This is an unscheduled ATM dealing with the test and evaluation of the HFE, conducted by a BxA suited subject at the Mission and Crew Engineering test facility on 9 August 1967.

Prepared by: Leslie D. Marrus
L. D. Marrus
Mission & Crew Engineering

Approved by: F. E. Harrison
F. E. Harrison
Group Manager
Mission & Crew Engineering

A. Test Objective

The purpose of this test was to evaluate the updated Heat Flow Probe Package, performing as complete a Heat Flow Experiment deployment sequence as present hardware development would permit.

The following sections of this ATM describe the hardware, facilities, constraints, and procedures, as well as the results and conclusions derived from the test. The photographs at the end of this ATM illustrate the various steps comprising the HFE deployment sequence.

B. Test Description

1. Hardware -

(a) Mission and Crew Engineering model of the Heat Flow Probe Package, with included Dual-Static Probes and one Emplacement Tool. This model was originally manufactured by A. D. Little and was subsequently updated by the BxA M & C Engineering Test and Evaluation Group to the level called out in the latest ADL drawings.

(b) Mission and Crew Engineering model of the Heat Flow Electronics Box. This model was originally the BxA "H-1" model and was subsequently partially updated by the BxA M & C Engineering Test and Evaluation Group to current BxA drawings.

(c) Mission and Crew Engineering mockup of the Experiment Handling Tool (EHT).

(d) Developmental model of the bore hole casing, provided by Columbia University.

(e) Pressurized Apollo A2L space suit and Mission and Crew Engineering mockups of the Thermal Micrometeoroid Garment (TMG) and the Portable Life Support System (PLSS).

2. Facilities - Mission and Crew Engineering simulated lunar surface with an included three meter simulated drill hole.

3. Constraints - The limiting factors which prevented a complete HFE deployment were the lack of an up-to-date model of the Apollo Lunar Surface Drill (ALSD) and the lack of a finalized design to accomplish the attachment of the Probe Package to the Electronics Box. In the first instance, no attempt was made to integrate the deployment of the ALSD within the overall HFE deployment. The proposed HFE ALSD interfaces within the HFE deployment sequence such as the temporary stowage of the extended emplacement tool within the ALSD Rack Assembly at the drill site and the retrieval of the Probe Package from the lunar surface using the drill spanner wrench, were not incorporated in the test. In the second instance, the preliminary steps in the HFE deployment sequence, such as the removal of the HFE from ALSEP Package I and the deployment of the combined Electronics Box/Probe Package from the Central Station to the site selected for the deployment of the Electronics Box, which are dependent on the configuration selected for the attachment of the Probe Package to the Electronics Box, were not performed due to the lack of a definite design.

4. Procedures - (a) The suited subject began the test at one corner of the simulated lunar surface, as shown in Figure #1. The point in the overall Heat Flow Experiment deployment sequence that is shown in Figure #1 follows the removal of the Electronics/Probe Package assembly from Package I, the 30 foot traverse with the astronaut carrying the assembly by means of the EHT inserted in the top of the Electronics Box and the separation of the Probe Package from the Electronics Box.

(b) The Probe Package was retained in one hand and the EHT was employed to emplace the Electronics Package on the simulated lunar surface, using the experiment orientation marks on the top of the Electronics Box sunshield to achieve a "rough" alignment of the experiment to the axis of solar incidence. (See Figure #2) The EHT was left inserted in the Electronics Box socket.

(c) The Probe Package was held in one hand (See Figure #3) so that the suited subject had access to, first, one and then the other of the two closure straps.

(d) The pull ring on each closure strap was grasped in turn, and the closure strap (mated strips of Velcro tape) was removed and discarded as shown in Figure #4 at either end of the Probe Package.

(e) The two halves of the Probe Package were pulled apart, as depicted in Figure #5. Note that the half of the Probe Package in the subject's right hand in Figure #5 has three international orange diamonds painted at the top of the package (on the top end and two sides). These markings indicate the half of the package that contains the emplacement tool and, secondarily, also indicate the top of the package containing the carrying strap, etc.

(f) The half of the Probe Package which did not contain the emplacement tool, was then leaned against the Electronics Box with the open face of the package placed downward.

(g) A pull ring attached to the emplacement tool holding device permits rotation of the holding device out of the way so that the probe cable can deploy out of its stowage location in the cable trough. In this test the holding device began to rotate because of the position in

which the suited subject held the Probe Package (see Figure #5). When the suited subject attempted to attach the holding device to a retaining strip of Velcro tape on the back of the package (see Figure #6) he could not successfully mate the two Velcro surfaces.

(h) Next, the subject inserted his hand into the carrying strap and paced off approximately 18 feet to the drill site, with the probe cable deploying behind him from the Probe Package, as shown in Figure #8.

(i) At the drill site the emplacement tool was simultaneously extended and removed from the Probe Package holding device. See Figure #9 and #10.

(j) Then the extended emplacement tool was leaned against the drill package and the Probe Package was laid open face down on the simulated lunar surface to free the subject's hands for the drilling operations.

(k) In this test the Probe Package was retrieved from the simulated lunar surface by the subject using the emplacement tool, as depicted in Figure #11. In actual operations the drill spanner wrench will probably be used as the retrieval tool rather than the emplacement tool.

(l) All the probe cable still remaining in the cable trough was pulled out.

(m) The pull ring at the top of the package was then grasped by the subject, the sleeve containing the Probe Assembly was rotated forward (see Figure #12 and #13), and the Probe Assembly was withdrawn from the foam spacer assembly, as shown in Figure #14.

(n) The empty Probe Package was then discarded on the simulated lunar surface.

(o) Figure #15 shows how the packing piece assemblies at either end of the Probe Assembly were removed and discarded.

(p) The Probe Assembly was next unfolded as depicted in Figure #16.

(q) The lower half of the probe assembly was lowered into the bore hole sheathing, as shown in Figure #17, and the upper half of the probe was left exposed.

(r) The emplacement tool was retrieved and the probe cable was inserted into the emplacement tool crow's foot (see Figure #18).

(s) The emplacement tool was then utilized to slide the lower radiation shield over the spring at the top of the Probe Assembly.

(t) Figures #19 and 20 show how the emplacement tool was used to lower the probe assembly to the bottom of the sheathed drill hole.

(u) The subject then noted and reported the first exposed alphanumeric marking on the emplacement tool, which indicated the depth of the probe in the drill hole casing (see Figure #21).

(v) The emplacement tool was then withdrawn from the drill hole as shown in Figure #22 and the emplacement tool crow's foot was removed from the probe cable.

(w) The emplacement tool was used to locate the upper radiation shield atop the drill hole sheathing which completed the deployment sequence.

C. Test Results

1. Originally the Probe Package was to have had one or two EHT sockets to permit the use of the EHT in the handling of the package, but such constraints as material thickness and envelope considerations prevented the incorporation of the EHT sockets into the final design.

   In the current design, prior to the separation of the two halves of of the Probe Package and the exposure of the two fabric carrying straps, no handle or other carrying device is provided.

   Therefore, before the carrying straps are available for use by the astronaut, he must (1) span distances of 3.34 or 4.46 inches if he attempts to "grasp" the package with one hand, (2) "cradle" the package using either one or two hands (i.e., as shown in Figures #3 and #5), or (3) grasp the cables which protrude from the package (i.e., as shown in Figure #1).

   Previous testing of the Heat Flow Probe Package (see ATM #638, dated 4 April 1967), using the Apollo A4H pressure suit glove, failed to identify any particular problem in grasping the package with one hand. However, in the present test, using the bulkier A2L glove which for the first time included the additional thickness of the thermal micrometeoroid outer layer, the suited subject reported that he had difficulty in grasping the package with one hand. To avoid this difficulty (and to decrease the possibility of dropping the package) the subject handled the package by either cradling it or by grasping the protruding cables. These methods of handling the package were reported to be reasonably satisfactory and do not seem to introduce any new problems. The Probe Package is so designed that it should not abrade the space suit when the astronaut cradles it, as shown in Figure #3, and the cable strength and strain relief should be more than adequate to preclude the possibility of damage to the experiment when the astronaut grasps the cable, as shown in Figure #1.

   Once the Probe Package was separated into its two half sections, the subject reported no difficulty in handling the half package by using the carrying strap, as shown in Figure #8, or by spanning the distance of 2.23 inches to grasp the package, as shown in Figure #7, #12, and #13.

2. When the suited subject inadvertently turned the Probe Package upside down, the emplacement tool began to deploy itself prematurely (see Figure #7). Aside from the awkwardness of handling the Probe Package after the emplacement tool has extended, the astronaut could very conceivably trip over the prematurely extended tool. Normally the relationship of the emplacement tool crow's foot to the holding device and the frictional coefficient between the sections of the emplacement tool are sufficient to prevent premature extension of the tool when the package is held in the upright position. The emplacement tool holding device is so designed that the emplacement tool could not fall out of the package, but no provision was made to prevent extension of the tool if the astronaut errs and turns the package over.

   The design of the tool is such that even when the suited subject tried to restow the emplacement tool within the holding device he was unable to do so. Figure #8 shows the inefficacious result of the suited subject's attempts to restow the tool within the package and the cumbersomeness of the 18 foot cable deployment that resulted.

3. The suited subject complained that although the three international orange diamonds painted at the top of the Probe Package were visible, they were not large enough to demand his attention. One possible reason for his having turned the Probe Package upside down and the resultant premature deployment of the emplacement tool might well have been the too small size of the present diamonds.

4. The pull ring that is attached to the emplacement tool holding device is intended to permit rotation of the holding device so that it can be attached, out of the way, to a strip of Velcro tape on the back of the Probe Package. Figure #5 shows that the holding device rotated of its own accord because the subject held the half of the Probe Package that contained the holding device upside down, rather than right side up.

   When the suited subject attempted to attach the holding device to the aforementioned Velcro strip he was unsuccessful. As a result the holding device was free to flap around during the traverse to the drill site, as shown in Figure #8.

5. Aside from a few minor problems the remainder of the deployment was satisfactory. The remaining problems were as follows:

   a. When the suited subject deployed the cable from the Probe Package, the force exerted was sufficient to cause the half of the Probe Package that was left leaning against the Electronics Box to fall to the simulated lunar surface.

   b. The suited subject objected to the lack of any positive indication that the emplacement tool sections had been fully extended and locked in place, other than that when an attempt was made to recollapse the sections he was not successful.

   c. The cloth removal strap on one of the packing piece assemblies separated from the packing piece because the suited subject pulled too strongly and, as a result, the removal of this packing piece was a bit difficult.

D. Recommendations

1. The lack of a handle or strap on the exterior surface of the Probe Package, prior to the separation of the two half sections and the exposure of the carrying strap, proved to be inconvenient but did not prevent the carrying out of the Heat Flow Probe deployment.

   To simplify the astronaut's task of handling the Probe Package and to prevent the astronaut's dropping the package and then having to retrieve it from the lunar surface, M & C Engineering recommends the addition of a strap to the exterior of the Probe Package, as shown in Figure #24. The strap could be made of the same orange nylon material being used for the present carrying straps and the strap should be attached on either side of the bottom half of the Probe Package, at the center of gravity. The strap should be approximately 21.5 inches in length and have a 1.00 inch square strip of Velcro tape centered approximately 12.25 inches from one end and approximately 9.25 inches from the other end.

   This configuration will permit attachment of the strap along the full height of either side of the Probe Package, partial stowage of the strap within the proposed carry tray, and enough strap length to permit attachment of the strap to the ALSEP Package I sunshield (during vibration) and for insertion of the astronaut's

gloved hand into the strap to permit lifting the Probe Package from the carry tray. When the astronaut lifts the Electronics Box/Probe Package assembly from the pallet, using the Experiment Handling Tool, the Velcro tape on the lift-off strap will pull free of the sunshield. The decision not to place the strap on the top half of the Probe Package was premised on the fact that following removal of the two closure straps, the bottom half of the package must be supported to prevent its falling on the lunar surface. Following removal of the two closure straps, the lift-off strap would permit inverting the Probe Package and separation of the two halves of the assembly and, at this point, the present carrying straps (which are attached to each half of the package) would be available for handling the Probe Packages.

2. The problem of premature extension of the emplacement tool can be readily solved by sewing a thin thread to the holding device and across the top of the emplacement tool crow's foot. This thread will not require much tensile strength to prevent premature extension of the tool and can be weak enough so that the astronaut can readily snap it when he grasps the crow's foot to extend the tool and remove it from the holding device.

3. Although the present diamonds were found to be seeable by the subject, they should be enlarged from their present 0.33 inch on a side measurement to 1.0 inch on a side, so that they will be "highly" visible. The included angles should be $60^{\circ}$ at the sides and $120^{\circ}$ at the top and at the bottom.

4. The failure to be able to secure the holding device to the back of the Probe Package was largely due to the relatively small size of the pieces of Velcro tape. An increase in the size of the two pieces of Velcro would greatly simplify the astronaut's task.

5a. Although the Probe Package did fall to the simulated lunar surface in this test, there is no great concern about the astronaut's being able to retrieve the package from the lunar surface. This test showed that the emplacement tool crow's foot can be readily used to fish the Probe Package off the surface and lift it up to a reachable height above 18 inches.

5b. In the past there was some discussion of indicating that an emplacement tool section had been fully extended by providing a colored band which would become visible when the section was fully extended. It is felt that such a colored band (with its inherent width) might in fact, provide a false indication that a section had been fully extended and locked in place and that the only reliable

indication that a section is fully extended and locked in place is the fact that it cannot be recollapsed.

5c. The packing piece assemblies have been redesigned and now the cloth removal strap is not only epoxied to the exterior surface of the packing piece, as was the case with the packing pieces used in this test, but is also entrapped within a hole that passes through the packing piece. This redesign should preclude the sort of failure encountered in this test.

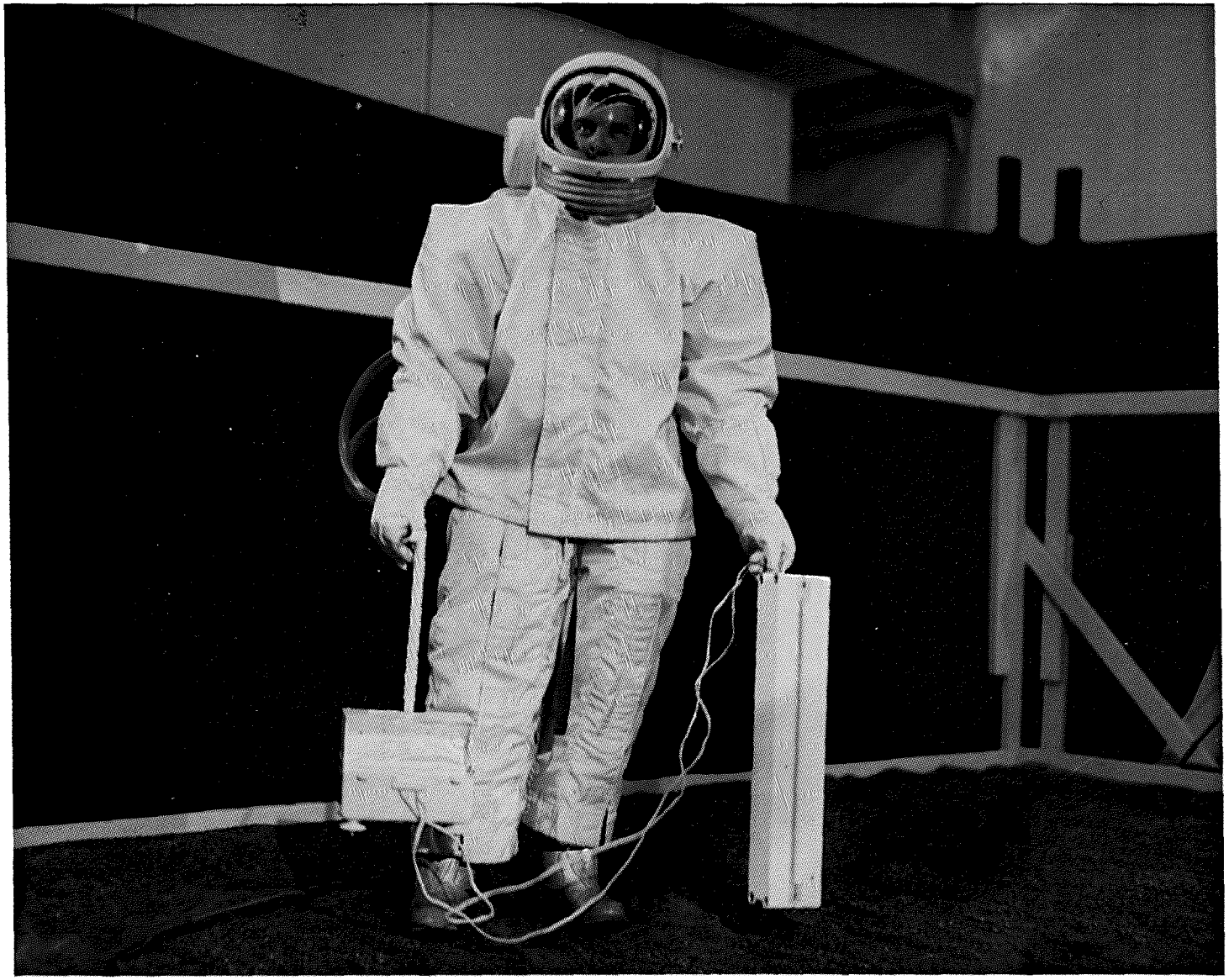

FIGURE #1 Suited subject carrying the Heat Flow Electronics Box and the Heat Flow Probe Package.

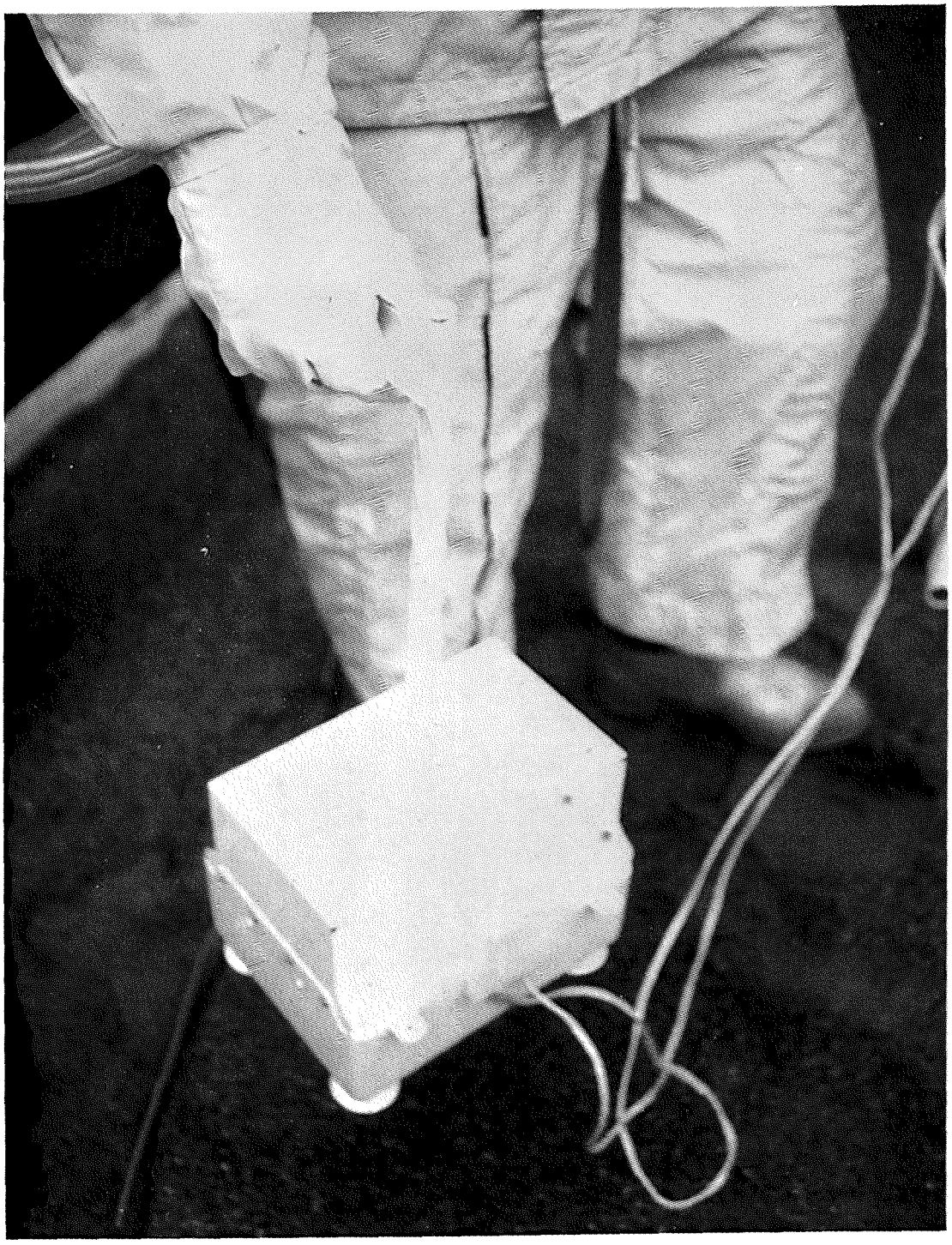

FIGURE #2 Emplacement of the Electronics Box on the simulated lunar surface.

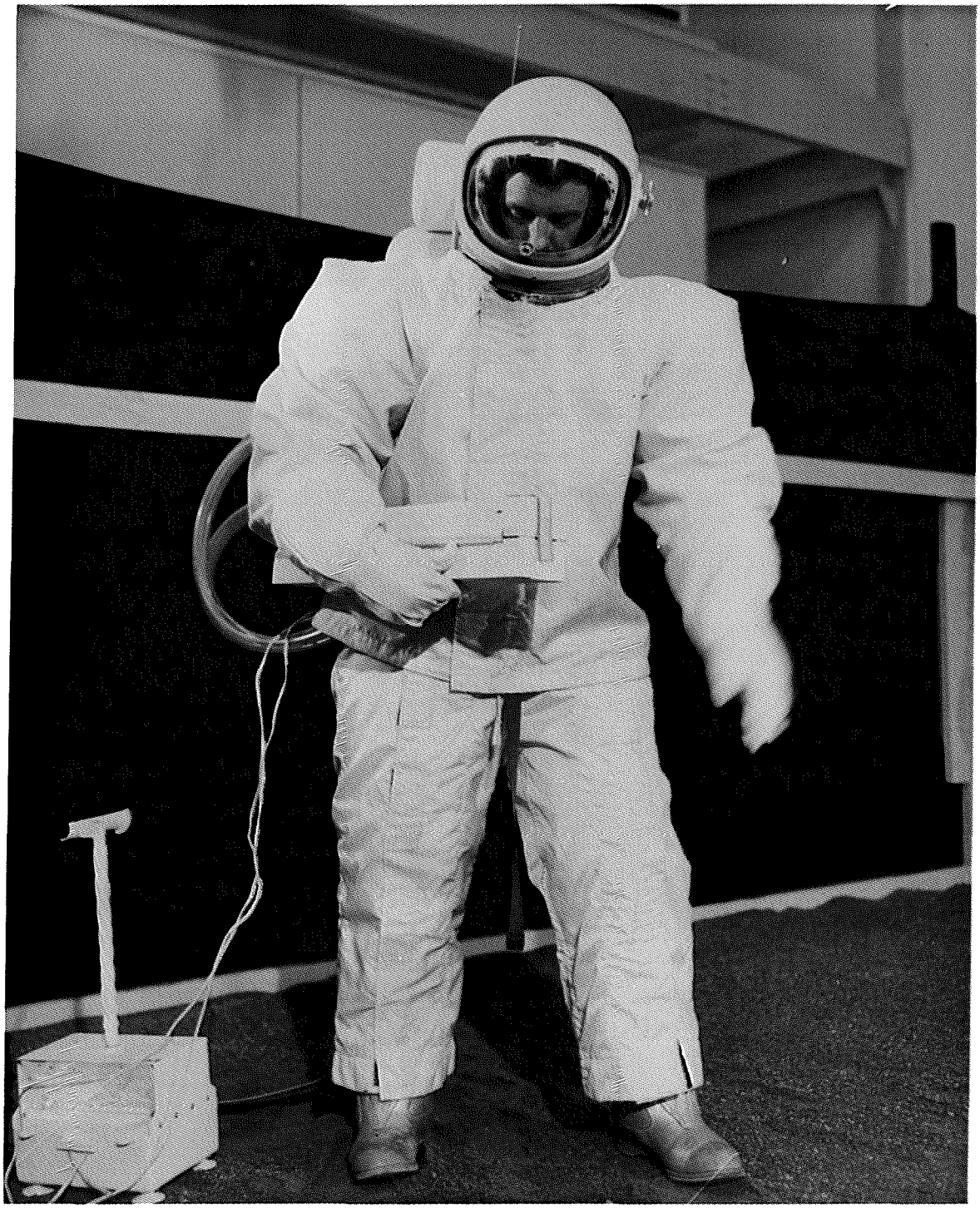

FIGURE #3 Probe Package being held in place to permit removal of the closure straps.

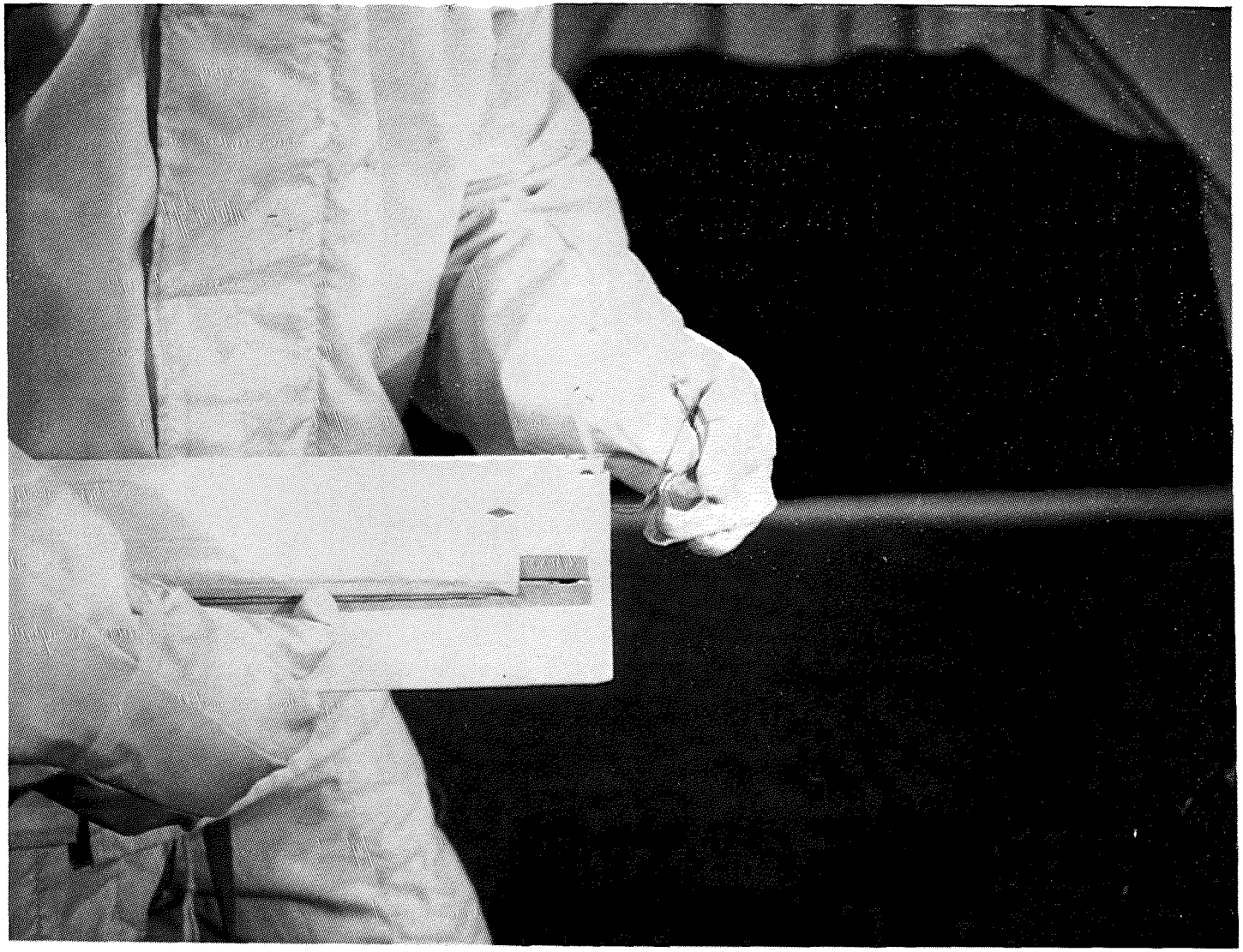

FIGURE #4 Thumb inserted into the pull ring to facilitate removal of the closure strap.

FIGURE #5 Probe Package being separated into the two half sections which contain the Heat Flow Probe Assemblies.

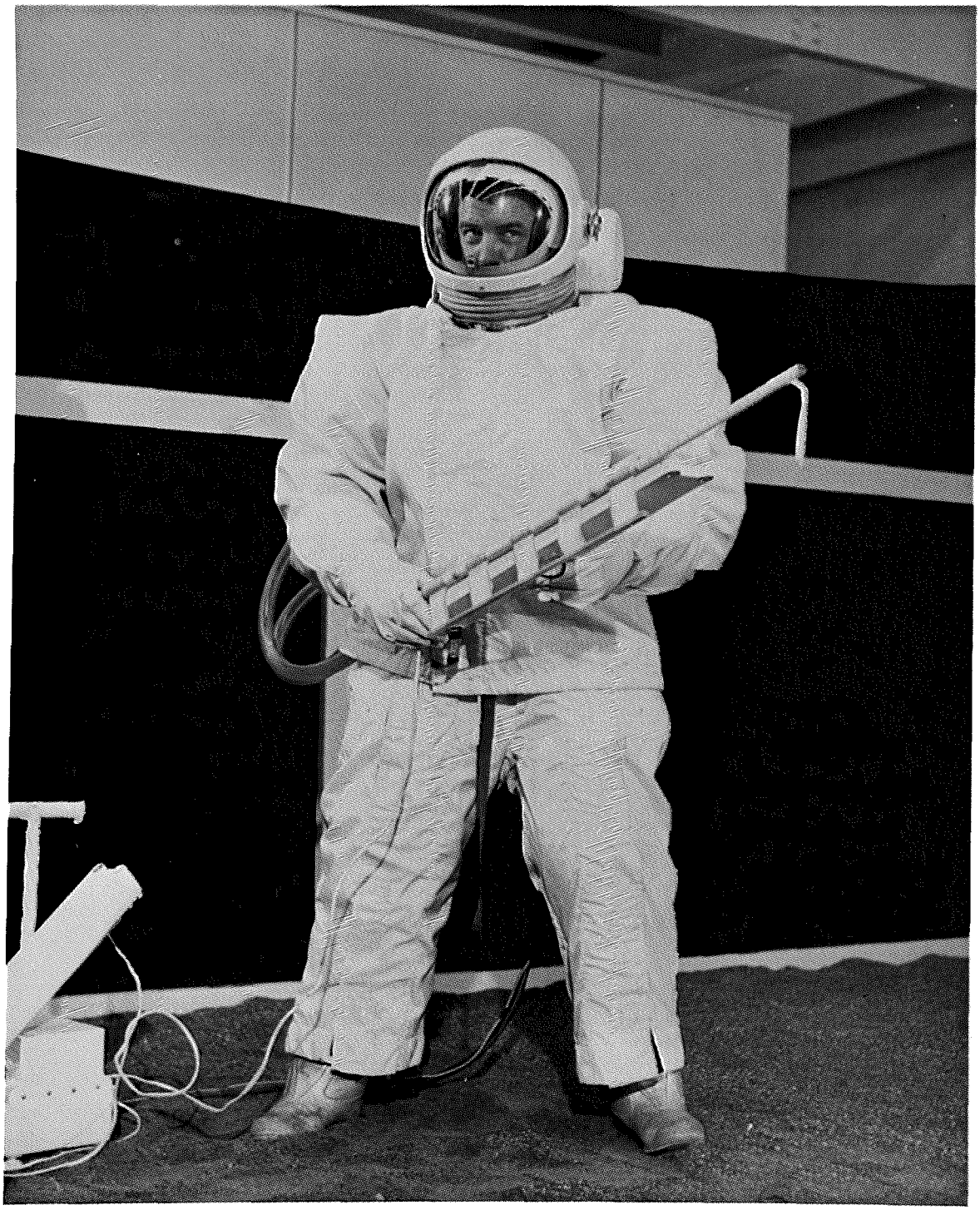

FIGURE #6 Rotation and attachment to the back of the Probe Package of the holding device, which contains the emplacement tool.

FIGURE #7 Emplacement tool prematurely extending when the suited subject turned the Probe Package upside down.

FIGURE #8 Traverse to the Drill Site, with the probe cable deploying from the Probe Package.

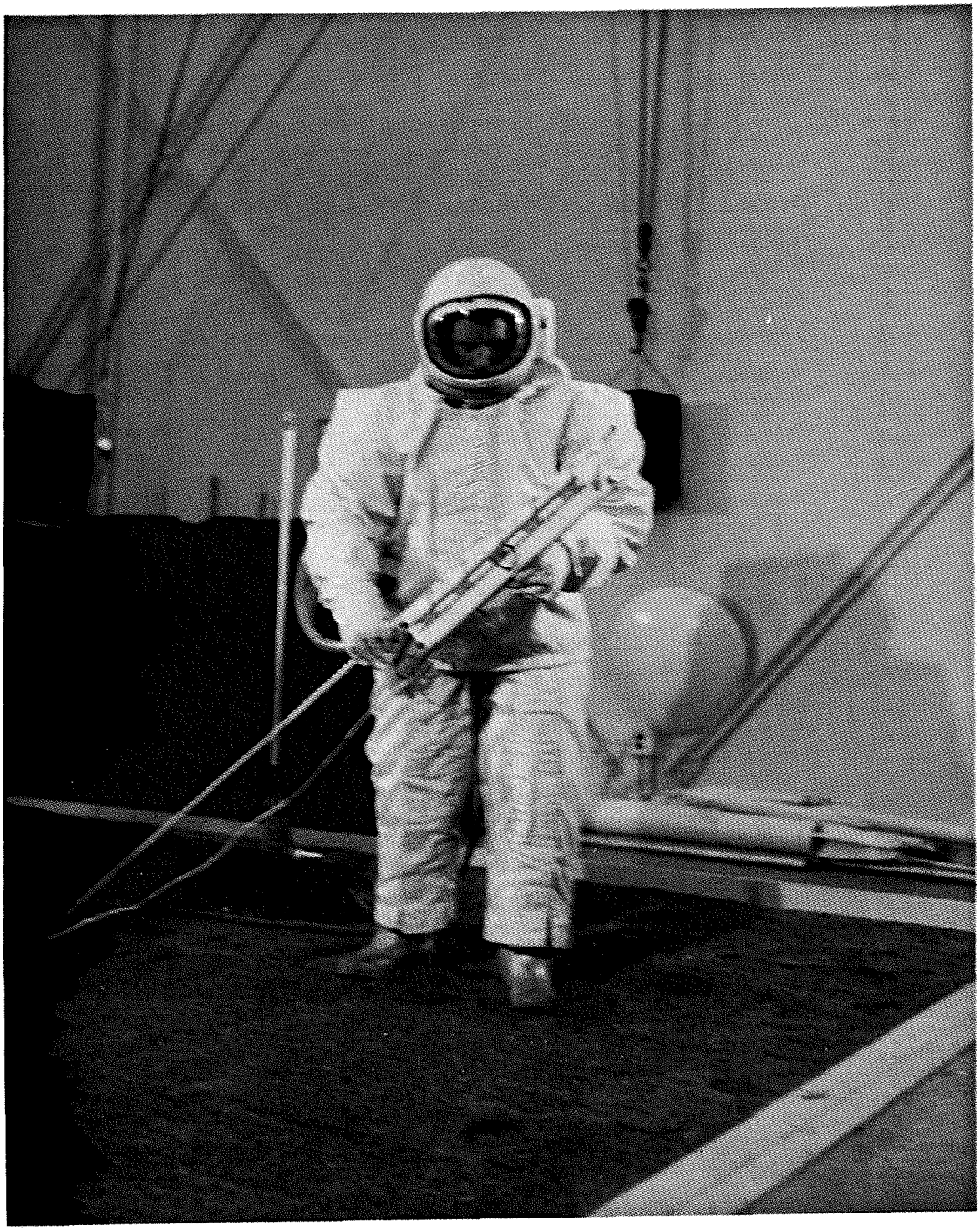

FIGURE #9 Extension and removal of the emplacement tool from the Probe Package holding device.

FIGURE #10 Emplacement tool being checked to ensure that it is fully extended and that the locking collars between tube sections are engaged.

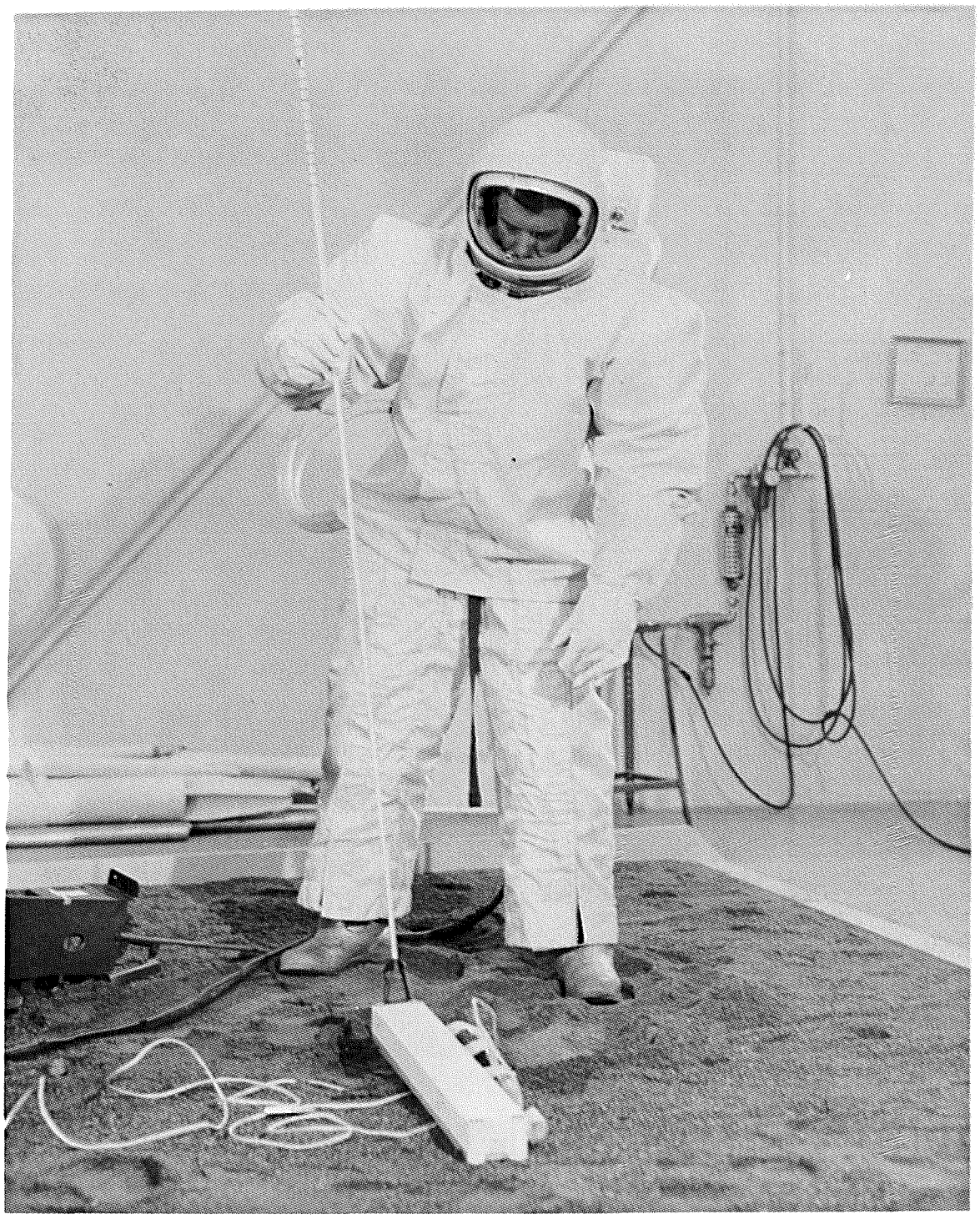

FIGURE #11 Retrieval of the Probe Package from the simulated lunar surface using the emplacement tool.

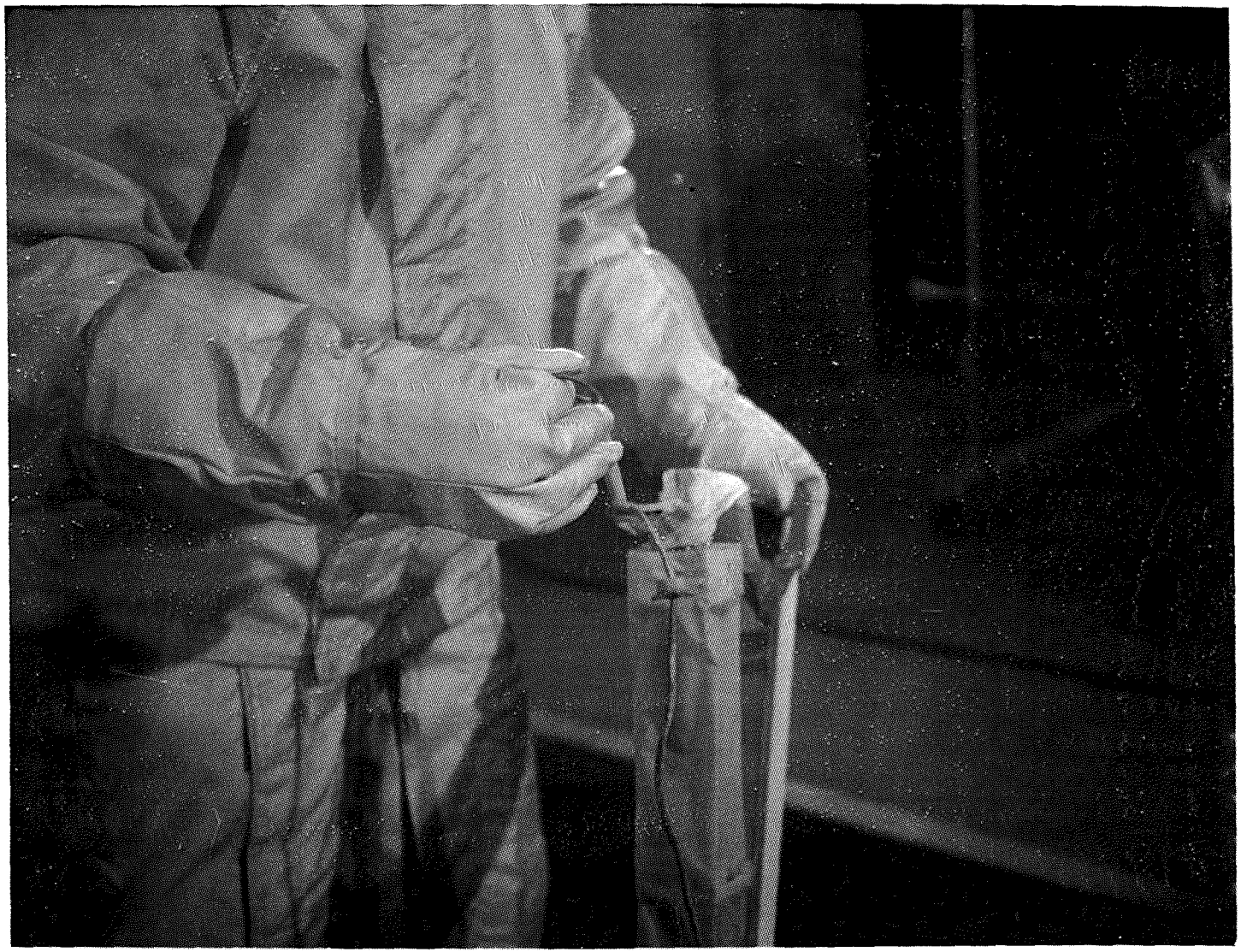

FIGURE #12 Finger inserted into the pull ring to facilitate the rotation of the foam spacer assembly out of the Probe Package.

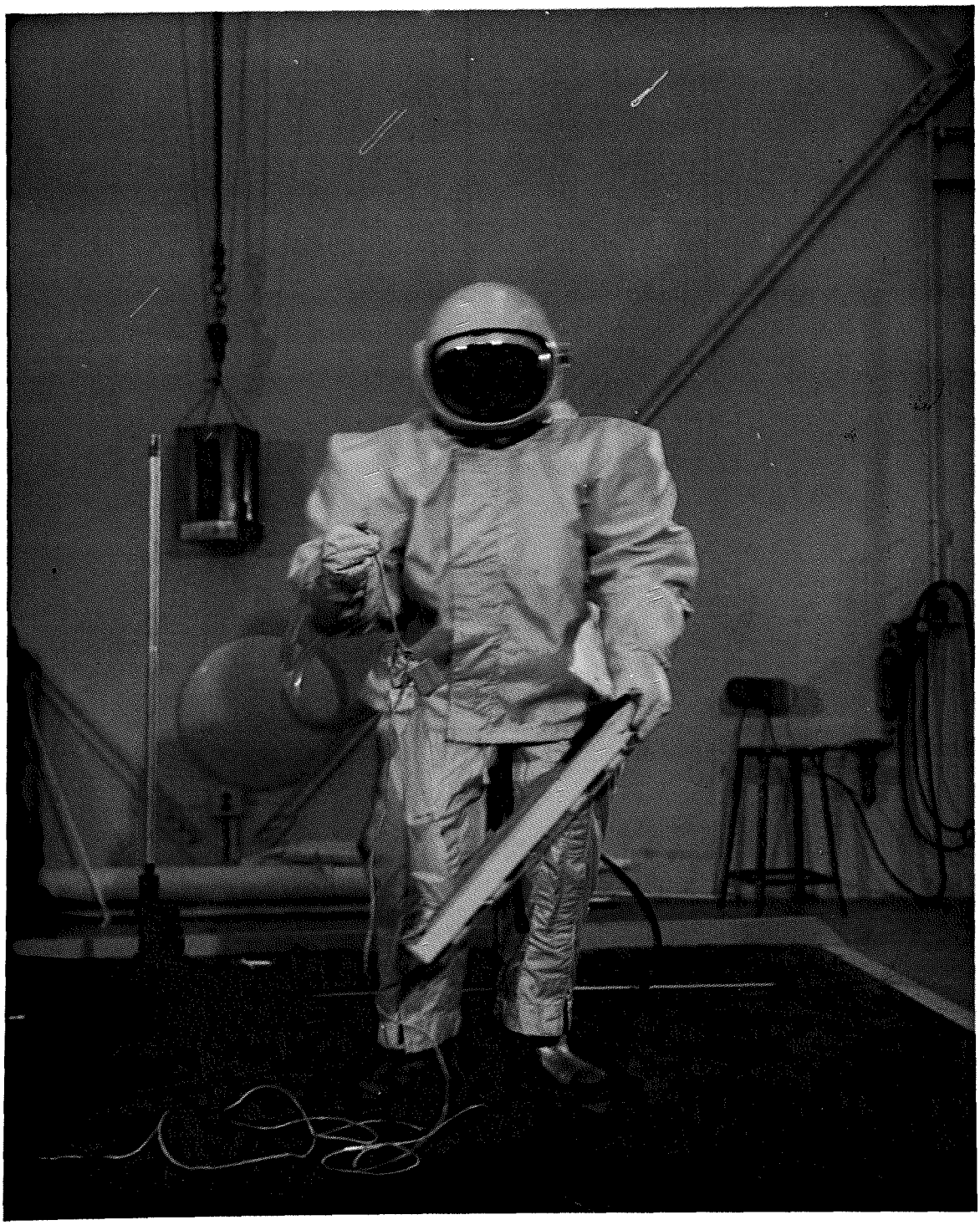

FIGURE #13 Rotation of the foam spacer assembly out of the Probe Package.

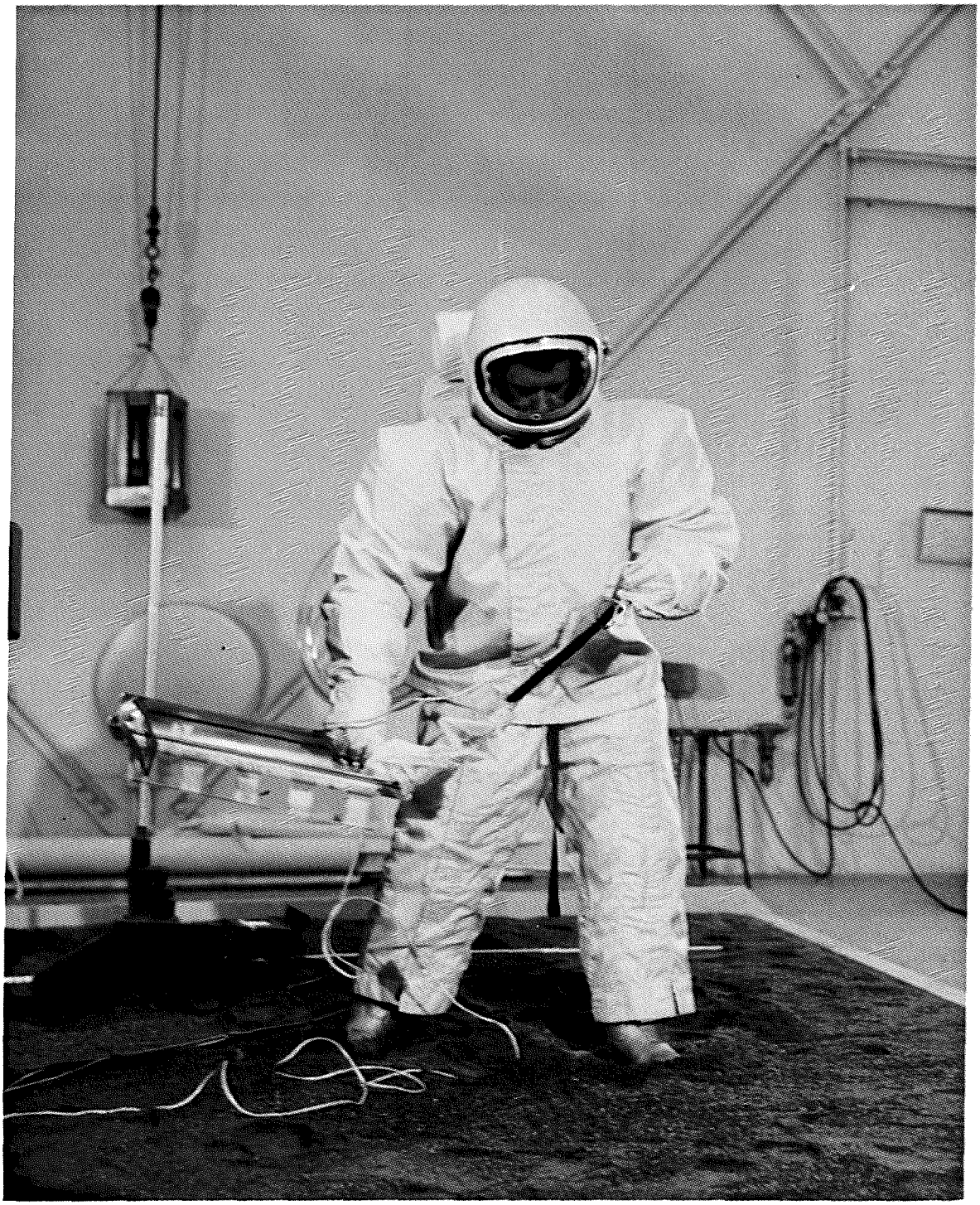

FIGURE #14 Removal of the Probe Assembly from the foam spacer assembly.

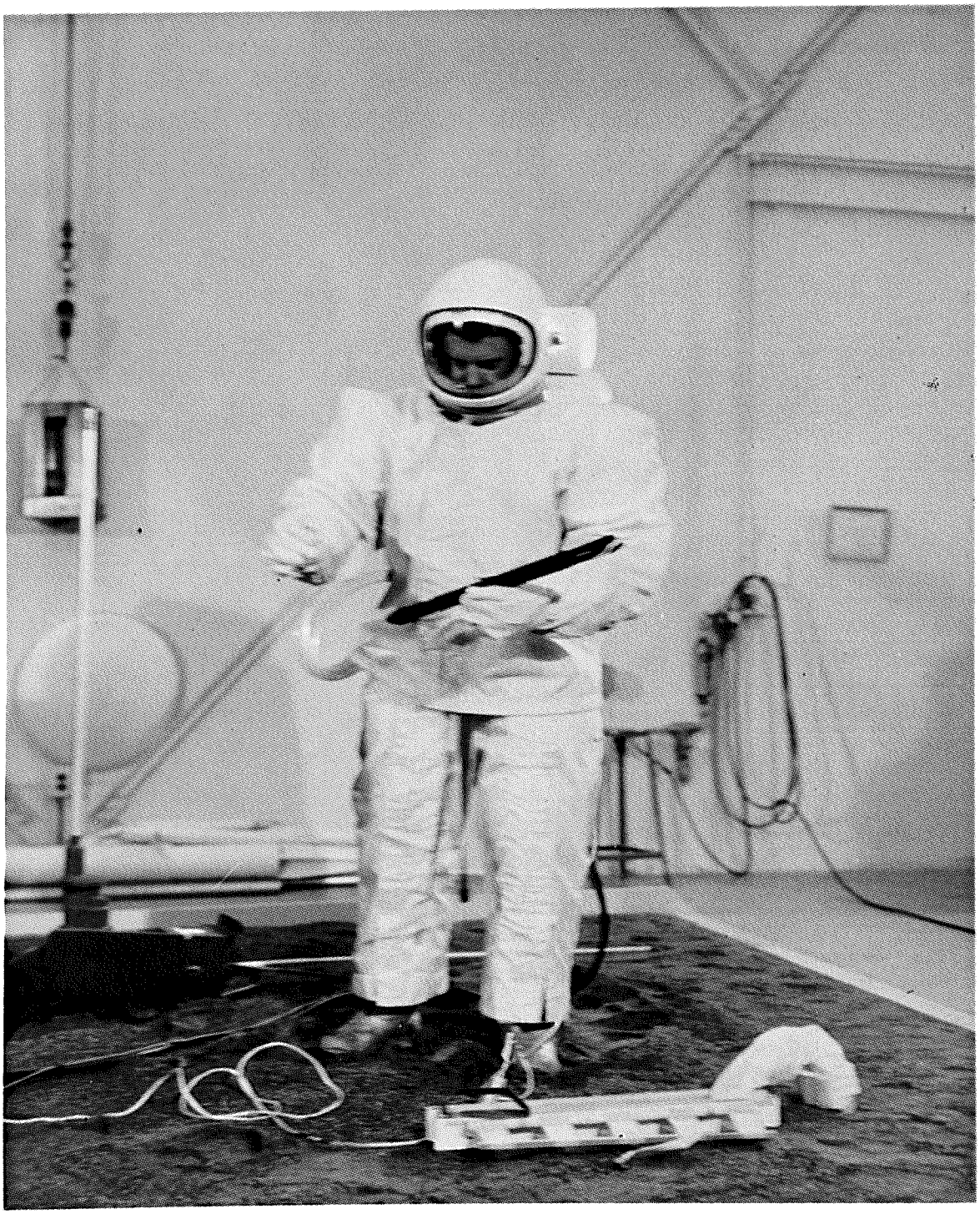

FIGURE #15 Removal of the packing piece assemblies from the Probe Assembly.

FIGURE #16 Unfolding of the Probe Assembly from its stowed configuration.

FIGURE #17 Insertion of the Probe Assembly into the sheathed drill hole.

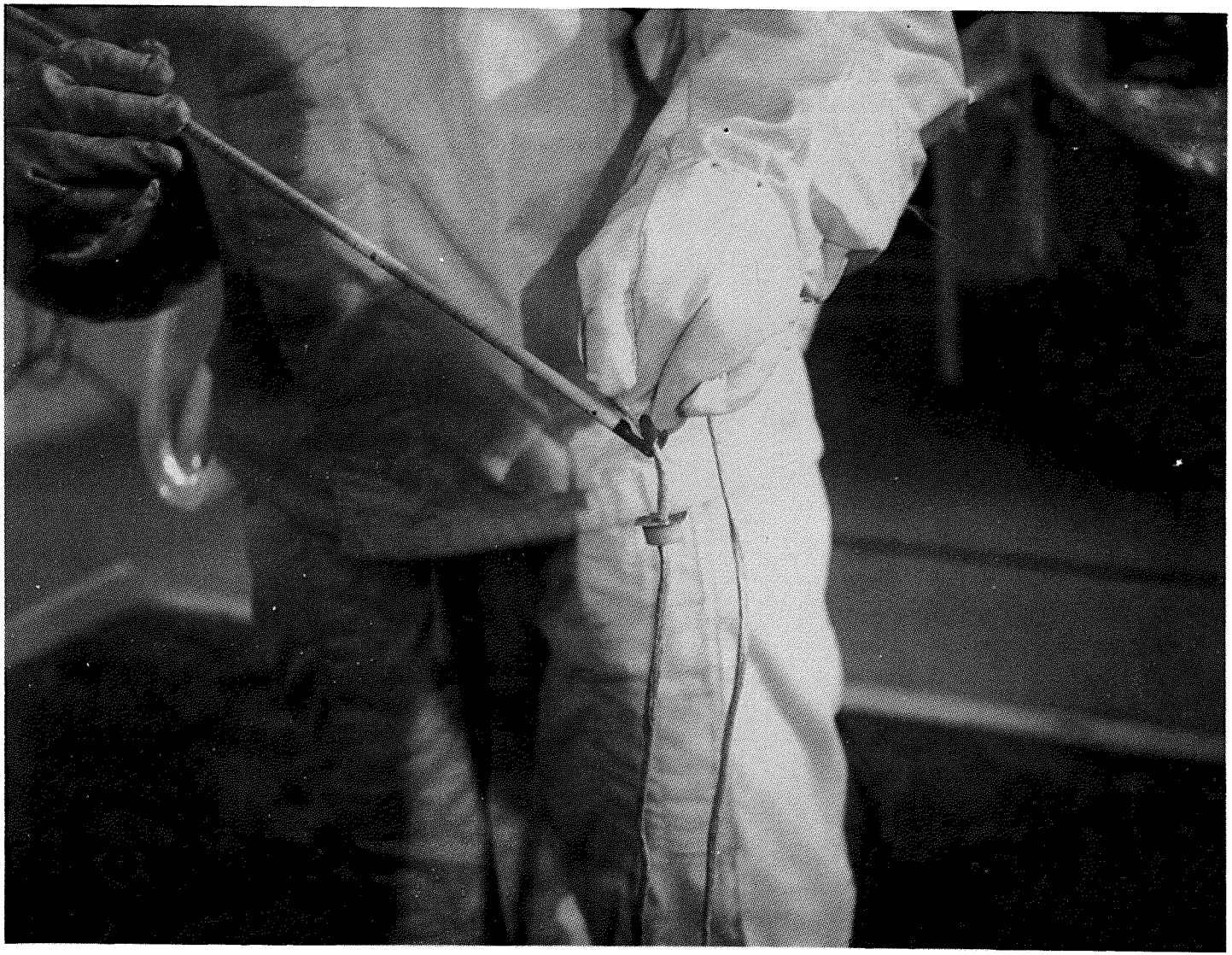

FIGURE #18 Insertion of the probe cable into the emplacement tool crow's foot.

FIGURE #19 Lowering of the Probe Assembly into the sheathed drill hole using the emplacement tool.

FIGURE #20 Emplacement tool being pushed down to the point where the Probe Assembly is at the bottom of the sheathed drill hole.

FIGURE #21 Graduation marks and alphanumeric coding on the emplacement tool indicate the depth of the Probe Assembly in the sheathed drill hole.

FIGURE #22 Removal of the emplacement tool from the sheathed drill hole.

FIGURE #23 Final view of the Heat Flow Probe Deployment Site, with the upper radiation shield covering the sheathed drill hole.

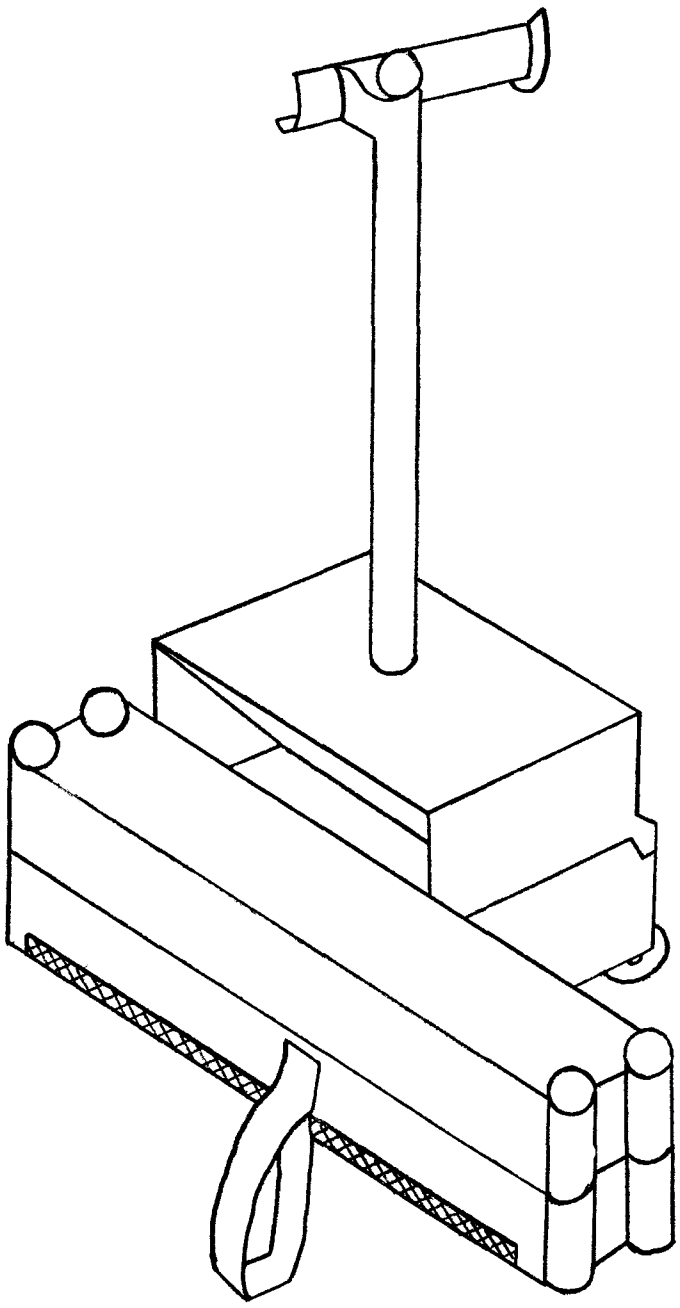

FIGURE #24 Proposed Heat Flow Experiment stowed layout for Flight III, showing the (cross-hatched) carry tray and the lift-off strap Velcroed to the Pallet I sunshield.