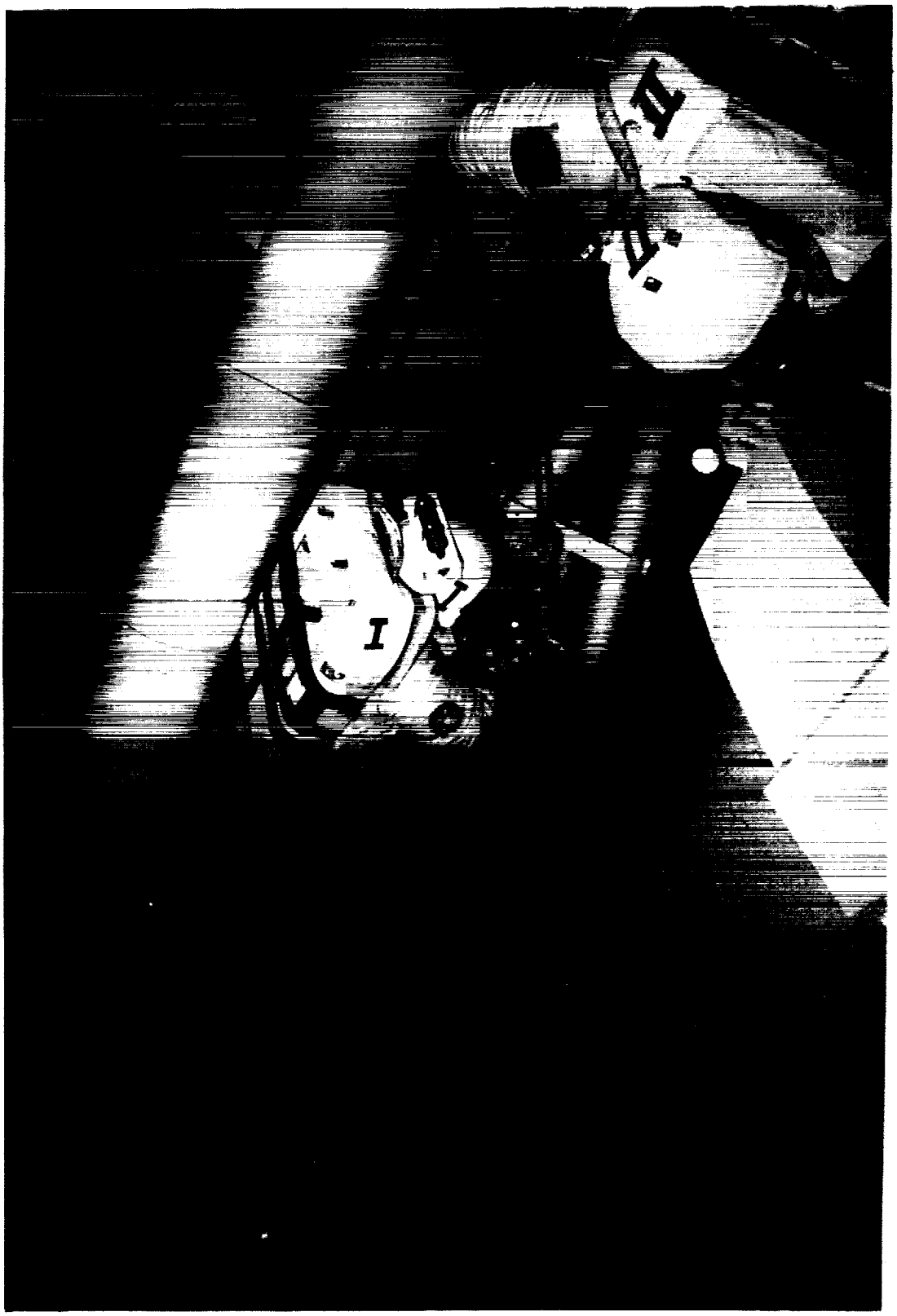

Figure 5. PRD line routing for detilt.

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Figure 6. ASE permanently mounted tilt bracket.

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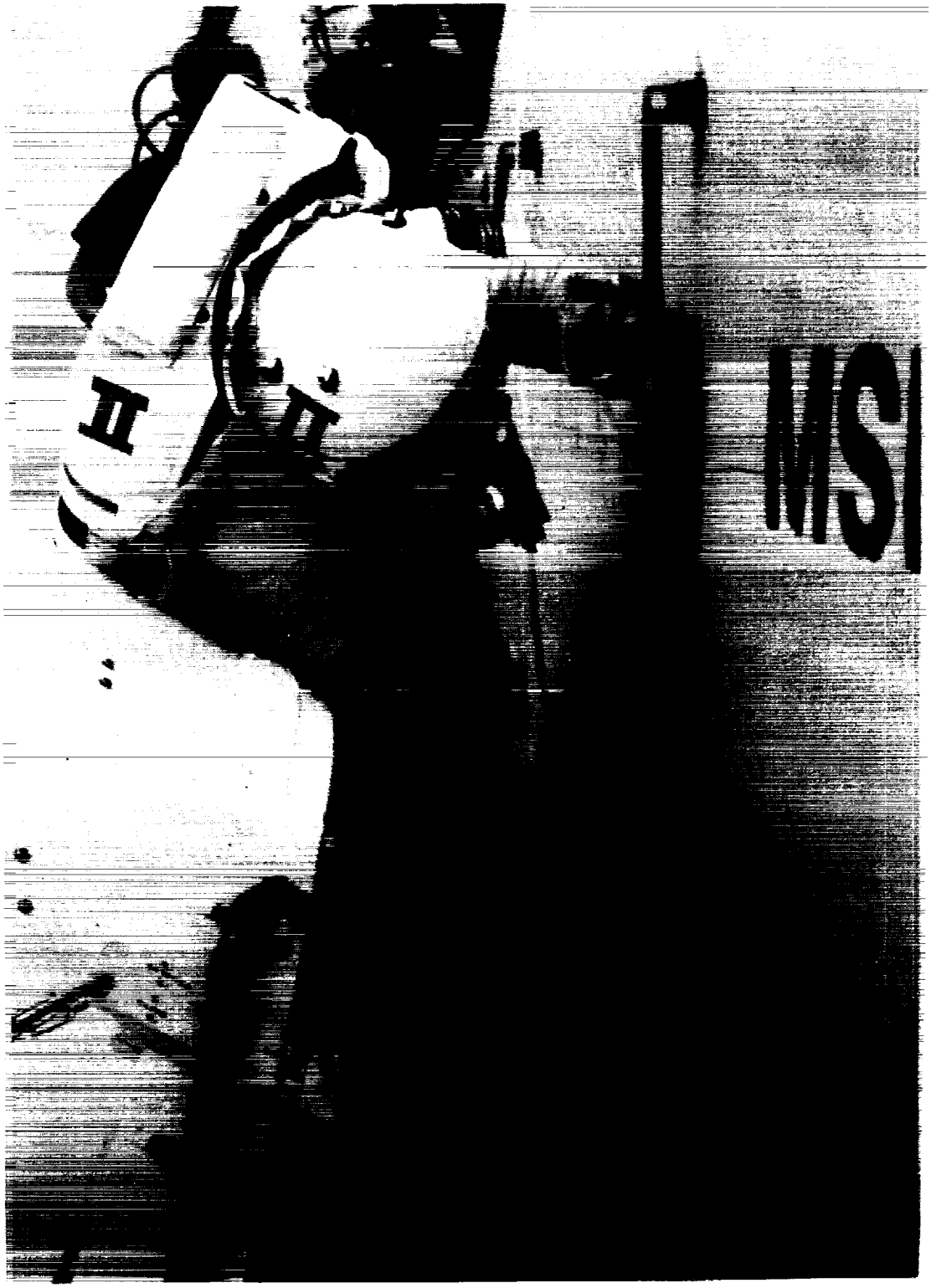

Figure 7. Access to aft bulkhead snatch block.

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Figure 8. EVA winch line routing for detilt.

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Figure 9. EVA winch line contact with handrail standoff.

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Figure 10. Operation of the PRD for detilt under the RMS.

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Figure 11. PFR setup for port tilt actuator pin pull.

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Figure 12. EVA pin pull operation.

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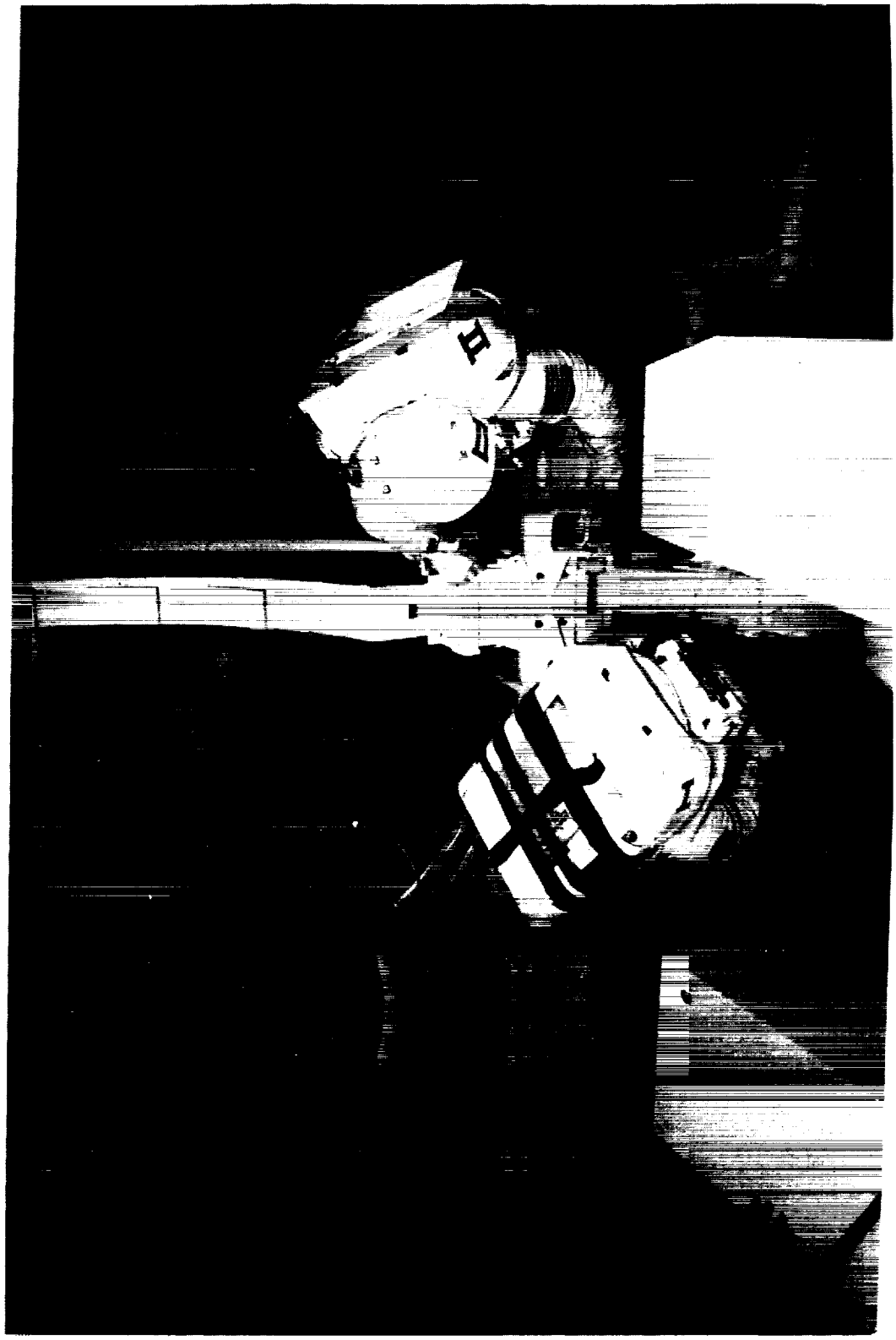

Figure 13. Installation of RD brackets.

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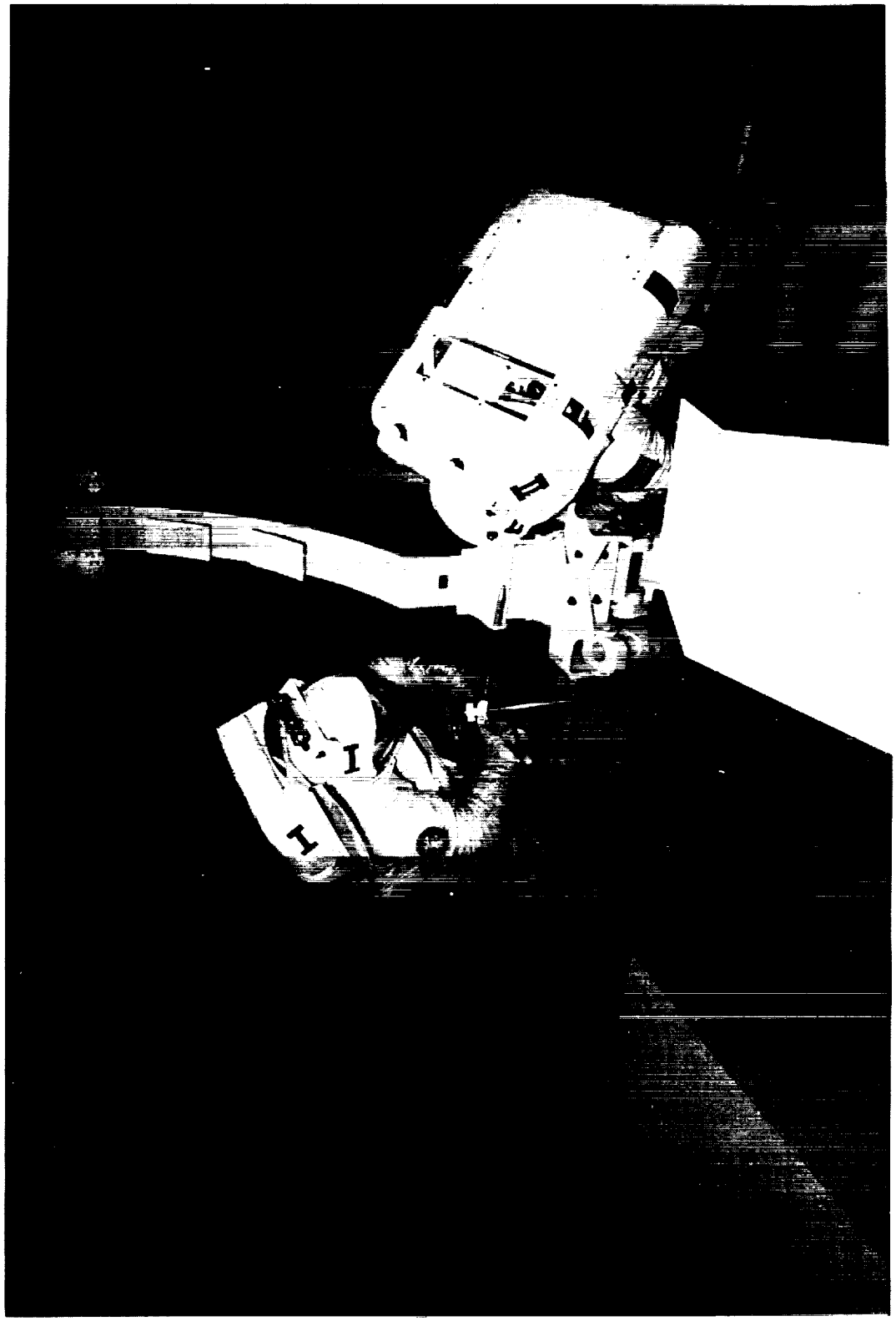

Figure 14. Installation of RD.

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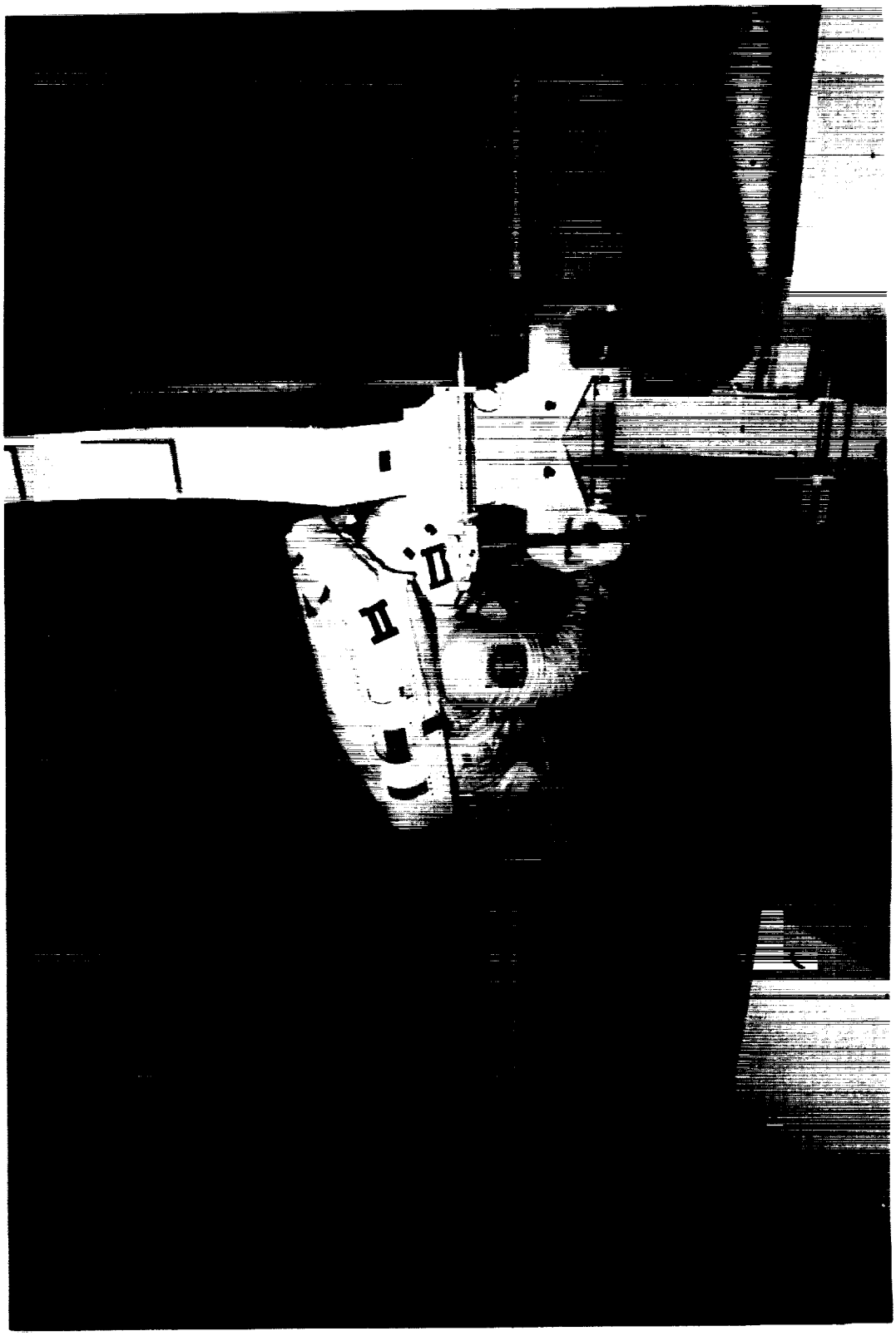

Figure 15. Access to rotation actuator pin pull.

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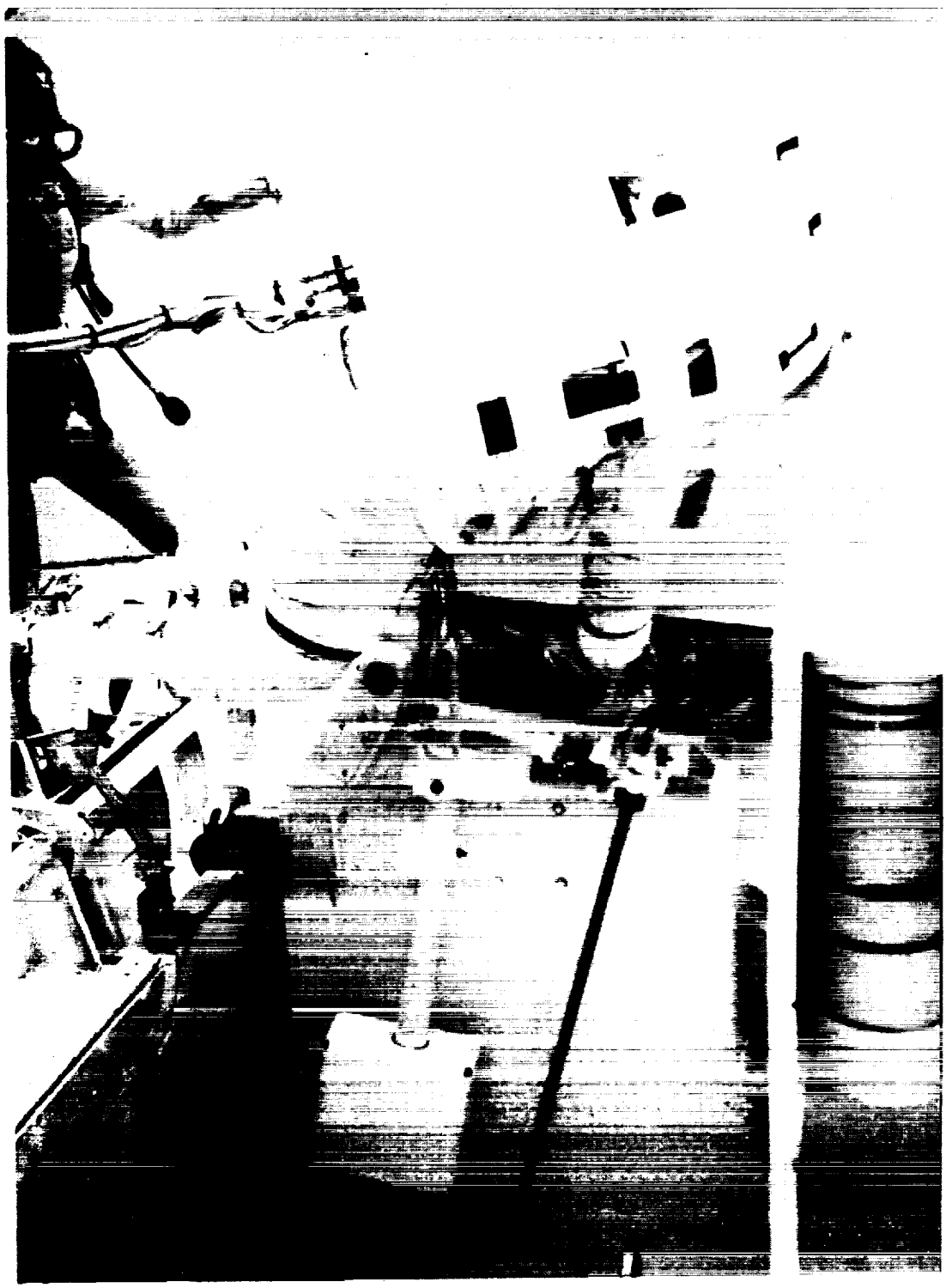

Figure 16. RD and upper forward ASE in closed position.

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Figure 17. Installation of TnD and TL from PFR on bridge 12.

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Figure 18. Installation of TnD and TL EV1 and EV2.

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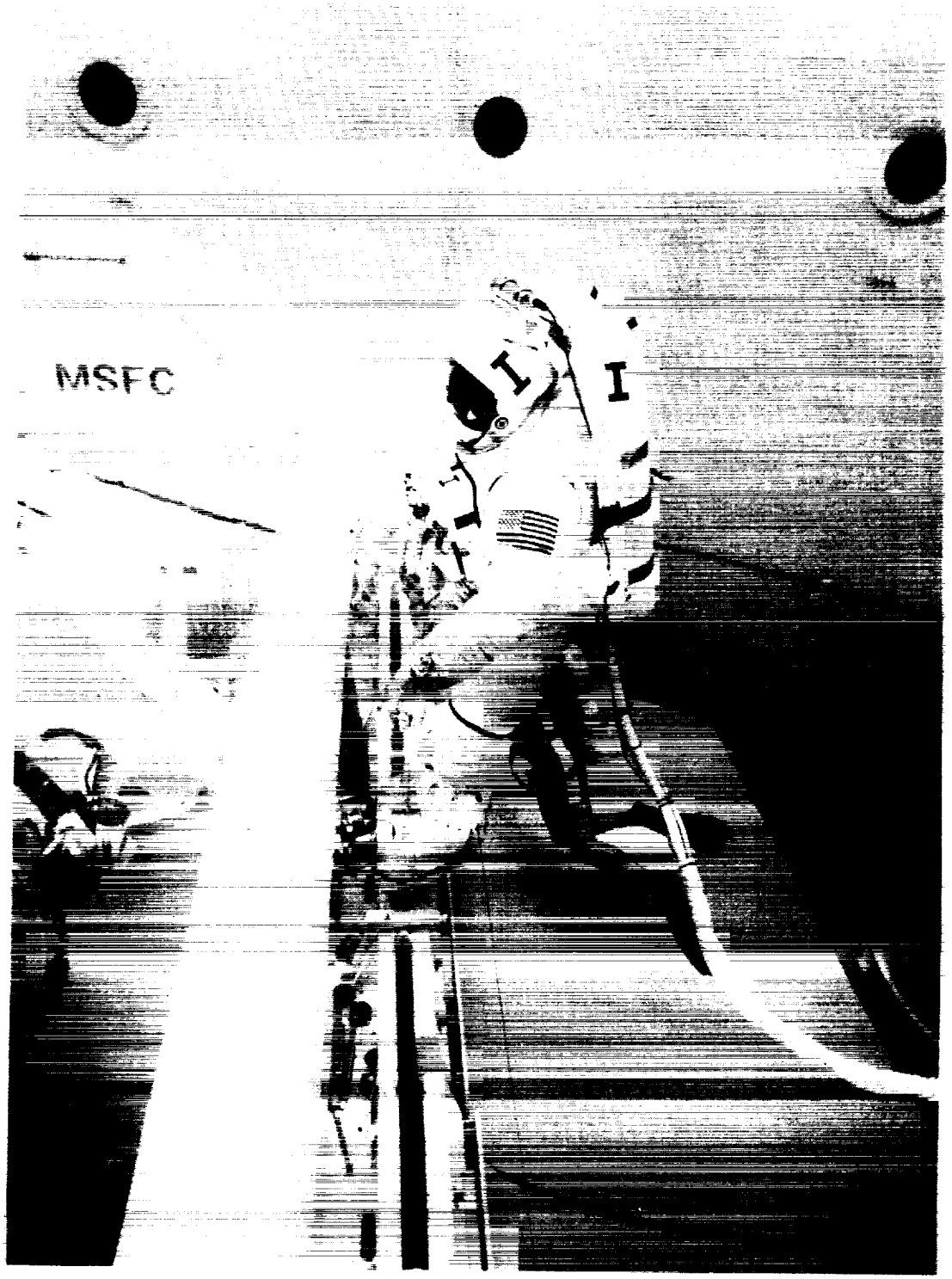

Figure 19. PFR position for latch closure with RMS stowed.

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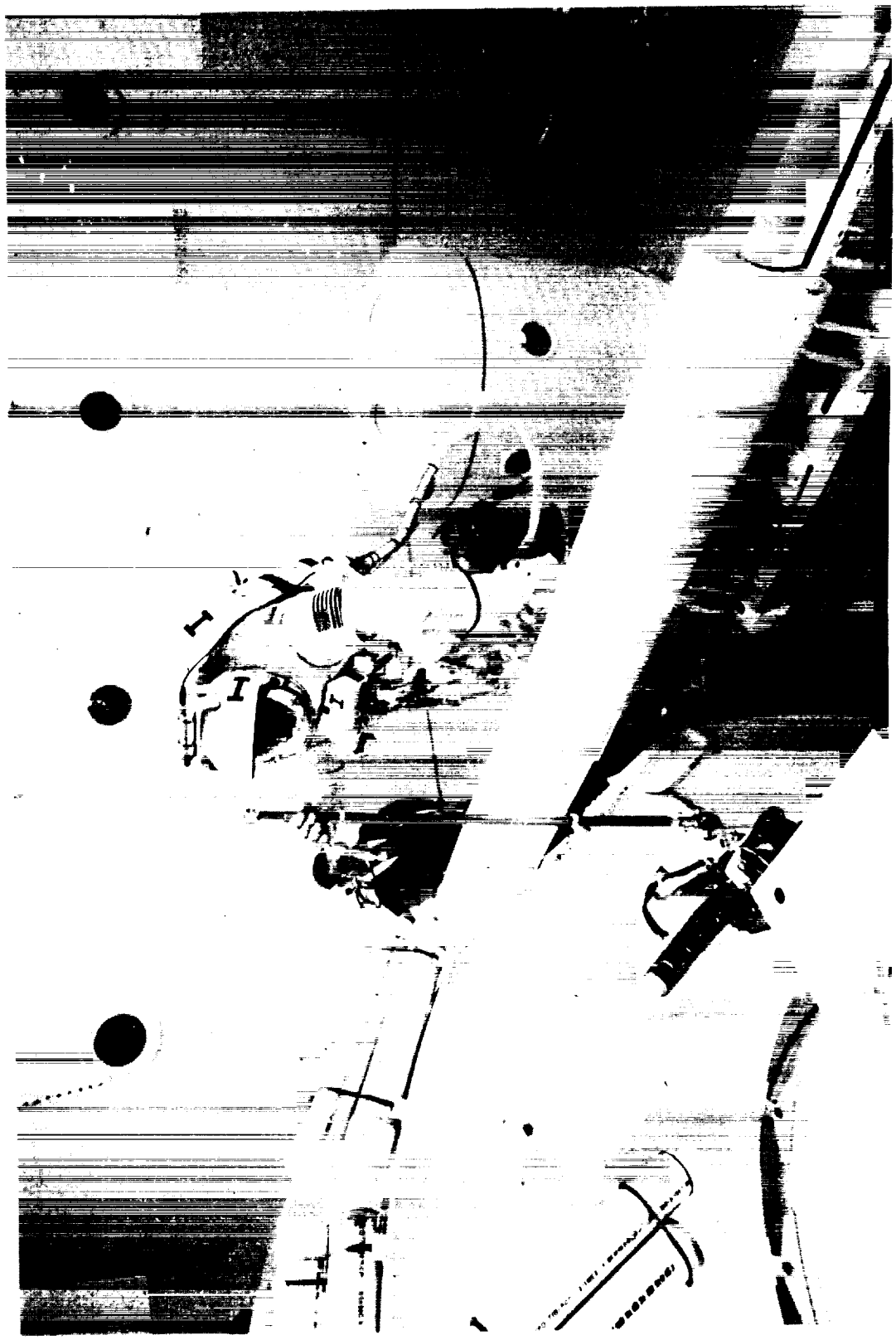

Figure 20. PFR position for latch closure with RMS stowed.

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Figure 21. PFR position for latch closure with RMS deployed.

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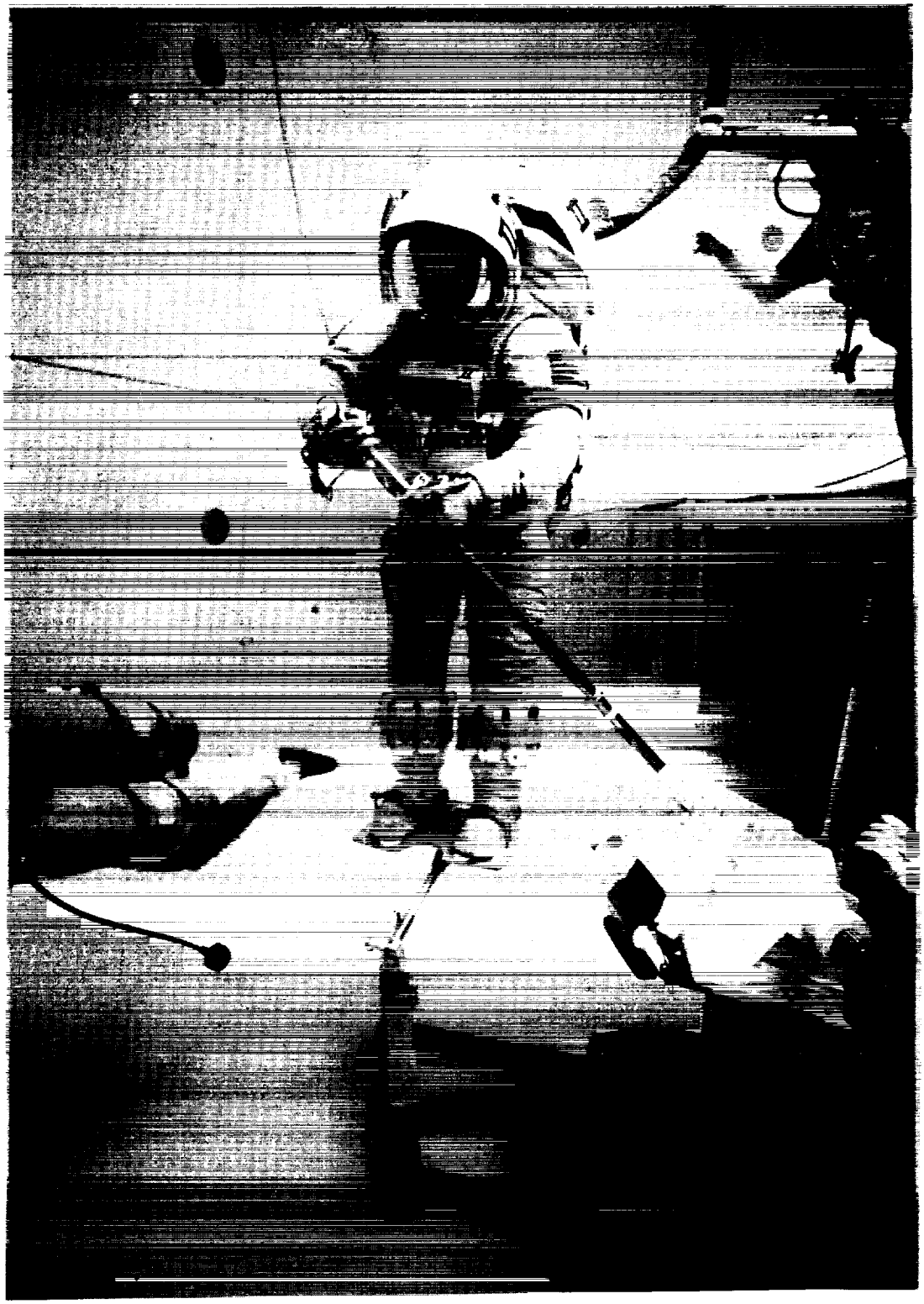

Figure 22. Operation of the high fidelity latch.

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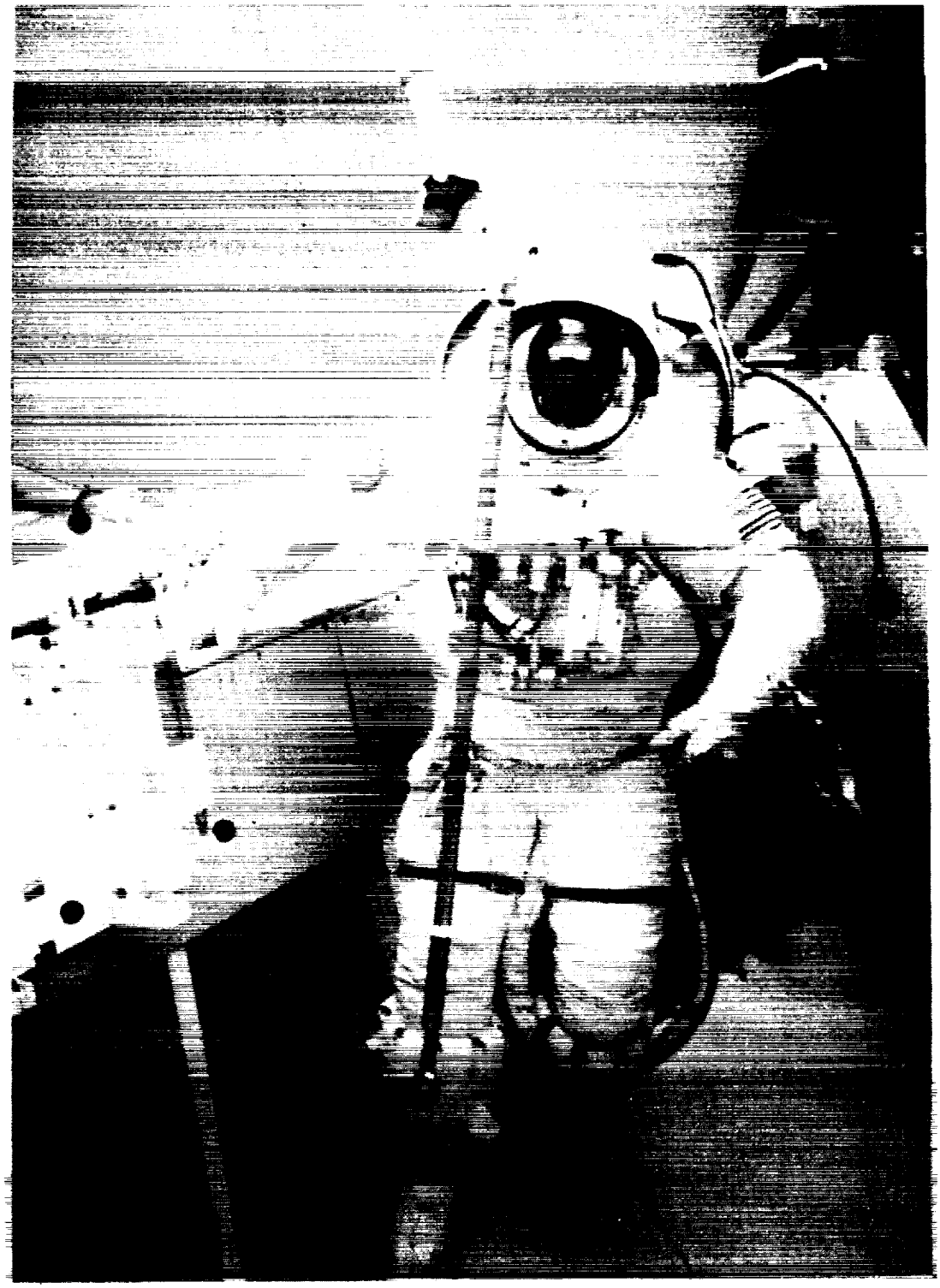

Figure 23. LAW on the miniworkstation.

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Figure 24. EV1 translating with LAW on miniworkstation.

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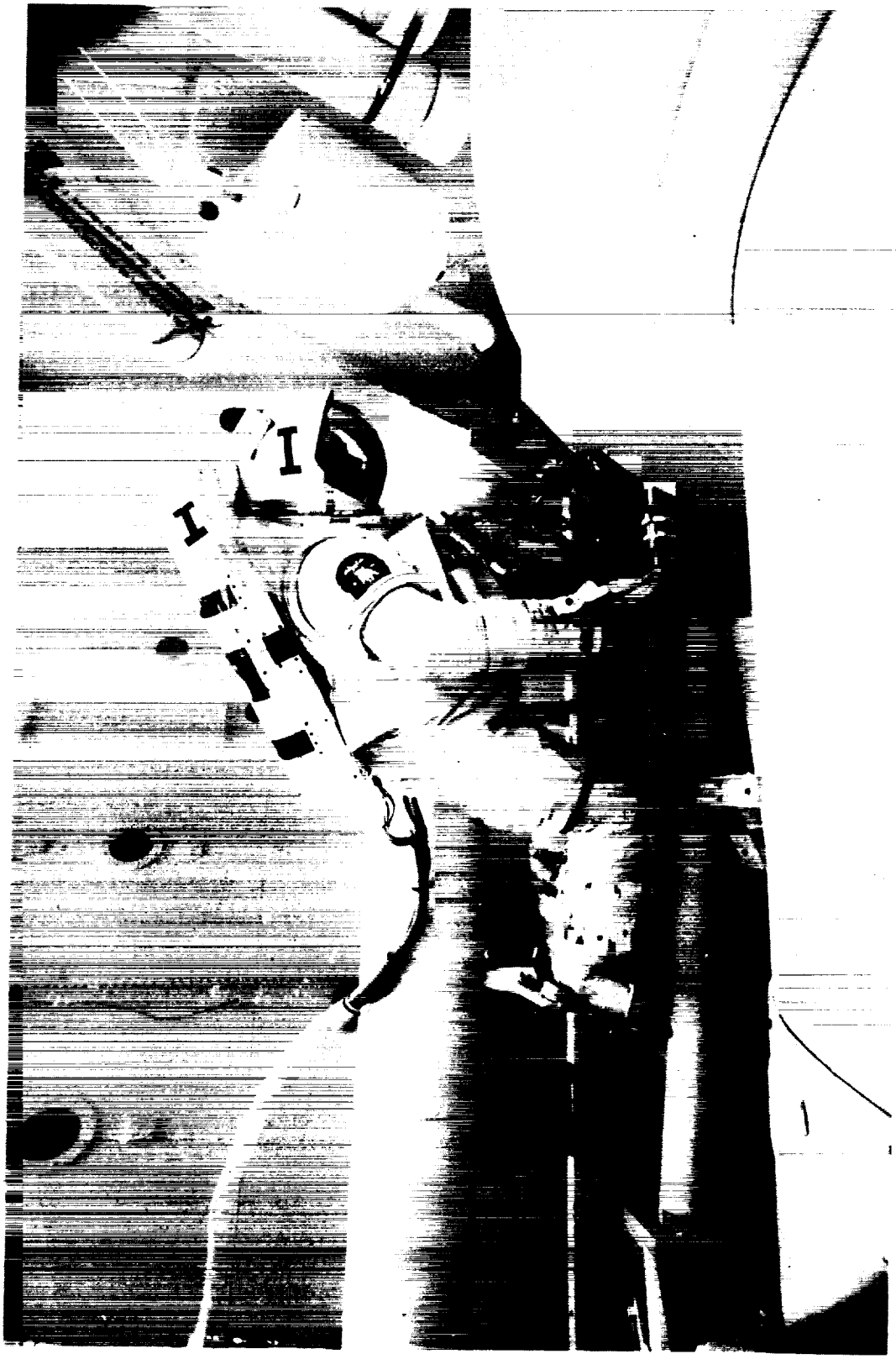

Figure 25. PFR position for secondary latch actuator.

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Figure 26. Tool stowage carrier evaluation.

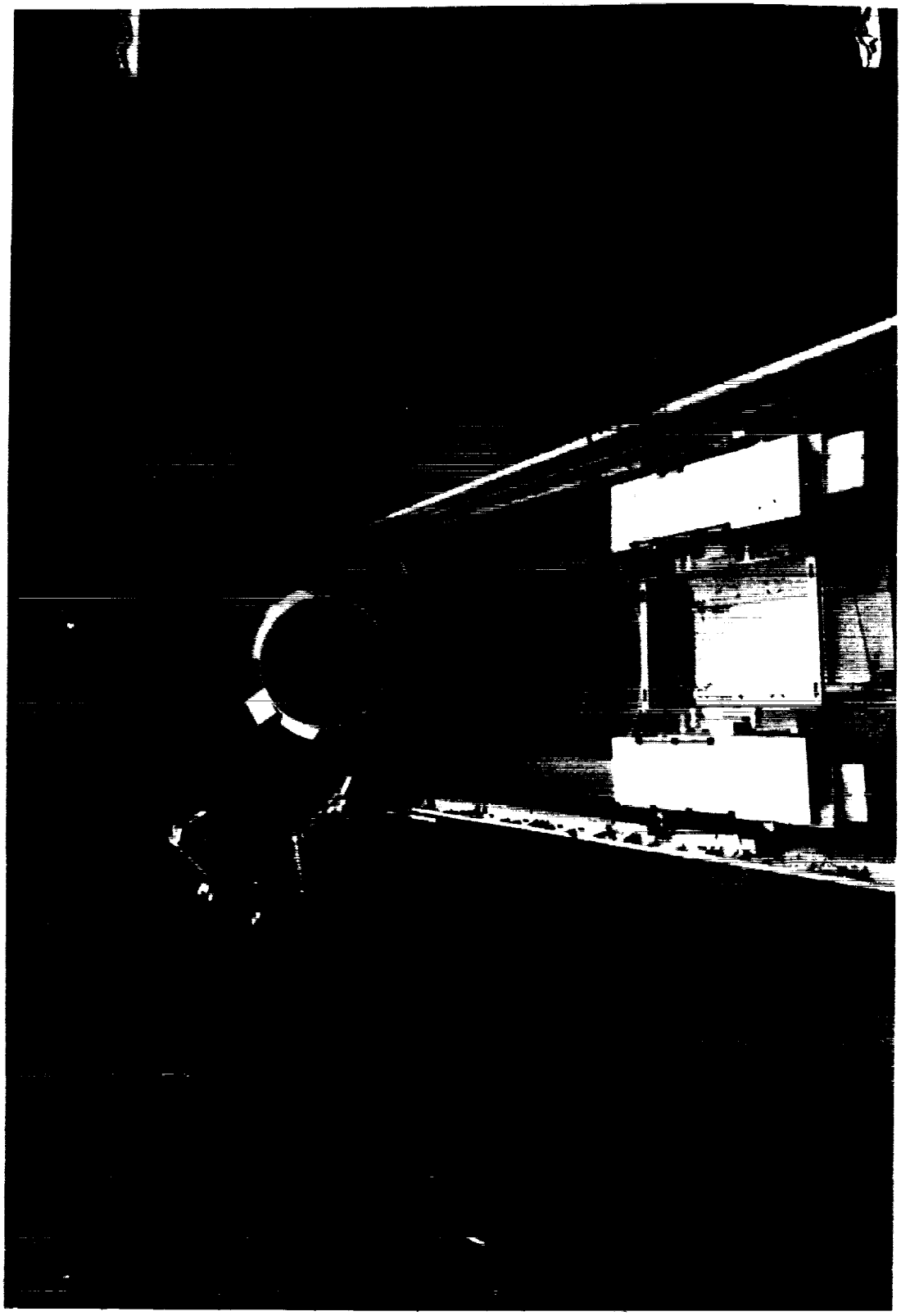

Figure 27. October 1990 test configuration.

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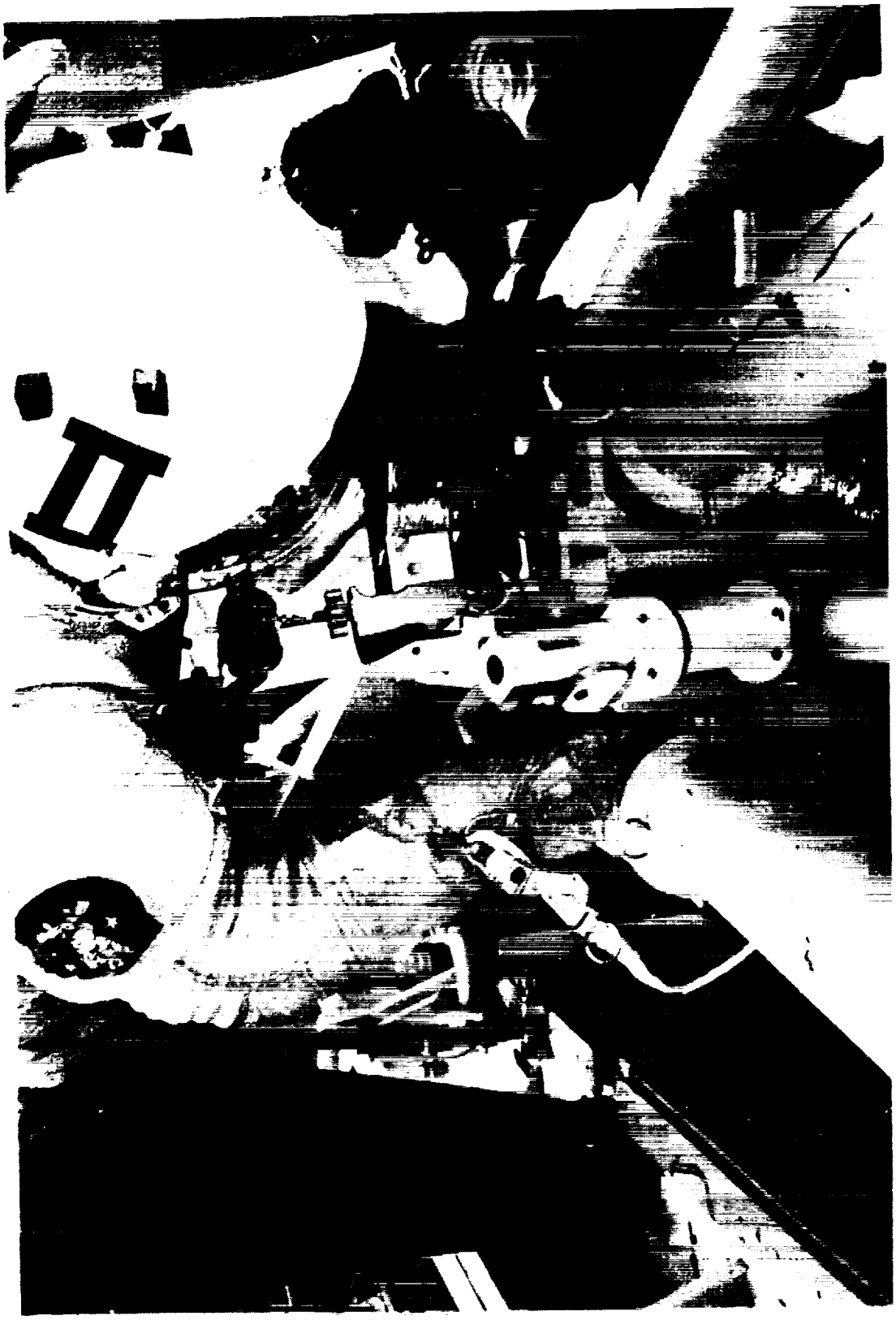

Figure 28. October 1990 tilt device being tested.

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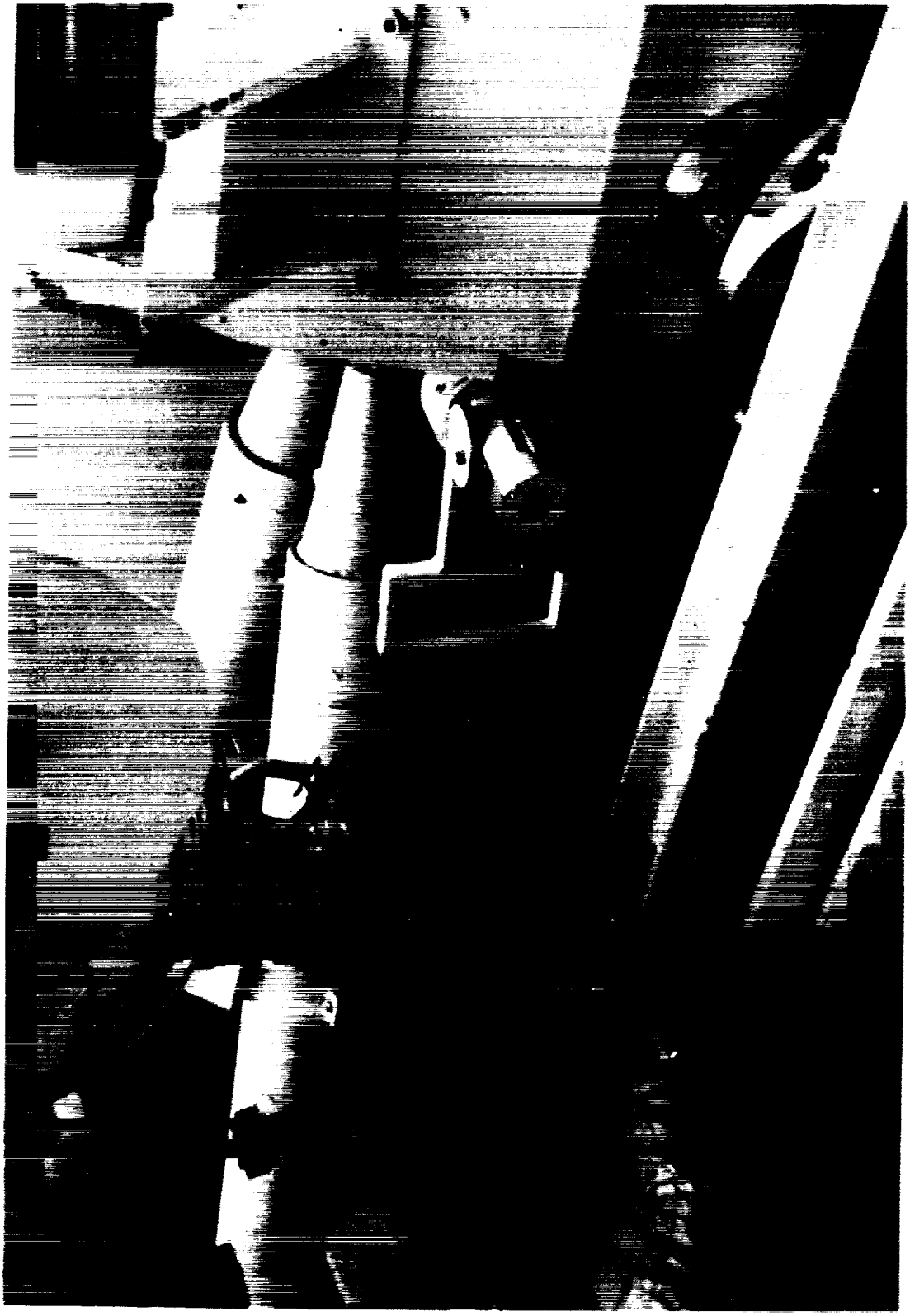

Figure 29. October 1990 EPP being tested.

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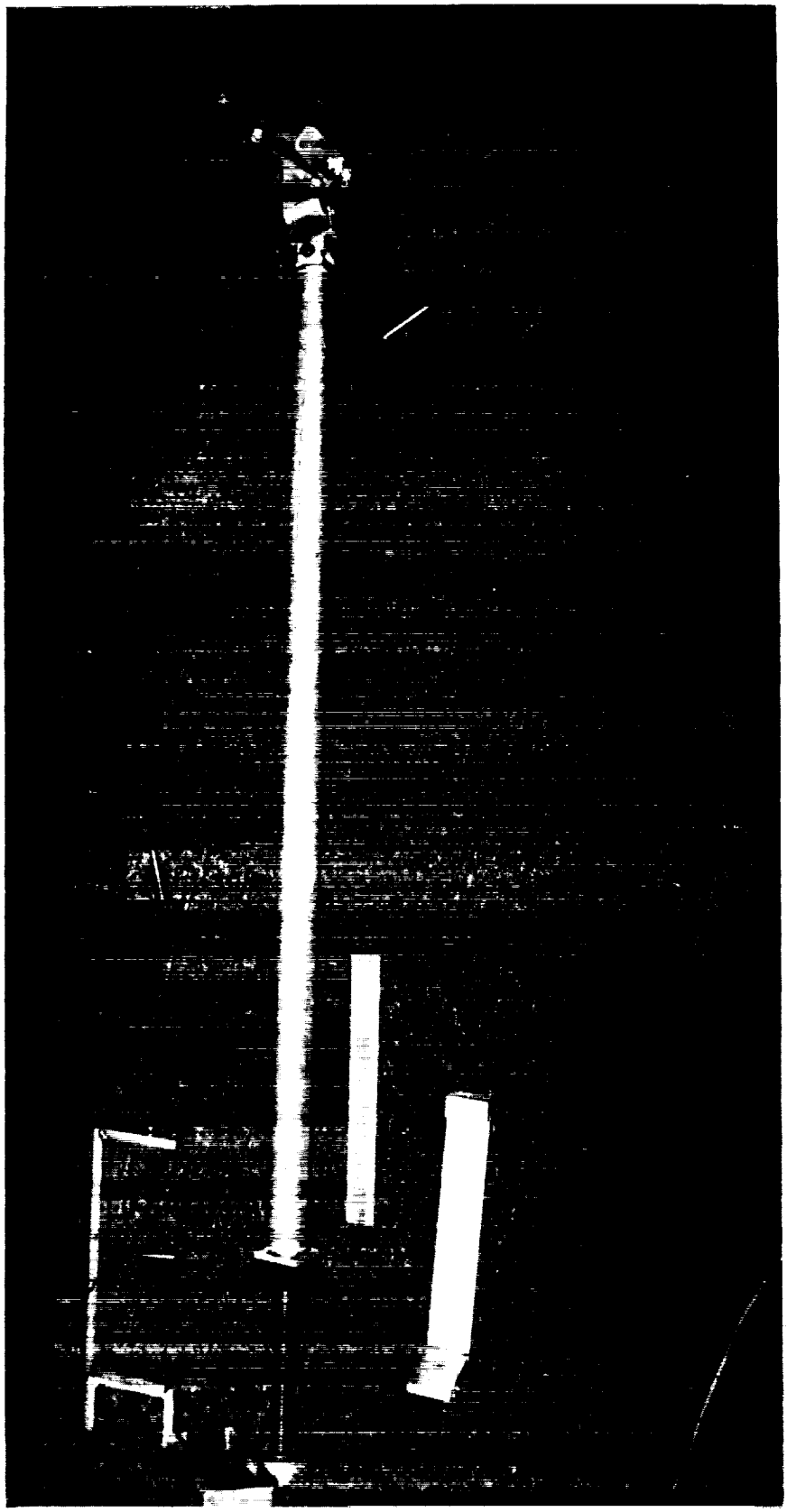

Figure 30. October 1990 tilt device.

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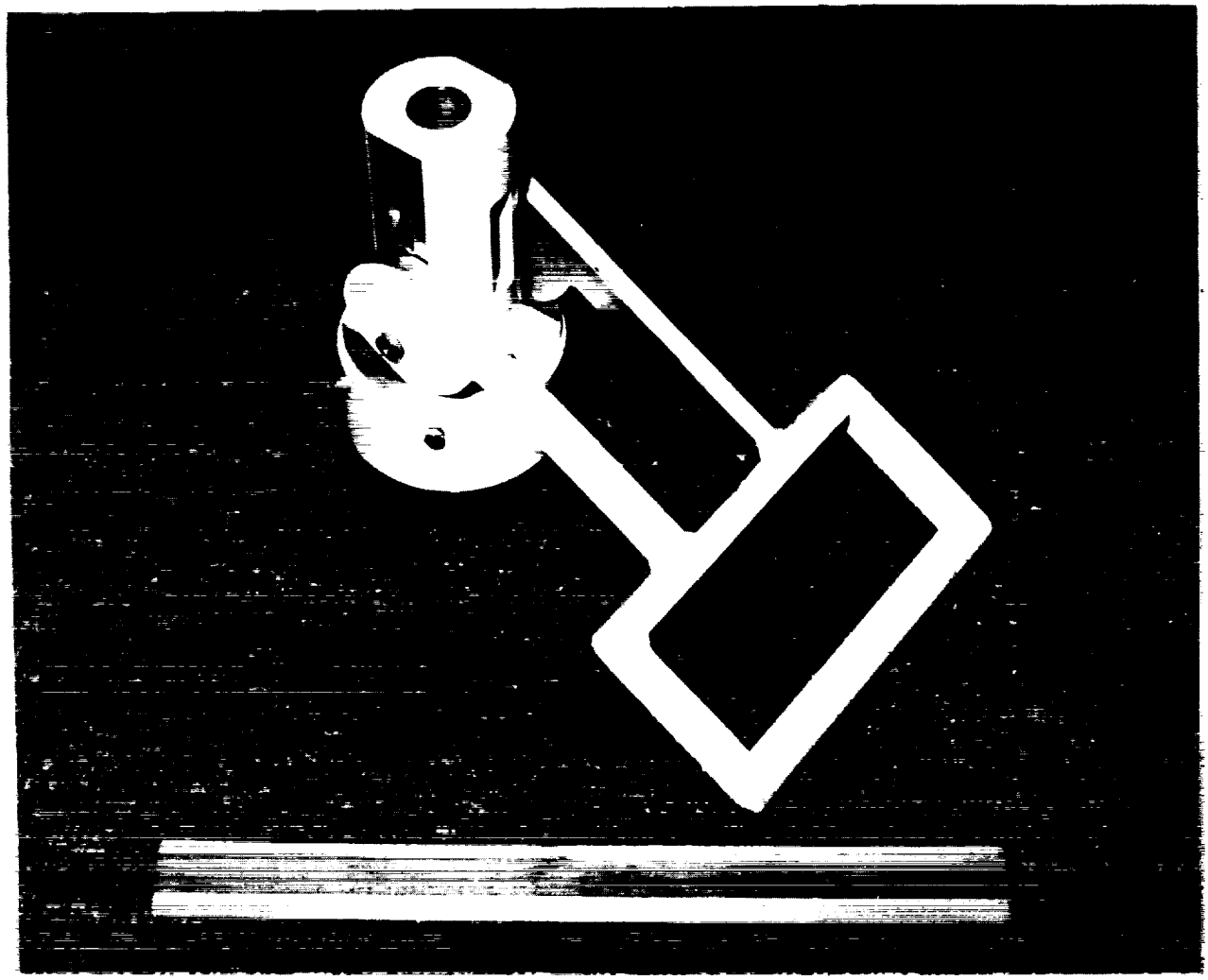

Figure 31. October 1990 EPP.

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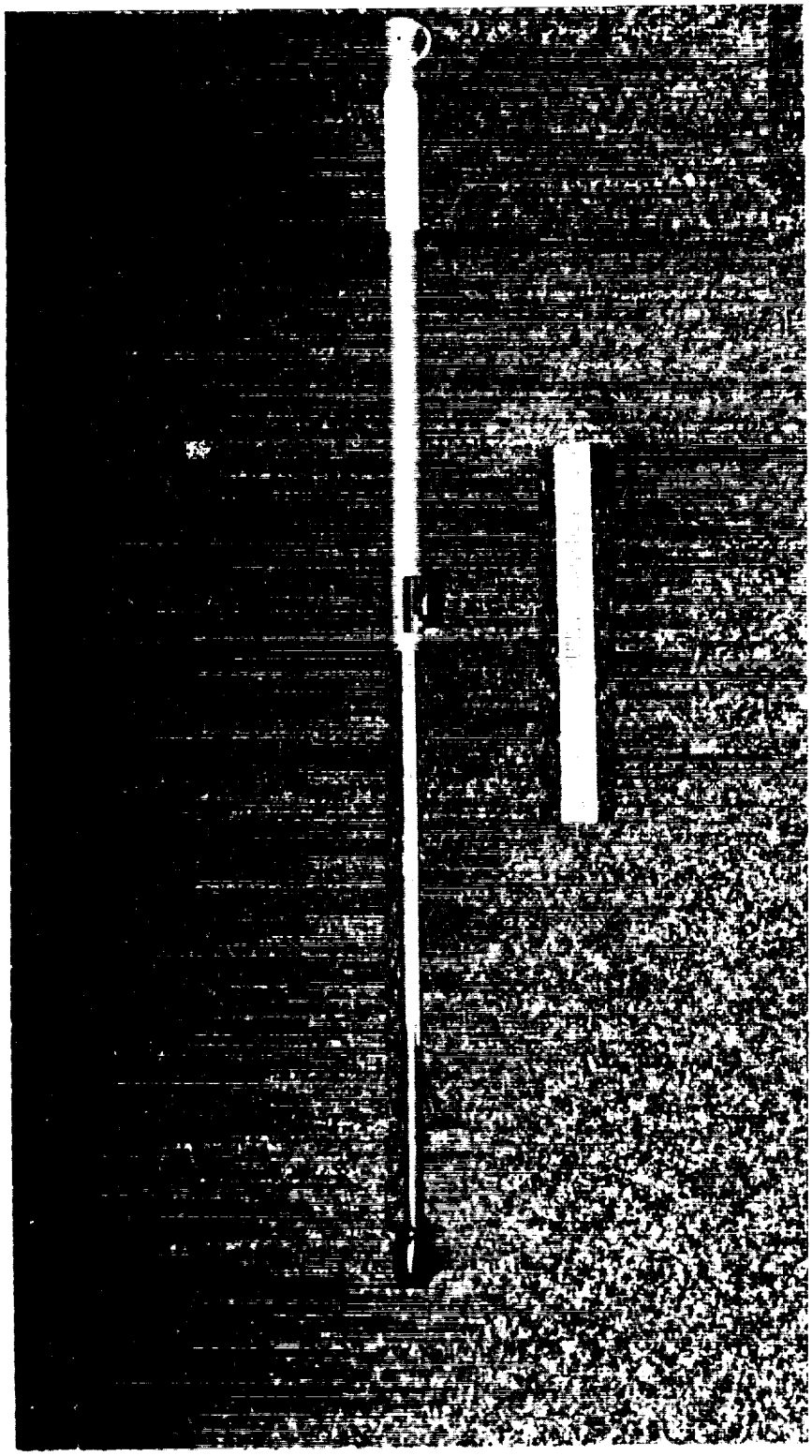

Figure 32. October 1990 LAW.

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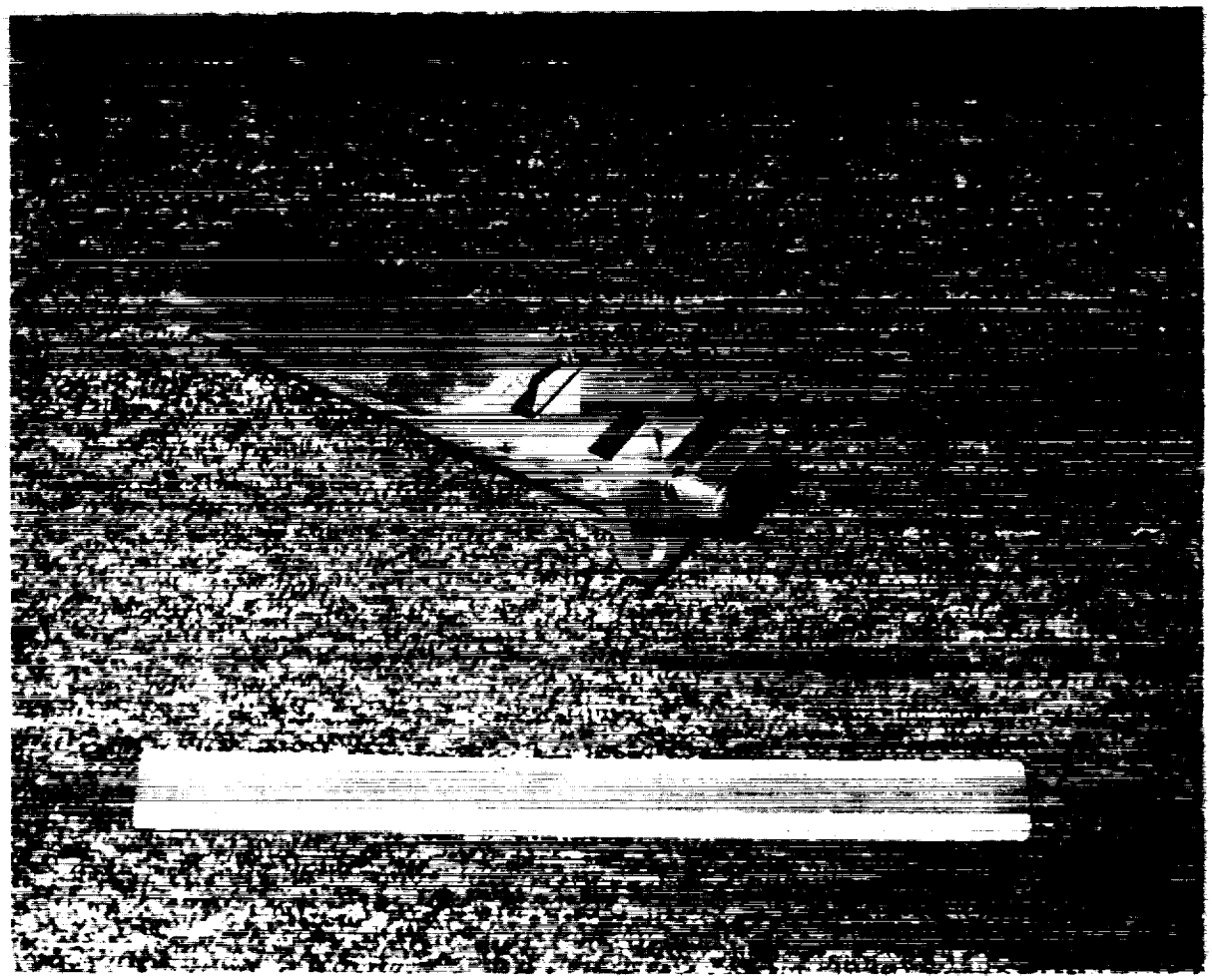

Figure 33. October 1990 overcenter latch lock.

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APPENDIX A

TOS EVA NB ACTION ITEM LIST—OCTOBER 1990

Created: November 8, 1990
Last Update: February 25, 1992

TOS EVA ACTION ITEM LIST RESULTING FROM OCTOBER 1990 NEUTRAL BUOYANCY TESTING

Number	Status	Actionee Closure Date	Action/Closure Description
		EVA PIN PULLER	
001	Closed	Albritton	Action: Add visual cue on window to show when the pin is fully engaged.
		5-9-91	Closure: Feature has been added.
002	Closed	Albritton	Action: Add another window 180 degrees from existing window for visibility of visual cue
		4-1-91	Closure: No longer applies due to total redesign of EPP.
003	Closed	Albritton	Action: Change allen drive to 7/16" external hex drive.
		4-1-91	Closure: Changed to 7/16" external drive.
004	Closed	Albritton	Action: Add a tether point.
		5-9-91	Closure: Tether point has been added.
005	Closed	Albritton	Action: Need a positive lock for the vertical position and horizontal pin-pulled position of the handle.
		3-13-91	Closure: Action no longer applies due to total redesign of EPP.
006	Closed	Albritton	Action: Change handle to T-handle, current handle is too wide.
		3-13-91	Closure: Action no longer applies due to total redesign of EPP.
007	Closed	Albritton	Action: EPP contacted bridge fittings on Starboard side on fwd. and aft sides of FWD. ASE. Procedure work around possible to solve this problem. Do not shorten handle, needed for leverage. Can we shorten base?
		3-13-91	Closure: Action no longer applies due to total redesign of EPP.

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TOS EVA ACTION ITEM LIST RESULTING FROM OCTOBER 1990 NEUTRAL BUOYANCY TESTING

Number	Status	Actionee Closure Date	Action/Closure Description
008	Closed	Albritton	Action: Three options considered on attachment to pin housing. 1. full threads, 2. half threads, 3. slip fit only. options 2 and 3 were preferred. Further study required. If option 2 then: concern of being fully seated and having freedom to reposition EPP (1 turn). Also don't want to load threads. If option 3 then: design so EPP is easy enough to reposition and remove but also tight enough to stay on while engaging pin and safe in case of inadvertent firing of pin.
		4-1-91	Closure: It was determined that the crew was most satisfied with option 2. Loading of threads and repositioning of the EPP was approved by stress.
009	Closed	Albritton	Action: Visual cue to show pin pulled position and unlocked position.
		4-1-91	Closure: Visual cue has been added. The unlocked position is no longer applicable due to total design change of the EPP.
010	Closed	Albritton	Action: Little tactile feedback was felt on the 45 degree clocking feature, visual cues must be added or the 45 degree clocking feature eliminated in favor of other rotation capabilities.
		3-13-91	Closure: Action no longer applies due to total redesign of EPP.
011	Closed	Albritton	Action: May want to square corner on cam so handle holds horizontal position.
		3-13-91	Closure: Action no longer applies due to total redesign of EPP.

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Last Update: February 25, 1992

TOS EVA ACTION ITEM LIST RESULTING FROM OCTOBER 1990 NEUTRAL BUOYANCY TESTING

Number	Status	Actionee Closure Date	Action/Closure Description
012	Closed	Albritton	Action: Ramp (bevel) inside edge of cap for self alignment on pin housing.
		4-1-91	Closure: Added full radius for self aligning feature.
		DUST CAP REMOVAL TOOL	
013	Closed	Alexander	Action: Move tether ring to top, needs to be able to rotate, needs to be stronger.
		2-26-91	Closure: All features have been added.
014	Closed	Alexander	Action: Resolve how circumferential band is to be restrained from rotating.
		2-25-92	Closure: Once tension is applied via the T-bolt clamp, rotation will not occur.
		ROTATION DEVICE BRACKETS	
015	Closed	Gagliano	Action: Need restraint between bracket and yoke rods.
		5-9-91	Closure: Pip pins were added to restrain yokes in brackets.
016	Closed	Gagliano	Action: Hex on upper bracket interferes with acme thread drive housing.
		5-9-91	Closure: Modification has been made to eliminate interference.
017	Closed	Gagliano	Action: Both brackets need a bayonet
		9-16-91	Closure: No longer feasible to add bayonet pins. Brackets can be transfered using equipment tethers.
018	Closed	Gagliano	Action: Need groove and paint as visual cue for release of brackets.
		2-26-91	Closure: Visual cue has been added.
019	Closed	Gagliano	Action: Need a 1/2 inch gap and rounded corners between pieces that cause pinch hazard.
		5-9-91	Closure: Modifications have been done.

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TOS EVA ACTION ITEM LIST RESULTING FROM OCTOBER 1990 NEUTRAL BUOYANCY TESTING

Number	Status	Actionee Closure Date	Action/Closure Description
		ROTATION DEVICE ACME THREAD	
020	Closed	Gagliano 5-9-91	Action: Add scalloped knob with hex interface. Closure: Knob and hex interface have been added.
021	Closed	Gagliano 2-26-91	Action: Acme thread too long, cut off excess. Closure: Modification has been made.
022	Closed	Gagliano 8-28-91	Action: Need tether point and bayonet. Closure: Tether point has been added. Bayonet will not be added due to lack of available space.
023	Closed	Gagliano 2-25-92	Action: Threads are too sharp for EVA contact. Closure: Per JSC crew inspection it was determined that the RD threads were not too sharp for EVA contact. The RD did have some sharp edges and these are being modified for EVA compatibility.
024	Closed	Sexton 10-23-91	Action: Need to have control of dangling yoke rods while translating. Closure: The crew has the option to use velcro straps to wrap around the yokes to prevent dangling of yokes. The velcro caddy is standard EVA equipment stowed in the PSA.
025	Closed	Gagliano 5-9-91	Action: visual cues on threads for full open position (should be stowed in this position) Closure: Addition of a visual cue is not feasible. Device will be stowed in open position.

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TOS EVA ACTION ITEM LIST RESULTING FROM OCTOBER 1990 NEUTRAL BUOYANCY TESTING

Number	Status	Actionee Closure Date	Action/Closure Description
026	Closed	Gagliano	Action: Add hard stop to eliminate inadvertent demate of screw and lower yoke. Stop should be below visual cue. Add hex on lower end of Acme Thread as backup.
		3-13-91	Closure: Hard stop has been added.
			TILT DEVICE AFT BRACKET
027	Closed	Gagliano	Action: Add T-Handle on whistle, avoid cable interference.
		3-13-91	Closure: No longer applies due to total redesign of tilt operation.
028	Closed	Gagliano	Action: Add pip pin (vertical) for three piece option.
		3-13-91	Closure: No longer applies due to total redesign of tilt operation.
029	Closed	Gagliano	Action: Pip pin lanyard on whistle must not interfere with cable during installation. Move to fwd. edge.
		3-13-91	Closure: No longer applies due to total redesign of tilt operation.
030	Closed	Gagliano	Action: Add tether point to T-Handle.
		3-13-91	Closure: No longer applies due to total redesign of tilt operation.
031	Closed	Gagliano	Action: Limit rotation angle.
		3-13-91	Closure: No longer applies due to total redesign of tilt operation.
			TILT DEVICE WINDOW FRAME BRACKET
032	Closed	Gagliano	Action: Limit rotation to avoid backward installation of acme thread.
		3-13-91	Closure: No longer applies due to total redesign of tilt operation.

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TOS EVA ACTION ITEM LIST RESULTING FROM OCTOBER 1990 NEUTRAL BUOYANCY TESTING

Number	Status	Actionee Closure Date	Action/Closure Description
033	Closed	Gagliano 3-13-91	Action: Need tether loop and bayonet. Closure: No longer applies due to total redesign of tilt operation.
034	Closed	Gagliano 3-13-91	Action: Need retention to keep the acme thread from floating out or driving itself out. Closure: No longer applies due to total redesign of tilt operation.
035	Closed	Gagliano 3-13-91	Action: Offset pip pin holes on both starboard and port sides so pip pin can be pulled without rod interference. Closure: No longer applies due to total redesign of tilt operation.
036	Closed	Gagliano 3-13-91	Action: Parking of pip pin required. Closure: No longer applies due to total redesign of tilt operation.
		TILT DEVICE ACME THREAD	
037	Closed	Gagliano 3-13-91	Action: Need a tether point on each end. Closure: No longer applies due to total redesign of tilt operation.
038	Closed	Gagliano 3-13-91	Action: Need to add bayonet. Closure: No longer applies due to total redesign of tilt operation.
039	Closed	Gagliano 3-13-91	Action: Add scalloped knob with hex interface. Closure: No longer applies due to total redesign of tilt operation.
040	Closed	Gagliano 3-13-91	Action: Acme thread too long, reduce length. Closure: No longer applies due to total redesign of tilt operation.

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TOS EVA ACTION ITEM LIST RESULTING FROM OCTOBER 1990 NEUTRAL BUOYANCY TESTING

Number	Status	Actionee Closure Date	Action/Closure Description
041	Closed	Gagliano	Action: Remove handholds. No handholds required.
		3-13-91	Closure: No longer applies due to total redesign of tilt operation.
042	Closed	Gagliano	Action: Threads are too sharp for EVA contact.
		3-13-91	Closure: No longer applies due to total redesign of tilt operation.
043	Closed	Gagliano	Action: The tilt device should be a two piece operation.
		3-13-91	Closure: No longer applies due to total redesign of tilt operation.
044	Closed	Gagliano	Action: Need a hard stop to keep acme thread from backing all the way out.
		3-13-91	Closure: No longer applies due to total redesign of tilt operation.
045	Closed	Gagliano	Action: Add visual cue for full installation length.
		3-13-91	Closure: No longer applies due to total redesign of tilt operation.
		LATCH ARM WRENCH RATCHET HANDLE	
046	Closed	Albritton	Action: Add bayonet on Ratchet handle
		4-1-91	Closure: Bayonet has been added.
047	Closed	Albritton	Action: Add box end wrench on end of handle as backup for latch operation. Box end can act as a tether loop too.
		4-1-91	Closure: Box end wrench and two tether loops have been added.

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TOS EVA ACTION ITEM LIST RESULTING FROM OCTOBER 1990 NEUTRAL BUOYANCY TESTING

Number	Status	Actionee Closure Date	Action/Closure Description
		LATCH ARM WRENCH SOCKET	
048	Closed	Albritton 4-1-91	Action: Move tether loop so socket can be installed while it is still tethered. Closure: Tether loop has been corrected.
049	Closed	Albritton 8-28-91	Action: Socket clearance too tight on latch arm. Closure: Mockup problem. Flight tool fit check will address any problems with fit and function.
050	Closed	Albritton 4-1-91	Action: Move lock to side, too hard to grip. Closure: Modification has been made.
051	Closed	Albritton 4-1-91	Action: Add visual cues "lock,pull,unlock" Closure: Visual cues have been added.
052	Closed	Albritton 9-16-91	Action Add bayonet Closure: Socket will be installed on the LAW while LAW is stowed. The LAW has a bayonet pin and the LAW and socket will be one assembly.
053	Closed	Albritton 4-1-91	Action: add graphics showing 96 degrees and CCW direction arrow. Closure: Direction arrow has been added. No need for angle decal.
		OVER CENTER LATCH LOCK	
054	Closed	Albritton 4-1-91	Action: Add graphics: lock and unlock and push. Closure: Tool has been eliminated from the TOS program.

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TOS EVA ACTION ITEM LIST RESULTING FROM OCTOBER 1990 NEUTRAL BUOYANCY TESTING

Number	Status	Actionee Closure Date	Action/Closure Description
055	Closed	Albritton 4-1-91	Action: Change V-groove to rounded groove for lock guide. Closure: Tool has been eliminated from the TOS program.
		TRUNNION LINK	
056	Closed	Albritton 4-1-91	Action: Move tether point from bottom to top Closure: Modification has been made.
057	Closed	Albritton 8-28-91	Action: Neutral buoyancy tool was very easy to slip on and off. Duplicate for flight tool. Closure: Flight tool fit check will address any problems with fit and function.
058	Closed	Albritton 3-13-91	Action: Add bayonet. Closure: Bayonet added.
059	Closed	Albritton 3-13-91	Action: Add graphics showing hook to face aft, outboard note readable from above. Closure: Graphics have been added.
		TENSION DEVICE	
060	Closed	Tyler 2-26-91	Action: Add second tether hole in handle standoff. Closure: Second tether hole has been added.
061	Closed	Tyler 2-26-91	Action: Add bayonet Closure: Bayonet added.
062	Closed	Tyler 4-1-91	Action: Add parking for EVA pip pins. Closure: Not enough room to add parking holes.

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Last Update: February 25, 1992

TOS EVA ACTION ITEM LIST RESULTING FROM OCTOBER 1990 NEUTRAL BUOYANCY TESTING

Number	Status	Actionee Closure Date	Action/Closure Description
		OTHER	
063	Closed	designers	Action: All pip pins should be double-acting where feasible
		8-28-91	Closure: Double acting pip pins have been used where feasible.
064	Closed	Sanders	Action: There is no PFR access for three pin pulls (fwd. & aft for rotation and aft for the latch) and the tilt-device aft-bracket. Determine if free-floating is acceptable to JSC.
		9-16-91	Closure: Superseded by July 1991 NB test data. See TOS EVA NB test report.
065	Closed	Sanders	Action: Determine weight and cost penalty for adding additional bridge fittings. (Bay 10 starboard, Bay 12 starboard & port).
		9-16-91	Closure: Superseded by action item number 075.
066	Closed	Sanders	Action: Analyze potential for misalignment of tension device and trunnion link which may cause point loads on trunnion.
		2-25-92	Closure: The EVA crew will mannually align the tools if any misalignment occurs.
067	Closed	Sanders	Action: Flight tools should be fit checked with flight ASE.
		8-28-91	Closure: Fit checks are scheduled for September 1991 and April 1992.

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TOS EVA ACTION ITEM LIST RESULTING FROM OCTOBER 1990 NEUTRAL BUOYANCY TESTING

Number	Status	Actionee Closure Date	Action/Closure Description
068	Closed	designers	Action: Must strategically locate tether loops so crewmen are able to tether tool before removing tool from miniworkstation and install tool on hardware while still being tethered.
		8-28-91	Closure: Tether loops and interface with miniworkstation proved sufficient during July 1991 TOS NBS.
069	Closed	designers	Action: All tools should have graphics which indicate direction of turns and number of turns.
		8-28-91	Closure: Graphics have been added to TOS EVA tools.

APPENDIX B

TOS EVA NB ACTION ITEM LIST—JULY 1991

Created: August 29, 1991
Last Update: March 4, 1992

TOS EVA ACTION ITEM LIST RESULTING FROM JULY 1991 NEUTRAL BUOYANCY TESTING

Number	Status	Actionee Closure Date	Action/Closure Description
070	Closed	Albritton	Action: Add McTether feature to EVA pin puller socket.
		2-25-92	Closure: McTether feature has been added.
071	Closed	Albritton	Action: More EVA glove clearance needed on tool carrier pip pin T-handles.
		2-25-92	Closure: Clearance has been provided and the tool carrier CDR was completed subsequent to this action.
072	Closed	Albritton	Action: Tool Carrier needs EVA graphics showing which latch to open last and any other vague operational characteristics.
		2-25-92	Closure: Graphics have been added and the tool carrier CDR was completed subsequent to this action.
073	Closed	Albritton	Action: Verify no interference caused between tool tether points, Bayonets, etc. and tool carrier pip pins during tool stowage on tool carrier.
		2-25-92	Closure: 3D models and analysis verify no interference.
074	Closed	Tyler	Action: Change Rotation Device pip pins from double acting to T-Handle pip pins.
		2-25-92	Closure: Change has been incorporated.

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Last Update: March 4, 1992

TOS EVA ACTION ITEM LIST RESULTING FROM JULY 1991 NEUTRAL BUOYANCY TESTING

Number	Status	Actionee Closure Date	Action/Closure Description
075	Closed	Sanders Sexton	Action: Bridge Longeron number 10 on the port and starboard sill and Bridge Longeron number 12 port must be added for flight in order to accommodate EVA restraint.
		3-4-92	Closure: Bridge longeron 12 port will be added to accomodate EVA. Bridge longerons 10 port and starboard are not available; Therefore the PFR adapter (PAD) will be manifested to provide EVA crew restraint via the RMS.
076	Closed	Sanders Sexton	Action: Can JSC maneuver the RMS to the rolled out position (deployed) to accommodate a TOS contingency EVA?
		10-23-91	Closure: The flight director has agreed to roll out the RMS for better access to EVA port operations.
077	Closed	Sanders Sexton	Action: Check possible tether points and handholds on TOS ASE while in Denver during the fit check.
		10-23-91	Closure: Needed restraint will be identified in WETF training. During the KSC walkdown inspection, possible restraint points will be verified.
078	Closed	Tyler	Action: Verify lubricant used on the Rotation Device ACME threads is compatible with the EMU gloves.
		2-25-92	Closure: Dry lube NTI 425 is baked on then burnished and appears to be no incompatibility with the EMU gloves.

Created: August 29, 1991
Last Update: March 4, 1992

TOS EVA ACTION ITEM LIST RESULTING FROM JULY 1991 NEUTRAL BUOYANCY TESTING

Number	Status	Actionee Closure Date	Action/Closure Description	
079	Closed	Sanders	Action:	Stow Tension Device and Trunnion Link on tool carrier.
		9-16-91	Closure:	Provisions for the Tension Device & Trunnion Link are being added.
080	Closed	Sanders	Action:	Add appendages to ACTS mockup and correct pip pin hole in latch arm wrench socket for JSC crew trainer.
		2-25-92	Closure:	These mods to the neutral buoyancy mockup have been added to the contract statement of work.
081	Open	Sexton	Action:	Can the EVA pin puller socket be stowed on a EVA tool board?
		3-4-92	Status:	Fit check with McCaddy tool caddy will be scheduled.

APPROVAL

REPORT FOR NEUTRAL BUOYANCY SIMULATIONS OF TRANSFER ORBIT STAGE CONTINGENCY EXTRAVEHICULAR ACTIVITIES

By J.D. Sexton

The information in this report has been reviewed for technical content. Review of any information concerning Department of Defense or nuclear energy activities or programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

for C.S. GRINER
Director, Mission Operations Laboratory

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