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The following compilation of Crew Engineering reports documents the human factors considerations that influenced the LRRR (300) design and the LRRR (300) deployment plans.

Prepared by: T. J. Kuechenmeister

Approved by:

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INTERFACE CONTROL SPECIFICATION

FOR

ASTRONAUT/LRRR (300)

Prepared by: Leslie D. Morris

Date: 24 September 1970

Approved for The Bendix Corporation

By: P S Curry

Date: 28 Sept 70

Approved for NASA/MSC (LSPO)

PBW fmd 10-22-70

By: [illegible]

Date: [illegible]

Approved for NASA/MSC (FCSD)

By: J. H. Roberts

Date: 31 Oct. 70

The Bendix Corporation
Aerospace Systems Division
Ann Arbor, Michigan

1.0 SCOPE

1.1 Scope - This specification establishes the requirements for the interface between the Laser Ranging Retro-Reflector (LRRR) experiment and the astronaut, while on the lunar surface.

1.2 Associated Equipment - The LRRR (300) experiment, its components and associated equipment, will be transported to the lunar surface aboard the Lunar Module (LM). The astronaut will provide optimum placement, setup and orientation of the LRRR on the lunar surface. The LRRR (300) will remain on the moon after the departure of the astronaut to complete its scientific mission.

2.0 APPLICABLE DOCUMENTS

2.1 The following documents, of exact issue shown, form a part of this specification. In the event of conflict between referenced documents and the content of Section 3.0, the detailed requirements of Section 3.0 shall be considered superseding requirements.

STANDARDS

Federal

Federal Standard No. 595	Colors, dated 1 March 1956.

NASA

MSFC-STD-267A	Human Engineering Design Criteria, dated 23 September 1966.

Military

MIL-STD-1472	Human Engineering Design Criteria for Military Systems, Equipment and Facilities, dated 9 February 1968.

DRAWINGS

Bendix

2338102	Assembly, Universal Handling Tool.

OTHER PUBLICATIONS

NASA

NASA-SP-3006	Bioastronautics Data Book, dated 1964.
NASA-CR-1205	Compendium of Human Responses to the Aerospace Environment, dated November 1968.
MSFC-10M32447B	Human Engineering Design Requirements, dated 16 January 1970.

MILITARY

AFSCM-80-3	Handbook of Instructions for Aerospace Personnel Subsystem Design, dated 15 April 1965.

3.0 REQUIREMENTS

3.1 Performance - The performance requirements for the LRRR (300) experiment/crew system interface are as follows:

3.1.1 LRRR (300) - The LRRR (300) shall be capable of safe, rapid, easy and accurate extraction from the LM, transportation to the deployment site, experiment deployment, emplacement on the lunar surface, and orientation with respect to the subearth point (the center of the pattern of earth position coordinates - Selenographic coordinate system - formed by the lunar librations) by one astronaut.

3.1.2 Astronaut - The astronaut must possess the training and skills necessary to safely perform the required operational tasks within the time and accuracy tolerances which will result in a correctly deployed and operational LRRR (300).

3.2 Interface Requirements - The interface which exists between the astronaut and the LRRR (300) occurs during the extravehicular activities on the lunar surface and is necessary for the successful deployment and operation of the LRRR (300). Due consideration shall be applied in the design of the LRRR (300) hardware and of the operational tasks in order to enhance the effectiveness of the astronaut during lunar deployment, through minimizing demands on human resources such as the astronaut's knowledge, skills, training, and needs for procedural data, so that over-all system requirements and constraints may be satisfied. Furthermore, the design of the LRRR (300) equipment shall be as simple as possible, consistent with functional requirements and the expected service conditions.

3.2.1 Astronaut Constraints - In applying crew engineering criteria to the LRRR (300) design and astronaut deployment tasks, consideration shall be given to constraints imposed by both the astronaut's capabilities and limitations with respect to such parameters as mental and physical skills, the training that the crew will receive, the psychophysical stresses of an Apollo mission, the psychomotor limitations imposed on the astronaut by the Extravehicular Mobility Unit (EMU), the ergonomic limitations imposed on the astronaut by the Portable Life Support System/Oxygen Purge System (PLSS/OPS), and the effect of the lunar environment and the EMU on the visual, auditory, tactile, kinesthetic, vestibular, and thermal sensory modalities.

3.2.1.1 Astronaut Safety - The prime consideration in the design of the LRRR (300) hardware and of the deployment tasks shall be the safety of the astronaut and, secondarily, the safety of the LRRR (300) hardware. The equipment and task design must not only minimize the hazards associated with LRRR (300) deployment on the lunar surface, but must also minimize the potential for human error during LRRR (300) deployment.

3.2.1.1.1 Protection from Mechanical Hazards - In order to prevent mechanical degradation of the EMU, all sharp edges and corners, protuberances, burrs, and abrasive surfaces shall be eliminated from the exterior of the LRRR (300) in those areas where the astronaut might reasonably be expected to be able to make contact with these edges, corners, protuberances, and surfaces. A minimum radius of 0.5 inch should be maintained on all corners and edges where material thickness permits. For a surface with a material thickness less than one inch but greater than 0.06 inch, the corner or edge should be to a radius of one-half the material thickness. The minimum radius for any external edge or corner shall be 0.03 inch. Where material thickness does not permit this radiusing, the use of beading on the exposed edges and corners is the preferred approach. However, the use of teflon tape or other means of protecting the crew will be considered. Astronaut/EMU exposure to all hinged surfaces and to other moving parts shall be precluded through the use of guards which shall prevent pinching or cutting of the EMU. Depending on the application, detents or friction hinges shall be utilized so that all hinged devices will remain as positioned by the crewman.

3.2.1.1.2 Protection from Thermal Hazards - Two potentially hazardous conditions should be precluded in the design of LRRR (300) equipment and deployment tasks:

(a) Close proximity of the astronaut to high heat sources which, through radiation, would result in thermal overloading of the PLSS or damage to the space suit.

(b) Physical contact by the astronaut/EMU with surfaces having excessive temperature values which, through conduction and compacting of the insulating layers of the space suit, would result in damage to the space suit or harm to the astronaut.

Therefore, if thermal analysis and/or thermal tests indicate the presence of a thermal hazard, deployment operations shall be formulated so that the astronaut will remain as well isolated as possible from high heat sources and equipment shall be designed so that the astronaut cannot inadvertently make physical contact with surfaces having excessive temperature values, as long as the astronaut adheres to prescribed task procedures and exercises normal caution. The maximum tolerable heat flow to a crewman's skin through space suit contact with a hot surface is 18 $BTU/ft.^2$ minute. The Apollo space suit is designed to come in contact with surface temperatures between 250°F and -250°F, with a loading of 2.0 psi, for a period of three minutes. Surface temperatures of equipment held in such a manner as to compress the layers of the Apollo space suit for periods in excess of three minutes shall be in the range between 60°F and 103°F. The pain thresholds for heat applied to any part of the body (113°F) and for cold applied to the hands (50°F) shall not be exceeded. All equipment surfaces which could present a thermal hazard to the astronaut/EMU shall be monitored by a device which provides a temperature status readout to the astronaut.

3.2.1.1.3 Protection from Explosive Devices - N/A

3.2.1.1.4 Protection from Electrical Hazards - N/A

3.2.1.2 Tools and Work Aids - Integral and detachable tools and work aids shall permit the astronaut to deploy the LRRR (300) from a standing position and shall adhere to the constraints imposed on the astronaut by the EMU.

3.2.1.2.1 Universal Handling Tool Interface - One or more fixed or rotatable interface sockets for the Universal Handling Tool (UHT-ref. drawing 2338102) shall be provided on the LRRR (300) for final emplacement of the LRRR (300), including leveling and alignment of the experiment. The UHT/LRRR (300) interface socket(s) shall be located in close proximity to the carry handle and shall be oriented at a T.B.D. angle from the horizontal (determined by a requirement that the handle of the UHT, when the UHT is engaged in the UHT socket, must be at least 30 inches from the lunar surface, both when the LRRR (300) is resting on its back support structure and when it is in its deployed position and resting on its leveling leg). The UHT/LRRR (300) interface socket(s) shall be as close to the center of mass of the deployed LRRR (300) configuration as is feasible, taking into account other design constraints, in order to increase LRRR (300) maneuverability.

3.2.1.2.2 Carry Handle - A carry handle shall be provided on the LRRR (300) for removal of the LRRR (300) from the Grumman Aerospace Corporation (GAC) subpallet, for temporary emplacement of the LRRR (300) on the lunar surface, for carry of the LRRR (300) to the emplacement site and for holding the experiment during deployment of the leveling leg, etc. The handle shall be located on the front of the experiment and opposite the back support structure and shall be oriented horizontally (with respect to a front view of the experiment - i.e., in line with the direction of carry). The distance between the center of mass of the stowed LRRR (300) configuration and the carry handle shall be minimized so as to ensure adequate package maneuverability. Mass moments of inertia (MOI in in-lb-sec^2) in the range of 0-65 provide excellent maneuverability, the range of 66-150 provides good maneuverability, and the range of 151-240 in-lb-sec^2 provides only fair maneuverability. The handle grip cross section shall be 0.65 x 1.25 inches (rectangular or elliptical), 5.5 inches or more in inside length, and a minimum two inch clearance shall be provided around the handle grip for finger ingress.

3.2.1.2.3 Back Support Structure - A back support structure shall be provided that will permit the astronaut to temporarily set the LRRR (300) down on a lunar surface slope of 15° without the experiment toppling.

3.2.1.2.4 Bubble Level and Sun Compass - The leveling and alignment devices shall be designed to be easily readable from a height of six feet above the lunar surface, with a sun elevation angle of between 7 and 20 degrees to the east.

3.2.1.2.5 Pull Rings - Pull rings (used to remove experiment components) shall be made from strips of plastic or metal wire that will not damage the EMU, shall have on inside diameter of no less than 2 inches, and shall only be employed for tasks requiring a pull-to-release force of less than five pounds.

3.2.1.2.6 Fasteners - Fasteners required for mounting the LRRR (300) to the GAC subpallet and for retaining the leveling leg and the side array panel shall be designed to provide simple release by the standing astronaut.

3.2.1.3 Task Design - Task design shall include consideration of PLSS/OPS purge rate and traverse time/distance ratios. The LRRR (300) design shall be such that the tasks required for the deployment of the LRRR (300) shall be capable of being completed in less than 10 minutes. Tasks shall be designed to present familiar operational conditions (i.e., stereotypy) to preclude or reduce the probability of reversal errors due to the stress created by the mission environment, fatigue, or other psychophysiological conditions and in order to simplify astronaut training. All experiment handling requirements shall be minimized and simplifed due to the mobility and fatigue constraints imposed by the pressurized EMU. Distance measurement on the lunar surface for the deployment of the LRRR (300) shall be accomplished by the astronaut pacing off the distance.

3.2.1.3.1 Visual Tasks - All visual tasks shall be designed for performance within the constraints imposed by the helmet and extravehicular visor assemblies. Visual tasks shall be designed to the optimum viewing angle of the astronaut in the EMU, rather than the maximum. The optimum viewing angle encompasses a 30 degree cone of vision circumscribed by 15 degrees left and right, 0 degrees up and 30 degrees down from the horizontal line of sight. The maximum operational visual field is defined as 90 degrees left and right, 70 degrees up and 85 degrees down from the horizontal line of sight. All equipment carry tasks shall be designed to permit the astronaut to view his feet, footing, and line of traverse. All tasks shall be designed to make full use of the astronaut's shadow, EMU and equipment reflectivity, and/or full sunlight in order to obtain the optimum visual advantage.

3.2.1.4 Glare - All LRRR (300) external surfaces which might cause problems for the astronaut due to reflection of sunlight should be provided with low reflection properties or protected with a removable cover or coating which has low reflective properties. White, matte thermal control paint or ink are the preferred means of thermal control, from an astronaut visual standpoint. Gold, rather than silver, aluminized mylar or kapton are the second best materials from an astronaut viewpoint. Second surface mirrors should be avoided entirely or, if they provide the only satisfactory solution to the experiment thermal control requirements, they should be covered while the astronaut is performing tasks associated with the experiment (and especially when visual monitoring of experiment components is required.)

3.2.1.5 Astronaut Cues - Corners, edges, adjustment and control surfaces shall be marked and colored in such a manner as to enhance the contrast quality of these surfaces, in so far as operational requirements necessitate the provision of these astronaut cues and the markings do not compromise the experiment thermal design. Consideration of the filtering effects of the extravehicular visor assembly and the effects of lunar sunlight, shadow, and vacuum on vision shall be given in the selection of hues, saturation, and brightness levels for the colors to be used in the marking of the experiment. The LRRR (300) shall have arrow(s) stencilled upon the exterior, indicating proper deployment orientation. The experiment shall have equipment-peculiar precautions and operating instructions printed on decals. The decals shall be mounted in such a manner that the precautions and the instructions may both be read in the deployed mode and the precautions (and, if possible, the instructions) shall be readable in the stowed mode. The crew shall approve all decals and decal placement.

3.2.1.6 Additional Requirements - Consideration shall be given in the design of LRRR (300) equipment and tasks to the requirements contained in the following subparagraphs:

(a) Tasks requiring the astronaut to move his hands or arms behind the frontal (Y-Z) plane and/or above shoulder height shall be eliminated.

(b) Tasks requiring twisting, turning, or torso rotation shall be eliminated.

(c) Task and equipment design shall avoid the necessity for the standing astronaut to have to reach any point within a distance of 22 inches off the ground or more than 66 inches and to perform any manipulations at a height less than 28 inches or more than 60 inches off the ground.

(d) Manipulative operations requiring the simultaneous use of both of the astronaut's hands, other than for simple holding, shall be limited to heights between 30 and 48 inches off the ground, as a design goal.

(e) Task and equipment design shall not require the astronaut to assume a kneeling or prone position on the lunar surface.

(f) The astronaut shall not be required to exert a force of less than 3 poinds at the point of application on any component or assembly, whether fullhand or fingertip, in order to ensure a tactile feedback to the astronaut.

(g) The astronaut shall not be required to exert a torquing force in excess of 3.8 pounds on any component of 0.75 inch diameter (for circular cross section) or diagonal (for rectangular cross section), 5.0 pounds for any component of 1.00 inch diameter or diagonal, 7.6 pounds for 1.25 inches and 9.6 pounds for 1.50 inches.

(h) Any requirement for the astronaut to exert a force in excess of 20 pounds (push or pull; up, down, left, or right; sustained or impulse) may cause the astronaut to lose his balance and, therefore, is prohibited.

(i) The astronaut shall not be required to exert a dynametric force in excess of 10 pounds.

(j) Human strength shall be used in the design of lifting and transportation tasks in order to eliminate the need for assistance devices with weight penalties.

(k) Where a man's strength is a design factor, consideration shall be given to this factor in the mechanical design or, where necessary, physical restraints shall be incorporated in the design in order to prevent the astronaut from exceeding the tensile strength or inertia limits of the equipment. The astronaut can exert a 60 pound static load and dynamic loads as high as 250 lbf under lunar surface gravity conditions and in extreme circumstances.

(l) Fine adjustment mechanisms shall be constructed of materials capable of withstanding maximum torque loads. The astronaut can exert a 20 pound load when employing only one hand to operate an adjustment mechanism.

(m) Where latching or unlatching is a requirement in the deployment, it shall be in the direction of easiest wrist joint motion (i. e., abduction-adduction).

(n) If design constraints dictate that a twisting motion is necessary it shall be in the direction of easiest wrist joint motion (i. e., supination).

3.2.2 LRRR Constraints - Specific training and practical experience shall be required of the astronaut to allow him to successfully deploy and emplace the LRRR (300). The following LRRR (300) requirements serve as constraints on the astronaut during the performance of the operational tasks.

3.2.2.1 Experiment Leveling - The astronaut shall separate the bubble from the wall of the ± 5 degree LRRR (300) bubble level by using the UHT to embed the LRRR (300) leg in the lunar surface, in order to properly level the LRRR (300).

3.2.2.2 Experiment Alignment - The astronaut shall align the shadow cast by the LRRR (300) gnomon to within ± 5 degrees of the indicated centerline by using the UHT to move the LRRR (300) along the lunar surface, in order to properly align the LRRR (300).

The following compilation of Crew Engineering human factors analysis design criteria and requirements inputs to the LRRR(300) Design Group constitutes the baseline parameters for the design of the LRRR(300).

Prepared by: Leslie D. Marrus
L. D. Marrus

The following design criteria and requirements inputs were provided to the LRRR(300) design group during the course of the LRRR(300) program:

1. Design the LRRR(300) for safe rapid, easy and accurate removal, transport and deployment by one astronaut.

2. Eliminate all sharp edges, corners, protuberances, burrs, and abrasive surfaces. The minimum radius for any external edge or corner should be 0.03 inch.

3. Prevent astronaut exposure to all hinged surfaces.

4. The LRRR(300) carry handle, UHT and UHT socket, fasteners and pull rings should permit the astronaut to deploy the LRRR(300) from a standing position.

5. The LRRR(300) design should permit the astronaut to perform one-handed reach operations between 22 and 66 inches off the ground, perform one-handed manipulation between 28 and 60 inches off the ground, and perform two-handed manipulations between 30 and 48 inches off the ground.

6. The UHT socket should be located as close to the center of mass of the deployed configuration as possible.

7. The carry handle should be opposite the back support structure, oriented horizontally and as close to the center of mass of the stowed configuration as possible.

8. Pull ring inside diameter should be 2 inches minimum.

9. White, matte thermal control paint (no glare) should be used on the LRRR(300).

10. Black or orange markings on a yellow or white background should be used for astronaut cues and instructional decals.

11. The astronaut should not be required to exert a force of less than 3 pounds or more than 20 pounds.

12. The clearance between the LRRR(300) release mechanism handle and the Grumman pallet should be at least 2 inches. (Grumman-supplied hardware.)

13. The length of the LRRR(300) release mechanism handle should be at least 4 inches, on the right side, measured from the side of the shaft. (Grumman-supplied hardware.)

14. The back support structure should permit setting the LRRR(300) down on a slope up to 15° without toppling.

Crew Engineering Design Effort for LRRR(300)

The following compilation constitutes the Crew Engineering LRRR(300) design inputs to the LRRR(300) Design Group.

Prepared by: Leslie D. Marrus
L. D. Marrus

The following Crew Engineering design inputs were provided to the LRRR(300) Design Group during the course of the LRRR(300) program.

1. Locate UHT socket on the side of the carry handle in line with the LRRR(300) deployed configuration center of gravity.

2. Place a light reflector behind the bubble level (with respect to the astronaut deployment station) to ensure adequate illumination of the bubble level at low sun angles.

3. Minimize size of leveling leg foot pad (consistent with requirement of supporting LRRR(300) lunar weight) to facilitate leveling operations.

4. UHT socket should be angled so that the UHT handle will be at a satisfactory work height for the standing astronaut. The angle of the socket should be adjustable to meet this requirement for the various possible elevation settings.

5. Based on a 20 pound force emission capability (multidirectional) for the spacesuited astronaut operating at 1/6G, recommended 20 pound force be used for possible astronaut input in stress analysis of LRRR(300) design. The point of application of the 20 pound force is at the midpoint of the UHT handle at any similar astronaut interface.

6. The UHT socket exterior surfaces should be painted white (improves visual contrast with the International Orange, UHT alignment stripes).

7. LRRR(300) carry handle should be similar in design to the ALSEP package carry handle.

8. LRRR(300) small array tie-down, leveling leg, alignment mechanism and dust cover pull rings should meet the specified 2 inch finger ingress requirement.

9. The bubble level should be located on the sun compass plate.

10. An array deployment handle should be provided to permit the astronaut to easily rotate the small array.

11. The array deployment handle and all pull rings should be painted International Orange for clear visibility.

12. The front of the dust cover should be colored orange to provide a cue to the astronaut that the dust cover is in place.

13. The alignment mechanism shall be spring-loaded to deploy automatically.

14. Pull rings stowed on the carry handle should not intrude on the space required for the astronaut to easily use the carry handle.

15. The gnomon should cast a single shadow on the compass rose.

16. The small array and the leveling leg should automatically lock in place following manual rotation.

This ATM discusses the results of Crew Engineering deployment of the LRRR concept model by a pressure suited subject, and recommendations for design improvements. resulting from the evaluation.

R. L. Redick
Crew Engineering

Crew Engineering performed a pressure suited, 1 G deployment of the 300C LRRR Mock-Up to evaluate the Astronaut interface in the areas of manipulative characteristics, reach parameters and emplacement including leveling and alignment.

The concept mockup presented a valid (configuration) design for CS&O evaluation in the following areas.

1. Carry Handle

   The orientation of the carry handle offers an adequate grasping surface to the pressure glove. The handle location is acceptable and common to the existing ALSEP design.

2. Pull Pins for Small Array

   The pull pin used for this evaluation demonstrated an accurate location on the pallet; and is acceptable. The existing astronaut specification call for minimum "O" ring dimensions of 2 inches for pull pins. The LRRR pallet did accommodate the minimum 2 inch "O" ring. Crew Engineering will be recommending, for future designs, that all pull rings be painted International Orange.

3. Array Deployment

   The Array Knob works very well as a grasping surface and is acceptable to the limits of Pressure Suit reach mobility parameters. A positive lock feature is not incorporated (per design) and I felt the spring force to hold the panel (array) open is adequate.

4. Universal Handling Tool Socket

   (Located on structure assembly to left of carry handle.) The socket location was evaluated with the Crew Engineering UHT. The three position socket located on the handle will add flexibility for crew preference. The angle of each socket should remain at an angle which accommodates a 30" working height and will require additional verification tests with the Astro-trainer to verify the final design position. The location is acceptable for leveling and alignment. Engagement will be accomplished from the Array side of the experiment, while holding the carry handle.

5. Sun Dial Deployment

The Pull Pin length is excessive in the Concept Model (8 inches) however, the final design provides for incorporation of a 2 inch length.

The spring force for rotating the sun dial is acceptable. With ±5 degrees alignment and leveling the design as presented is similar to previous models.

6. Extension Leg and Lock Mechanism

This particular task is analogous to the tasks associated with previous LRRR designs and with consideration for multiple sites, works very well. The locking device on the leg is strong enough to prevent accidental collapse of the leg. The Crewmans positioning, to the side of the experiment, is acceptable when the leg is deployed.

7. Emplacement

Three techniques were evaluated to lower the unit to the deployed position on the surface as follows, the UHT attached to the handle socket, the handle of the UHT in the carry handle opening and lowering the unit by hand while standing to one side.

a. Lowering the unit with the UHT in the handle socket.

   This technique is the most reliable due to the positive control it affords the crewman. The UHT is attached to the socket while standing on the array side of the package with one hand supporting the LRRR by the carry handle. Rotation to the deployed position is performed while the crewman is at one side. The UHT is immediately available at that time for leveling and alignment.

b. Lowering the unit with the UHT engaged in the carry handle opening.

   This technique is certainly reliable but offers less control during rotation. The UHT must then be attached after emplacement and requires one hand to secure the unit while attaching the UHT.

c. Lowering the unit by hand.

Lowering the unit by hand requires the crewman to release the handle before the extension leg foot pad reaches the surface. The "dropping" effect may cause some stability problems. To elaborate on this point, existing 1/6 G reach parameters suggest that tasks requring any manipulation, such as grasping, be prohibited below 22 inches, and the height of the carry handle may be 10-12 inches above the lunar surface when deployed. The drop may present some problems, including crew stability and before suggesting this technique, further tests should be performed (KC-135 Aircraft) to verify those reach parameters.

8. Array Dust Cover

The dust cover design used on previous LRRR models is utilized on the 300C LRRR and is adequate. The pull ring/lanyard design should incorporate Velcro tiedowns and mount on the carry handle as in the previous design.

9. Back Support Structure

The height will allow for stability during temporary emplacement and with the existing design the unit will be supported by the loop type support structure.

10. Sundial Alignment and Leveling, Prime Site

The suggested location and astronaut tasks are acceptable. The handle socket is suggested for leveling and alignment, with the UHT handle in the Experiment Handle being secondary.

Additional design verification tests will be required to verify those tasks not evaluated and must be accomplished at a later date when the concept model reflects the completed design. C. S. &O. personnel will monitor the design effort to ensure timely inputs to 300C LRRR flight design.

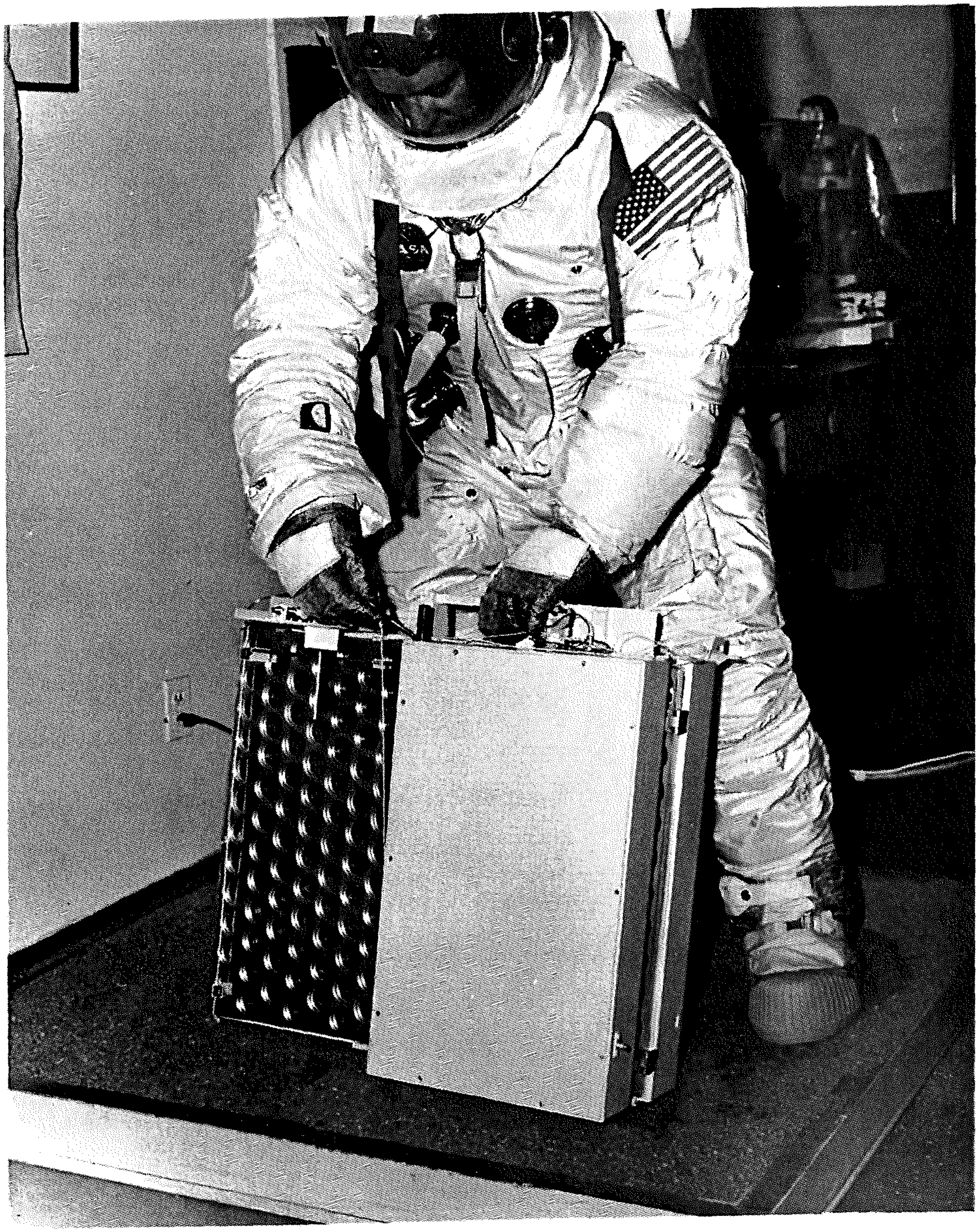

Figure 1. Removing Reflector Array Pull Ring/Pull Pins

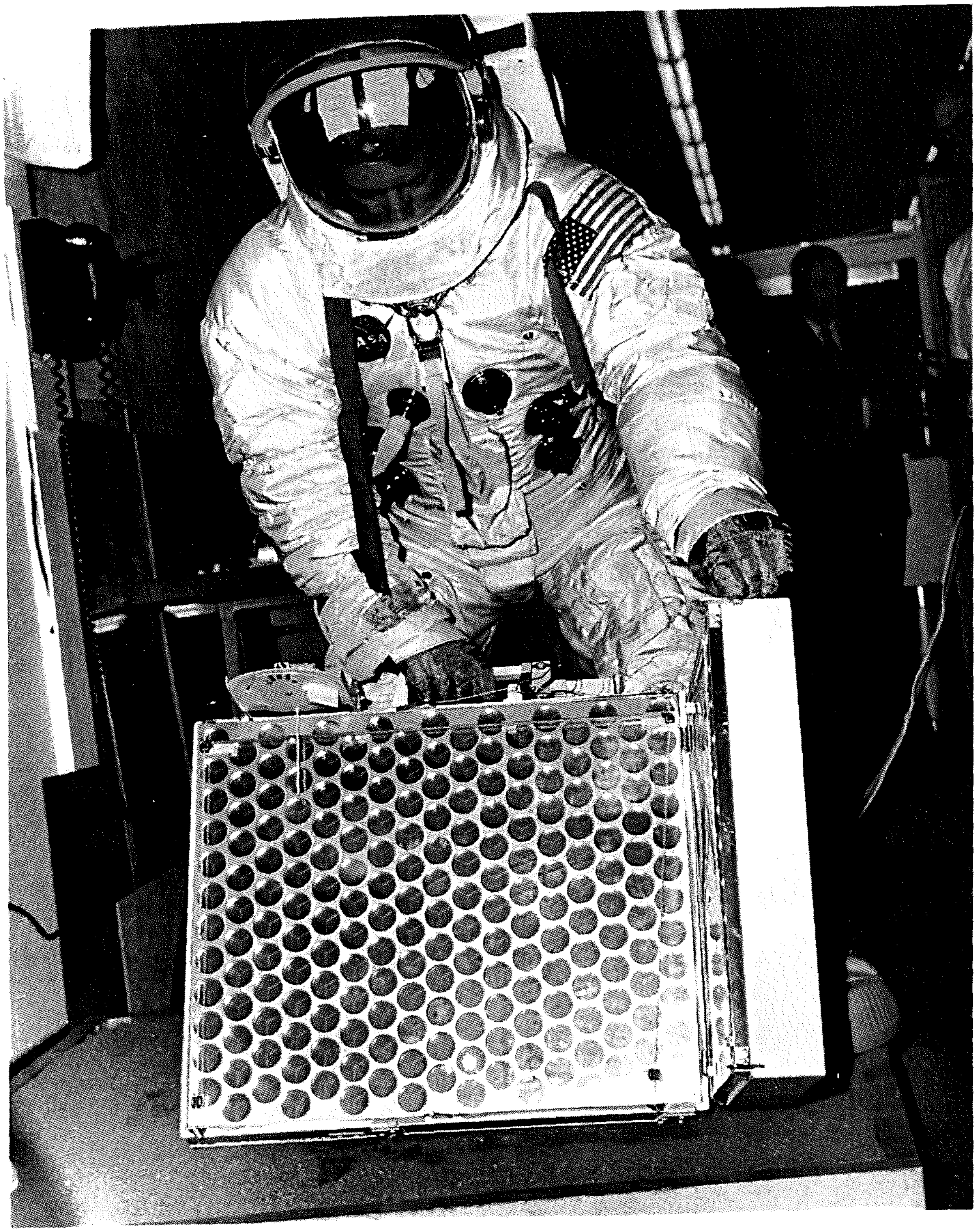

Figure 2. Deployment of Small Reflector Array

Figure 3. Removing leveling leg pull ring/pull pin.

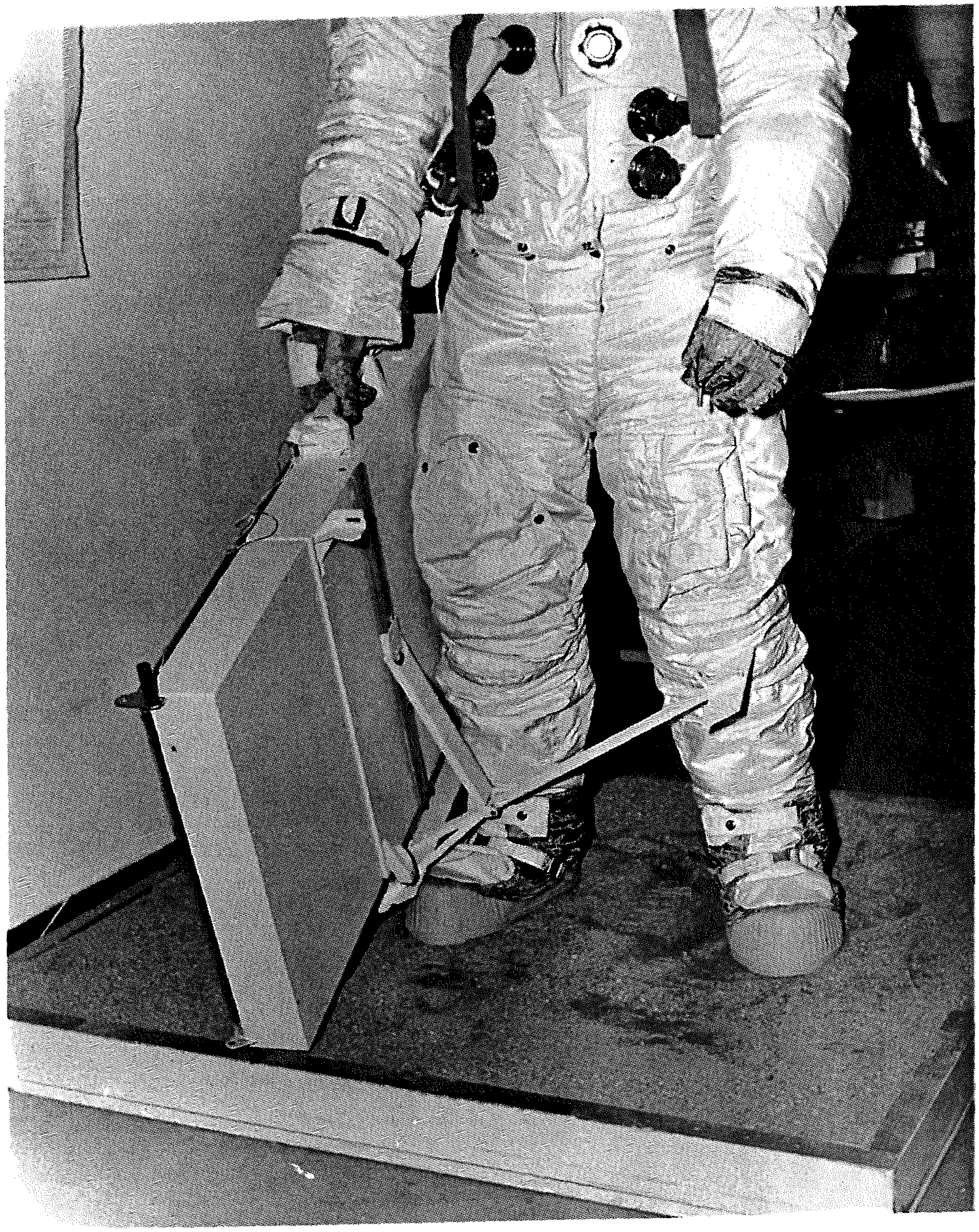

Figure 4. Leveling Leg Deployed

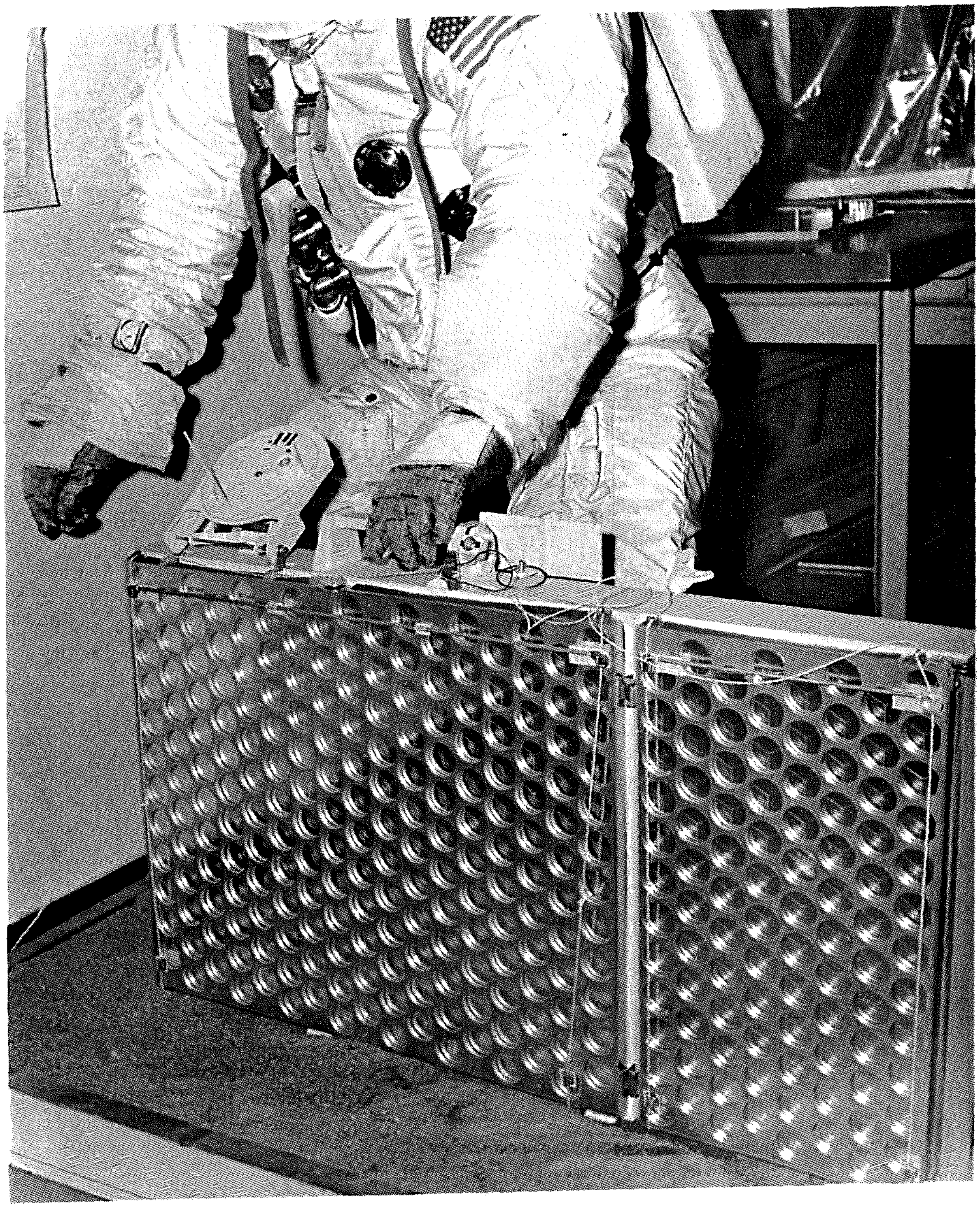

Figure 5. Removing Alignment Mechanism Pull Ring/Pull Pin

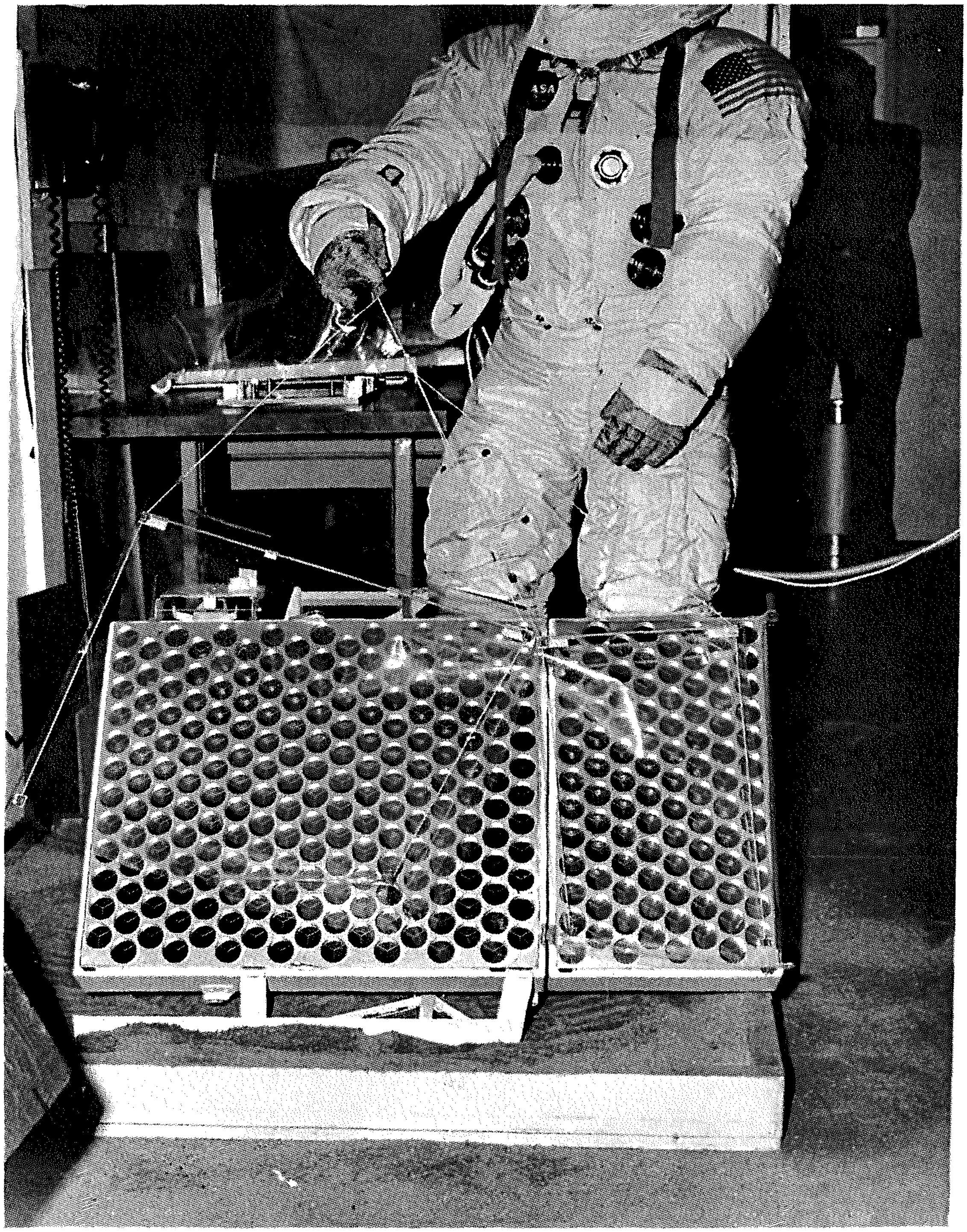

Figure 6. Removing Dust Covers

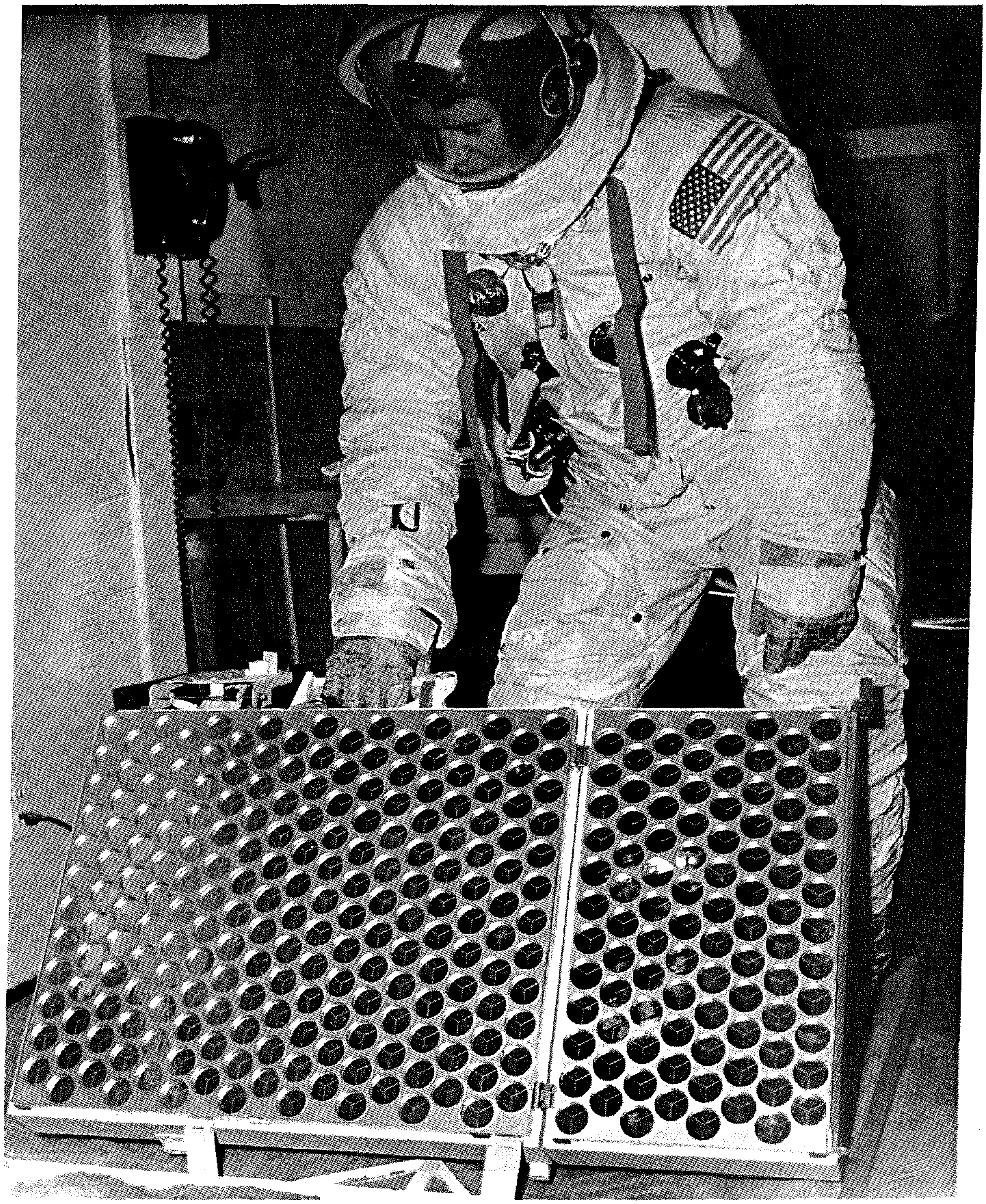

Figure 7. Leveling and Alignment.

Bendix Aerospace Systems Division	End Item Specification for the LRRR (300) Crew Training Model	NO. CP 100024	REV. NO.
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		DATE 1Sept 1970	

PERFORMANCE/DESIGN AND PRODUCT CONFIGURATION REQUIREMENTS

for the

LASER RANGING RETRO-REFLECTOR (300) CREW TRAINING MODEL

Prepared by: Leslie D. Manus

Date: 24 September 1970

Approved for The Bendix Corporation

By: [signature]

Date: 29 Sept '70

Approved for NASA/MSC (LSPO)

FKM Inml - 10-22-70

By: [signature]

Date: 10/23/70

Approved for NASA/MSC (FCSD)

By: Joe H Roberts

Date: 21 Oct. 70

The Bendix Corporation
Aerospace Systems Division
Ann Arbor, Michigan

1.0 PURPOSE AND SCOPE

1.1 Purpose - This specification defines the performance, design, construction, and interface requirements for the Crew Training Model of the Laser Ranging Retro-Reflector (LRRR). This model is a mechanical simulation of the LRRR (300) flight configuration incorporating most visual, and all handling and manipulative features and characteristics suitable for training a space-suited astronaut on a simulated lunar surface.

1.2 Scope - This document specifies technical requirements agreed to by the Bendix Corporation and NASA/MSC. Nothing contained in this document shall be deemed to alter the terms of any existing contract or purchase order negotiated between the Bendix Corporation and NASA/MSC.

2.0 APPLICABLE DOCUMENTS

The following documents, of exact issue shown, form a part of this specification to the extent specified herein. Unless otherwise stated, the applicable issue of each document shall be that in effect on 20 July 1970. In the event of conflict between the referenced documents and the content of Sections 3.0, 4.0 and 5.0, the detailed requirements of Sections 3.0, 4.0 and 5.0 shall be considered superseding requirements.

STANDARDS

Military

MIL-STD-129	Marking for Shipment and Storage
MIL-STD-130C	Identification Marking of U.S. Military Property

DRAWINGS

Grumman

LID 360-22830	LM/LRRR Structural Interface (LM Descent Stage) (Quad I, LM-8)

OTHER PUBLICATIONS

NASA

NPC 500-1	Apollo Configuration Management Manual as ammended by MSC Supplement No. 1, Revision B, dated 26 April 1956

3.0 REQUIREMENTS

The LRRR (300) Crew Training Model shall be configured to simulate the flight hardware in terms of most visual, and all the handling and manipulative features required to satisfactorily train a space-suited astronaut on a simulated lunar surface, at 1G. Precise duplication of non-astronaut interface flight model details shall not necessarily be reflected in the LRRR (300) Crew Training Model design.

3.1 Performance - The lightweight LRRR (300) Crew Training Model shall be ballastable to earth weight, be fully deployable, ruggedly constructed, and shall simulate the LRRR (300) flight configuration in most visual, and all astronaut interface mechanical, crew handling, and manipulative features. It shall provide functionally accurate astronaut interfaces. The alignment mechanisms shall provide the exact flight performance characteristics. The retro-reflectors will not be incorporated into the LRRR (300) Crew Training Model. The array panel structure and thermal control insulation cover shall be visually simulated. The dust cover, mounting hardware, astronaut carry handle, UHT socket(s), array tilting mechanism and fasteners shall be accurately simulated.

3.2 Reliability - The LRRR (300) Crew Training Model will reliably duplicate the interface between the astronaut and the LRRR (300) flight model and will reliably permit astronaut training for a flight deployment, with reasonable handling care on the part of the user.

3.3 Maintainability - Whenever possible, the design of the LRRR (300)Crew Training Model shall incorporate features to minimize maintenance of components during training. There shall be a minimum number of damage-prone components. Discrete design variations from the flight design will be built into the Crew Training Model to assist the customer (NASA/MSC) in the maintenance and replacement of damage-prone components.

3.3.1 Logistic Support - Logistics spares, as selected by BxA and approved by NASA/MSC, shall be provided to permit maintenance to support failures generated by normal wear and/or normal training performance, only, for a period of nine months.

3.4 Service and Access - Equipment arrangement, accessibility and interchangeability features shall be incorporated into the design to permit efficient servicing and maintenance. LRRR (300) Crew Training Model components with the same part numbers shall be physically and functionally interchangeable.

3.5 Useful Life - The LRRR (300) Crew Training Model shall be designed to be capable of ten deployment cycles without scheduled maintenance, with reasonable handling care by qualified personnel only.

3.6 Natural Environment - The LRRR (300) Crew Training Model shall be capable of being deployed by a space-suited astronaut, during training exercises on a simulated lunar surface, at 1G, and shall be capable of sustaining loads of 1.5G.

3.7 Transportability - Full design recognition shall be given to the durability requirements of the LRRR (300) Crew Training Model relative to its handling before and after training exercises.

3.8 Human Performance - The human factors characteristics of the LRRR (300) flight model design shall be reflected in the design of the LRRR (300) Crew Training Model.

3.9 Safety - The LRRR (300) Crew Training Model design will ensure the safety of the space-suited astronaut while unloading, transporting, and deploying the equipment; it will ensure the safety of support personnel while handling the equipment before, during and after training exercises; and it will be compatible with the safety requirements for LRRR (300) flight equipment.

3.10 Induced Environment - The LRRR (300) Crew Training Model shall not be submerged in water, placed in a vacuum chamber, or used for thermal or stress testing.

3.11 Interface Requirements - The LRRR (300) Crew Training Model shall be capable of installation in and removal from Quadrant I of the LM Descent Stage as defined in LID 360-22830. Tolerance increases to facilitate the design and manufacture of the LRRR (300) Crew Training Model shall be incorporated, as required, only if they cause no change to the LM interface or to crew visual, handling and manipulative features.

3.12 Design and Construction

3.12.1 Design Configuration - The LRRR (300) Crew Training Model shall be constructed by the fabrication and assembly of new components using Class C drawings, and shall visually and manipulatively simulate the LRRR flight design in both the stowed and deployed configurations.

3.12.2 General Design Features

3.12.2.1 Volume - The LRRR (300) Crew Training Model mounting provision configuration, envelope dimensions, and form factor shall be identical to those of the flight model and shall meet the LM interface requirements specified for the flight equipment to be stowed in Quadrant I of the LM Descent Stage as defined in LID 360-22830.

3.12.2.2 Weight - The weight of the LRRR (300) Crew Training Model shall be a maximum of 25 pounds in the unballasted configuration and as close to lunar weight as is structurally practical (consistent with the requirement for repeated Crew Training Model usage), and a maximum of 100 pounds in the ballasted configuration.

3.12.2.3 Center of Gravity - The center of gravity of the ballasted LRRR (300) Crew Training Model shall be within the spherical envelope, +20% and -0%,as defined in LID 360-22830.

3.12.3 Materials, Parts and Processes - Materials, parts and processes used in the LRRR (300) Crew Training Model shall be compatible with the intended usage of this equipment, consistent with the number of deployment cycles specified in paragraph 3.5, and the environmental requirements specified in paragraphs 3.6 and 3.10.

3.12.3.1 Welding - Welding shall be structurally sound and neat in appearance.

3.12.3.2 Protective Treatment - Exposed surfaces which are primed and painted shall be resistant to cracking, chipping, peeling or scaling. Exposed surfaces shall be coated for resistance to corrosion. Colors shall be representative of flight hardware finishes.

3.12.4 Standardization - Maximum economic standardization of parts and components shall be provided. Flight design parts shall be used where applicable. Where identical or similar functions are performed in more than one application with the LRRR (300) Crew Training Model, an effort shall be made to use the same design for all applications.

3.12.5 Moisture and Fungus Resistance - There are no special requirements on this item.

3.12.6 Corrosion of Metal Parts - Metals shall be of a corrosion-resistant type or suitably treated to resist the corrosive conditions likely to be met in storage or in normal service, as defined in paragraphs in paragraphs 3.6 and 3.10.

3.12.7 Interchangeability and Replaceability - See paragraph 3.4.

3.12.8 Workmanship - The LRRR (300) Crew Training Model shall be constructed, finished and assembled in accordance with good commercial practices and procedures.

3.12.9 Electromagnetic Interference - Not applicable.

3.12.10 Identification and Marking - The LRRR (300) Crew Training Model shall be marked for identification in the same manner as the flight hardware.

3.12.10.1 Nameplate Data - Standard Bendix Aerospace System nameplates shall be utilized. Nameplates shall be in the flight unit locations. The nameplate shall include the following data, per MIL-STD-130:

a. Item nomenclature
b. Item part number
c. Item serial number

3.12.11 Storage - A reusable wooden shipping container shall be provided for the LRRR (300) Crew Training Model for protection against deterioration and damage during short periods of storage between training cycles.

3.12.12 Shelf Life - The LRRR (300) Crew Training Model shall have a shelf life of two years, when stored in its packing container, in an environment having an ambient temperature controlled within the range of 50°F to 80°F and a relative humidity less than 50%. This shelf life shall extend from customer acceptance of the unit to just prior to customer use of the LRRR (300) Crew Training Model in the first training exercise.

4.0 QUALITY ASSURANCE PROVISIONS

4.1 Inspection - The following requirements of Section 3.0 of this specification shall be verified and documented by an inspection of the final assembly of the LRRR (300) Crew Training Model at the contractor's plant at the time of NASA acceptance (execution of DD Form 250).

3.1	-Performance (verified by the performance of a 1G, space-suited, functional deployment with the model in the unballasted configuration, in a carpeted area of the contractor's facility - the deployment will not include LRRR (300) removal from a LM model or separation of the LRRR (300) from the GAC subpallet)
3.11	-Interface Requirements
3.12.1	-Design Configuration (verified by a visual inspection)
3.12.2.2	-Weight
3.12.2.3	-Center of Gravity (there is no requirement to determine the center of gravity of the unballasted LRRR (300) Crew Training Model)
3.12.8	-Workmanship
3.12.10	-Identification and Marking

5.0 PREPARATION FOR DELIVERY

The methods of preparing, packaging and shipping the LRRR (300) Crew Training Model shall ensure satisfactory performance of the equipment following shipment and shelf storage in its container, as specified in paragraph 3.12.12. The shipping container shall incorporate a mounting fixture and a three inch clearance between the training unit and the interior surface of the shipping container. Materials and the container used for packaging and shipping shall be in accordance with good commercial packaging. The marking of the package for shipment and storage shall be in accordance with MIL-STD-129.

6.0 NOTES

6.1 Specification Preparation - This specification was prepared in accordance with the format and content requirements of Exhibit II of NPC 500-1 and Appendix A of MSC Supplement No. 1, as appropriate.

The following is the Crew Engineering Acceptance Plan for the LRRR(300) Astronaut Trainer.

Prepared by: H. W. Geiss
H. W. Geiss

This plan provides a means of recording the activities associated with the deployment of the LR^3 (300) Astronaut Trainer prior to delivery. The Operational Log (attached) outlines the objectives of the test and the facility used to implement the test. Other aspects of the test are mentioned under general comments. Letter No. 9712-124 "LR^3 (300) Acceptance Test Deployment Sequence", will be used as the reference document for all deployments whether shirt sleeve or suited.

General

A. All technicians and engineering personnel will wear white gloves when handling the Trainer. This includes the sequence of events when the CE subject deploys the Trainer and hands the removed parts to the supporting technicians.

B. Quality Control personnel will be present at the deployment to insure safe handling procedures are followed.

C. Manufacturing and Engineering personnel will be required to perform on-site decisions in the case of equipment failure.

D. Crew Engineering personnel will insure the LR^3 (300) model is an exact mechanical simulation of the LR^3 (300) Flight Configuration and duplicates the handling and manipulative features of the flight unit.

The deployment of the Trainer will be in the Crew Engineering Laboratory on the CE simulated lunar surface (washed sand). Repackaging will be performed in the assembly area under the direction of H. Reinhold, Manufacturing.

OPERATIONAL LOG

Date	Objective	Activity	Personnel	Test Facilities	Remarks
Dec. 23	Verify deployment characteristics of trainer using LR^3 (300) Deployment Seq. 9712-124 as a reference.	At BxA in the Crew Engineering Lab.	1. R. Redick (subject) 2. T. Tallmadge (tech.) 3. Quality Control 4. Manufacturing 5. DCASR 6. Engineering	Apollo Blk II pressure suit with PGA gloves in CE simulated Lunar Surface.	The trainer will be deployed on the lunar surface simulator with ballast removed to demonstrate leveling and alignment techniques.

General: 1. CE will provide liaison with Quality Control during the deployment. Letter No. 9712-124 Deployment Sequence will be used as a suggested deployment procedure and should not be used as a (QC) operational procedure. The prime objective in the Crew Engineering Acceptance Test is not to verify a procedure but to verify mechanical handling and deployment characteristics of the LR^3 (300) Trainer.

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The following deployment procedure is the Crew Engineering Acceptance Test Sequence for the LRRR(300) Trainer.

This deployment sequence includes all the tasks and equipment manipulations that the astronauts will be required to perform with the LRRR(300) during training and on the lunar surface, with the exception of package removal tasks. These tasks and the included hardware manipulations, which have been verified previous to the present acceptance deployment, have been deleted from this acceptance deployment sequence.

Prepared by: H. W. Geiss
H. W. Geiss

Task No.	Astronaut Activities
1.0	Carry LRRR(300) by carry handle to the emplacement site.
2.0	Emplace LRRR(300) on ground in vertical position.
3.0	Unstow UHT from yo-yo.
4.0	Engage UHT into UHT socket.
5.0	Hold LRRR(300) by carry handle or UHT while unstowing reflector array pull ring, remove reflector array pull pins and hand pull pins to technician.
6.0	While holding LRRR(300) by carry handle or UHT with one hand, grasp reflector array deployment knob with the other hand, swing small reflector array outward and around 180° until completely deployed and verify that small array is fully deployed and locked.
7.0	While holding LRRR(300) by carry handle or UHT unstow leveling leg pull ring, remove leveling leg pull pin and hand pull pin to technician.
8.0	Ensure leveling leg is fully deployed and locked.
9.0	While holding LRRR(300) by carry handle or UHT remove alignment mechanism pull pin and hand pull pin to technician.
10.0	Verify that alignment mechanism is fully deployed.
11.0	While holding LRRR(300) by carry handle or UHT unstow dust cover pull ring, pull on lanyards to remove LRRR(300) dust covers and hand dust covers to technician.
12.0	Use UHT to emplace LRRR(300) on ground in deployed position.
13.0	Observe sun compass and use UHT to rough align LRRR(300).
14.0	Observe bubble level and use UHT to level LRRR(300).
15.0	Observe sun compass and use UHT to finely align LRRR(300).
16.0	Disengage UHT from UHT socket.
17.0	Recheck leveling and alignment.

The Acceptance Test performed by CS&O provides a means of evaluating the astronaut interface manipulative characteristics for the LRRR(300) Astronaut Trainer prior to delivery. CS&O personnel ensure that the LRRR(300) is a satisfactory mechanical simulation of the Flight Model. Discrepancy Reports by the QA Department record any material defects, drawing errors and assembly errors in the model.

The deployment of the trainer was carried out in the Crew Engineering laboratory, on a carpeted area, by a Crew Engineering shirt sleeve subject wearing PGA gloves. The (Grumman) Pallet for the LM interface was not evaluated with the LRRR(300).

Prepared by: [signature]
R. Redick

A. Carry Handle

Acceptable per design and earlier tests.

B. Universal Handling Tool Socket

Acceptable per design and earlier tests.

C. Pull Pins for Small Array Tie-Down

Acceptable per design.

D. Swing Out Array and Lock Mechanism

Spring force on the locking device and protection from hinges acceptable. See I-2, Painted Surfaces, below.

E. Pull Pin for Extension Leg Release

Acceptable per design.

F. Extension Leg and Lock Mechanism

Spring forces on the locking device and the positive stop feature acceptable. Visibility of locking mechanism was good.

G. Emplacement

Lowering the unit to the deployment position using two techniques was evaluated. The most reliable method is by using the UHT inserted in the socket prior to rotating the unit. The unit is immediately available for leveling and alignment using this method. Lowering the unit with the UHT handle in the carry handle and guiding it to the deployed position is acceptable but offers less stability to the crewman and unit. He then must insert the UHT to level and align.

H. Gnomon/Suncompass Assembly

The spring force for the design does not deploy at 1G as expected (full rotation unassisted).

I. Painted Surfaces

1. The International Orange tape on the Dust Covers is missing (along top edge only).

2. The swing out Array deployment knob is white, it should be International Orange.

3. The rear support requires touch up per point.

J. Array Dust Covers

See I-1, Painted Surfaces above.

K. Stability During Temporary Emplacement on Back Support Structure (BSS).

Temporary emplacement on a 15° slope is not an apparent problem at earth gravity.

L. Leveling and Alignment Hadley Rille Site

Acceptable per design and earlier tests.

Additional testing by NASA/MSC in the Lunar Gravity Aircraft (KC-135) will verify the design and crew deployment techniques.

Note: The discrepancies pointed out above were corrected prior to the Trainer delivery and final acceptance was received at MSC.

LRRR(300) Emplacement Range and Azimuth From LM

Object. - Since the lifetime goal of the LRRR(300) is 10 years it is desired to minimize degrading or disabling conditions which could be brought about by LM. Potential damage to the LRRR could be caused by excessive heat, dust or kapton contamination of the retro-reflector faces, or physical movement of the LRRR which produces misalignment.

Prepared by: T. J. Kuechenmeister
T. J. Kuechenmeister

Considerations. - There are three primary phenomena which must be considered in the selection of the LRRR(300) emplacement site. These are:

1. Heating from LM ascent stage exhaust gas;
2. entrained dust in the LM exhaust;
3. debris torn loose from the descent stage by descent engine blast.

Heating From LM Exhaust Gas. - A detailed analysis has not been performed of this effect relative to the LRRR(300) since similar work has been performed for the ALSEP. The same criteria, i.e., a deployment distance of 300 feet minimum from the LM, as is in effect for ALSEP, is recommended. Supporting evidence for the adequacy of this criteria is the satisfactory operation of the EASEP LRRR which was deployed about 50 feet from the LM.

Entrained Dust. - It is very probable that lunar surface dust will be entrained in the LM exhaust gas flowing radially outward from the LM. The amount of such dust is impossible to predict since it will depend on the natural dustiness of the site, the amount of dust blown from the site during the landing, and the effectiveness of the descent stage as a blast deflector. These uncertainties, together with the adhesiveness shown by the lunar dust during previous Apollo missions, make it mandatory that the corner reflectors not "see" the LM. The LRRR(300) must accordingly be emplaced in a semi-circular area centered about the LM. The azimuth of the line through the LM which divides the "acceptable" from "unacceptable" is a function of the emplaced LRRR(300) azimuth which in turn is a function of the landing site location.

Descent Stage Debris. - Tests have shown that at ascent stage lift-off some of the kapton which covers portions of the descent stage is torn loose in pieces of various sizes and carried radially away from the LM by the exhaust gases. The amount of such debris varies as a function of azimuth from the LM, given a nominal LM landing orientation. Figure 1 illustrates this situation. It is desirable to locate the LRRR(300) in one of the two diametrically opposed bands of minimum debris ($\pm 17.5^{o}$ from both +Y and -Y direction). However, if such a location presents a conflict with the criteria for location with respect to dust, then the dust criteria should take precedence.

Conclusions. - The above stated criteria were applied to the LRRR(300) emplacement at the Hadley Rille site. Since Hadley Rille is East of the Prime Meridian the face of the LRRR(300) will be oriented essentially West. It is assumed the ALSEP is located due West of the LM at the distance of 300 feet minimum. In order to easily deploy the LRRR(300) in conjunction with ALSEP and not have any blockage of the LRRR(300) field of view by ALSEP, a deployment location 100 feet west of ALSEP was selected. This location provides the maximum LM-LRRR(300) separation in the "acceptable" area from the standpoint of entrained dust.

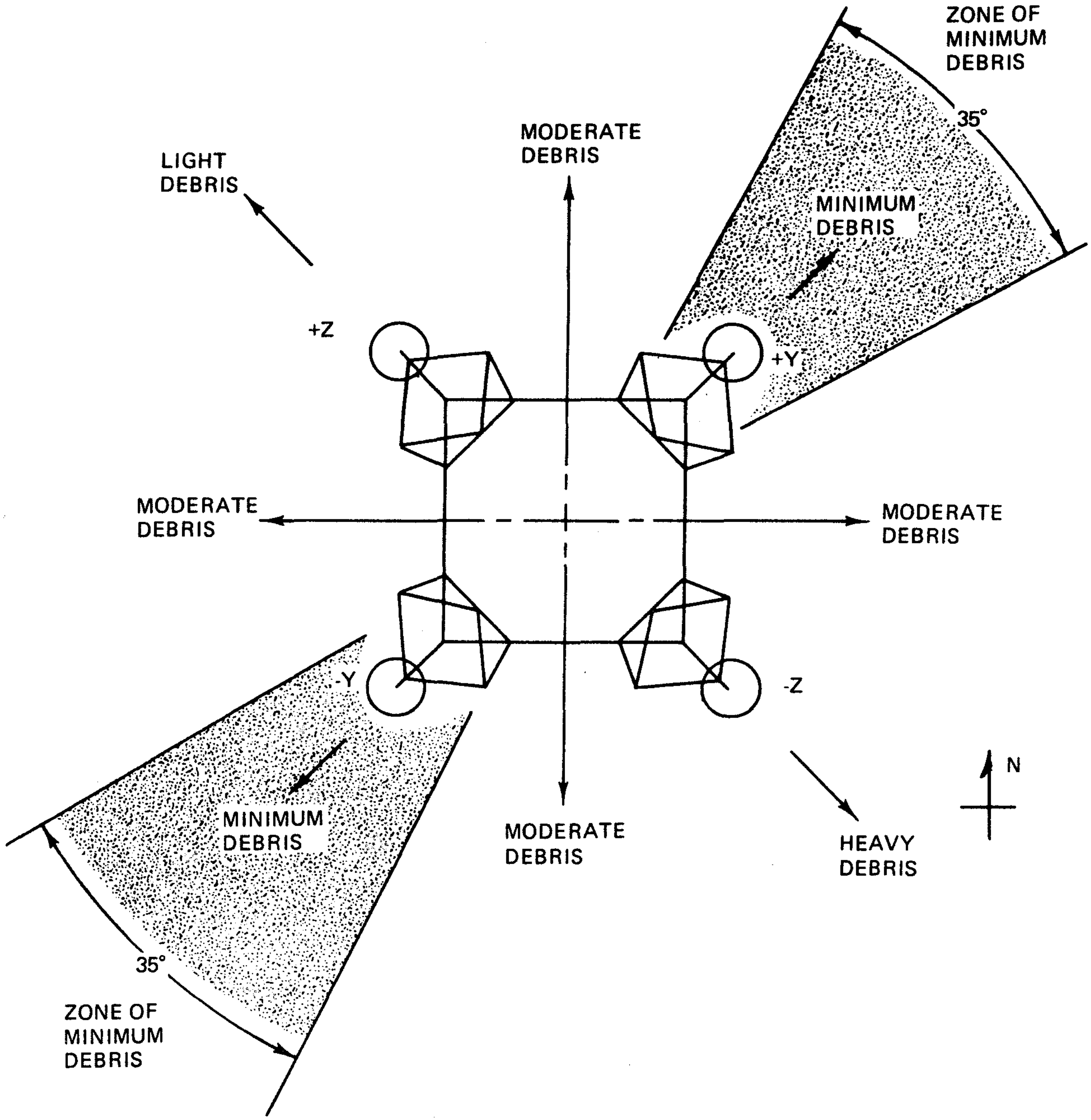
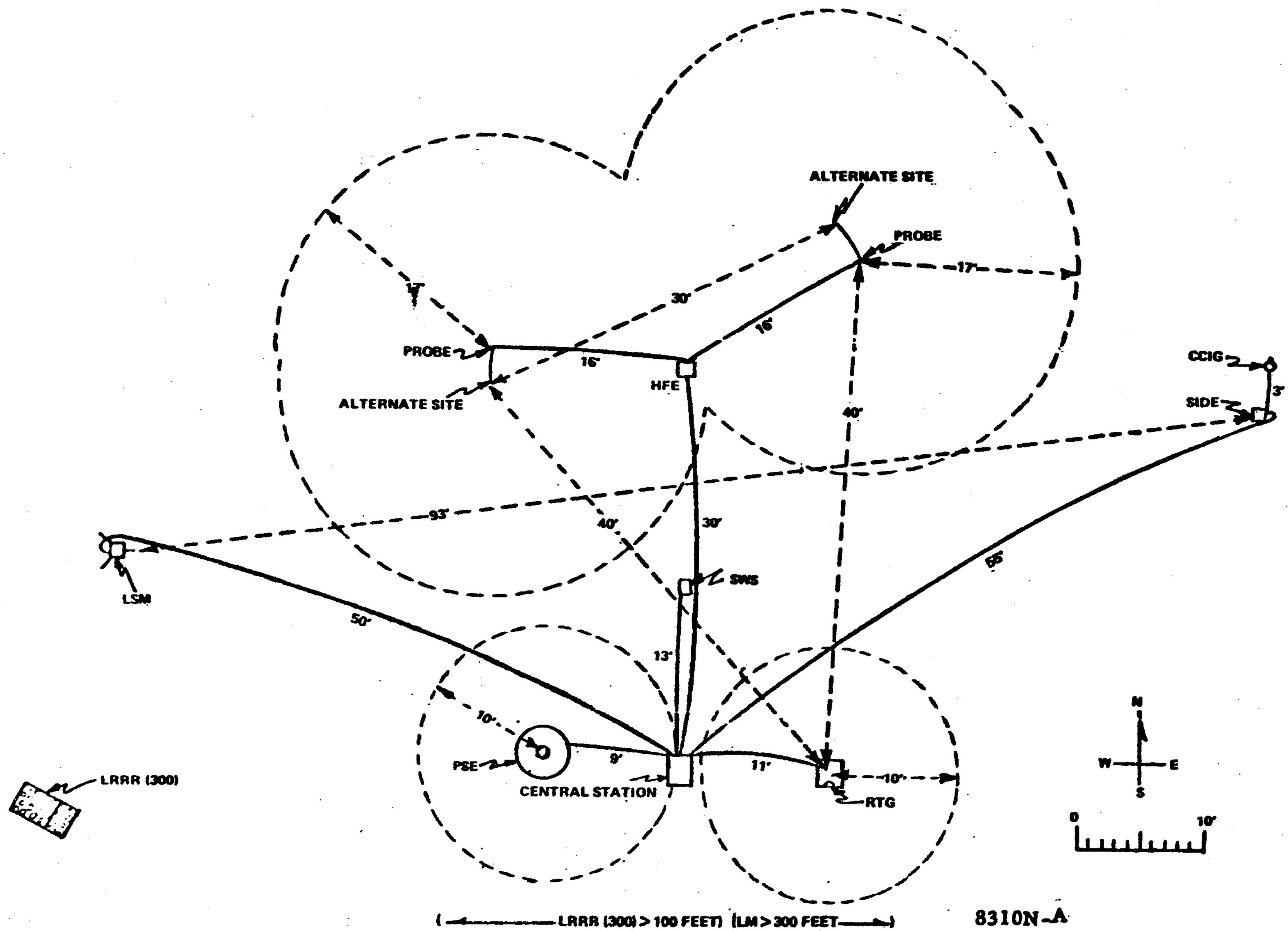


Figure 1 – Kapton Debris Density Relative to LM Orientation

FIGURE 2

ALSEP ARRAY A-2 LAYOUT FOR HADLEY RILLE - 3°E, 25°N



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The attached LRRR (300) Task Sequence/Timeline for the Hadley Rille Landing Site provides a basic description of the astronaut operations required to completely deploy the Apollo 15 configuration of the LRRR (300). The times allocated are fairly conservative. The 5 minutes and 55 seconds total deployment time is well within the 10 minute time limit specified in the Statement of Work. Additional tasks (i.e., photography) will undoubtedly be interspersed with the LRRR deployment tasks, as presently defined, and the total LRRR deployment time will therefore be bound to increase.

Prepared by Leslie D. Marrus
L. D. Marrus

Time (min:sec)	Astronaut Activities
00:10	Release LRRR (300)/LM adaptor tie-downs.
00:15	Pull LRRR (300)/LM adaptor from LM stowage and lower to lunar surface.
00:20	Release and remove forward support of LM adaptor.
00:10	Release LRRR (300) tie-downs.
00:10	Separate LRRR (300) from LM adaptor and discard LM adaptor.
01:40	Use carry handle to transport LRRR (300) to ALSEP deployment site 300 feet west of LM.
00:05	Emplace LRRR (300) on lunar surface in vertical position.
00:35	Following deployment of ALSEP central station, use carry handle to transport LRRR (300) to LRRR (300) deployment site 100 feet west of ALSEP.
00:05	Emplace LRRR (300) on lunar surface in vertical position.
00:05	Unstow UHT from yo-yo.
00:10	Engage UHT in UHT socket while standing on array side of LRRR(300).
00:15	Unstow reflector array pull ring, remove reflector array pull pins and discard pull pins.
00:15	Use reflector array deployment knob to rotate small reflector array 180° to deployed position. Verify that small array is fully deployed and locked.
00:15	While standing on leveling leg side of LRRR(300), unstow leveling leg pull ring, remove leveling leg pull pin, discard pull pin and verify that leveling leg is fully deployed and locked.
00:10	Remove alignment mechanism pull pin, discard pull pin and verify that alignment mechanism is fully deployed and locked.

Time (min:sec)	Astronaut Activities
00:15	Unstow dust cover pull ring, pull on lanyards to remove dust covers and discard dust covers.
00:10	Use UHT to emplace LRRR (300) on lunar surface in deployed position with arrays directed toward the subearth point (nominally south-westward).
00:10	Observe sun compass and use UHT to rough align LRRR (300).
00:20	Observe bubble level and use UHT to level LRRR (300).
00:10	Observe sun compass and use UHT to finely align LRRR (300).
00:05	Disengage UHT from UHT socket.
00:05	Check leveling and alignment.
05:55	Total Time