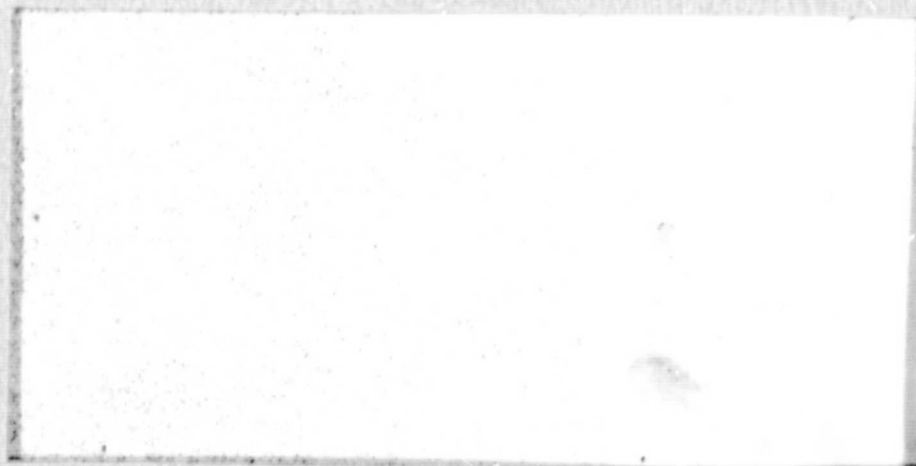


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Apollo Lunar Surface Experiments Package



FACILITY FORM 602

N71 31609	
(ACCESSION NUMBER)	(THRU)
33	63
(PAGES)	(CODE)
CR-115108	76
(NASA CR OR TMX OR AD NUMBER)	(CATEGORY)

Prepared for
NASA/Manned Spacecraft Center
by



**Aerospace
Systems Division**

DESIGN CERTIFICATION REVIEW REPORT

FOR THE

APOLLO 15 LASER RANGING

RETRO-REFLECTOR EXPERIMENT

BSR 3148

15 July 1971

NAS 9-5829

**THE BENDIX CORPORATION
Aerospace Systems Division
Ann Arbor, Michigan**

REVISIONS

LTR.	DATE	PAGE	DESCRIPTION

NASA APPROVAL REQUIRED

TYPE

PRELIMINARY

FINAL



**Aerospace
Systems Division**

BENDIX DOCUMENT:

BSR-3148

DATE: 15 July 1971

TITLE

Design Certification Review Report for
the Apollo 15 Laser Ranging Retro-
Reflector Experiment

DELIVERY REQMT.

CCP-269, Item 35

CONTRACT

NAS 9-5829

APPROVALS

NASA

COGNIZANT MANAGER

PROGRAM MANAGER

BENDIX

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ABSTRACT

This report provides detailed documentation of the design certification of the Apollo 15 Laser Ranging Retro-Reflector -300 corner (LRRR(300)) experiment. The information presented illustrates the design maturity of the LRRR (300) and its suitability for use in manned space flight.

A brief review is given of the Apollo Lunar Surface Experiments Package (ALSEP) Program background, the Early Apollo Scientific Experiments Package (EASEP) LRRR experiment, the Apollo 14 LRRR and the LRRR design objectives. Following a description of the performance required of the LRRR (300) during the Apollo 15 mission and lunar surface operation, the program of testing this performance is outlined.

The results of the Apollo 15 LRRR (300) test program are summarized to show that the LRRR designed for this lunar surface experiment meets the specified requirements. Reference is also made to testing previously conducted on the EASEP and Apollo 14 LRRR Experiments.

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SECTION 1

BACKGROUND

The Apollo 15 Laser Ranging Retro-Reflector -300 Corners (LRRR (300)) is part of the science payload of the Apollo 15 Lunar Module which will be programmed to land at Hadley Rille on the lunar surface.

The LRRR (300) program was initiated in August 1970, after approval of the LRRR as an experiment for the Apollo 15 flight. This latest LRRR evolved directly from the LRRR experiments previously developed for the Apollo 14 and as one of the two experiments comprising the Apollo 11 Early Apollo Scientific Experiments Package (EASEP). The EASEP was the package of experiments deployed on the lunar surface during man's first landing on the moon in the Apollo 11 mission.

EASEP was initiated in October 1968 as a result of, and in conjunction with, the development of the Apollo Lunar Surface Experiments Package (ALSEP). ALSEP had been under development since August 1965 to implement the scientific goals set forth by the National Academy of Sciences. Eight scientific instruments were selected for ALSEP and these are to be flown in the combinations listed in Table 1-1. The initial Apollo schedule of astronaut extra-vehicular activities on the lunar surface calls for two sorties of up to at least two hours each. The experiments for ALSEP were selected, in part, to be compatible with a total ALSEP deployment time of less than 90 minutes. In the planning of the first lunar landing, the second astronaut sortie was deleted and it became necessary to devise a scientific instrument package that would provide high priority scientific data, yet could be deployed properly within five to ten minutes. An instrument package was developed, using a stripped-down ALSEP (containing a passive seismometer and powered by solar energy) and a passive retro-reflector array suitable for laser ranging of the earth-moon distance.

All primary and secondary objectives of the EASEP deployed with Apollo 11 were met, and the LRRR continues to function on the lunar surface. (Documentation of the design certification of the EASEP LRRR experiment is included in BSR 2699 Revision A (7/7/69), Design Certification Review Report for the Early Apollo Scientific Experiments Package.)

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Subsequent to the EASEP program and the Apollo 11 flight, the first ALSEP was deployed on the lunar surface during the Apollo 12 mission. This ALSEP continues to perform on the lunar surface.

The second LRRR was deployed in the Apollo 14 mission. All objectives of this Apollo 14 LRRR were met. (Documentation of the design certification of the Apollo 14 LRRR experiment is contained in BSR 3009 (9-15-70), Design Certification Review Report for the Apollo 14 Laser Ranging Retro-Reflector Experiment.)

This latest LRRR for the Apollo 15 flight has the same objectives as the Apollo 14 and EASEP LRRR, except that a 10-minute time period is permitted for deployment.

The Apollo 15 objectives specifically are as follows:

1. Successful deployment of the LRRR on the lunar surface within 10 minutes.
2. Laser signal return from LRRR over a 10-year period.

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TABLE 1-1

EXPERIMENT FLIGHT ASSIGNMENTS

Experiment	ABBR	Apollo Number						
		11	12	13	14	15	16	17
Passive Seismic	PSE	X	X	X	X	X	X	
Active Seismic	ASE				X		X	
Seismic Profiling	LSPE							X
Magnetometer	LSM		X			X	X	
Solar Wind	SWS		X			X		
Suprathermal Ion	SIDE		X		X	X		
Lunar Mass Spectrometer	LMS							X
Heat Flow	HFE			X		X	X	X
Lunar Ejecta and Meteorites	LEAM							X
Charged-Particle	CPLEE			X	X			
Lunar Surface Gravimeter	LSG							X
Cold Cathode Gauge*	CCIG			X				
Lunar Field Geology**		X	X	X	X	X	X	
Laser Ranging Retro-Reflector	LRRR	X			X	X		

NOTES:

*Included in Suprathermal Ion on certain flights

** Equipment partially carried by ALSEP

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SECTION 2

DESCRIPTION

2.1 LRRR (300) MISSION

The LRRR (300) is a scientific experiment which will be deployed on the lunar surface by an Apollo Astronaut. It will establish a fiducial point, utilizing a retro-reflector array, for laser ranging to obtain precise measurement of earth-moon distances. These data, together with those obtained from the LRRR packages deployed at the Apollo 11 and 14 lunar sites, will be used to derive information on the composition and structure of the lunar body and the geophysical dynamics of the Earth-Moon relationship.

The LRRR (300) will be transported to the moon in the Apollo 15 Lunar Module spacecraft on the fourth manned lunar landing mission. After landing, an astronaut will extract the LRRR package from the LM and deploy it. After deployment, it will be possible for earth-based laser transmitter/receiver facilities to range on the LRRR.

2.2 LRRR TECHNICAL REQUIREMENTS

To fulfill this mission, certain technical requirements were established for the LRRR (300). These requirements, which have been documented in detail in a design and performance specification for the LRRR (300) (CP 100730), are summarized below.

2.2.1 Apollo Mission Requirements

This equipment item must be compatible with those requirements of the Apollo mission pertinent to scientific equipment stowed in the LM descent stage during transportation to the lunar surface. This implies:

1. Compatibility with the operational procedures established at Kennedy Space Flight Center for handling and installing equipment into the Qual III equipment bay of LM as shown in Figure 2-1
2. Compatibility of the mounting interfaces and form factor constraints imposed by that equipment bay

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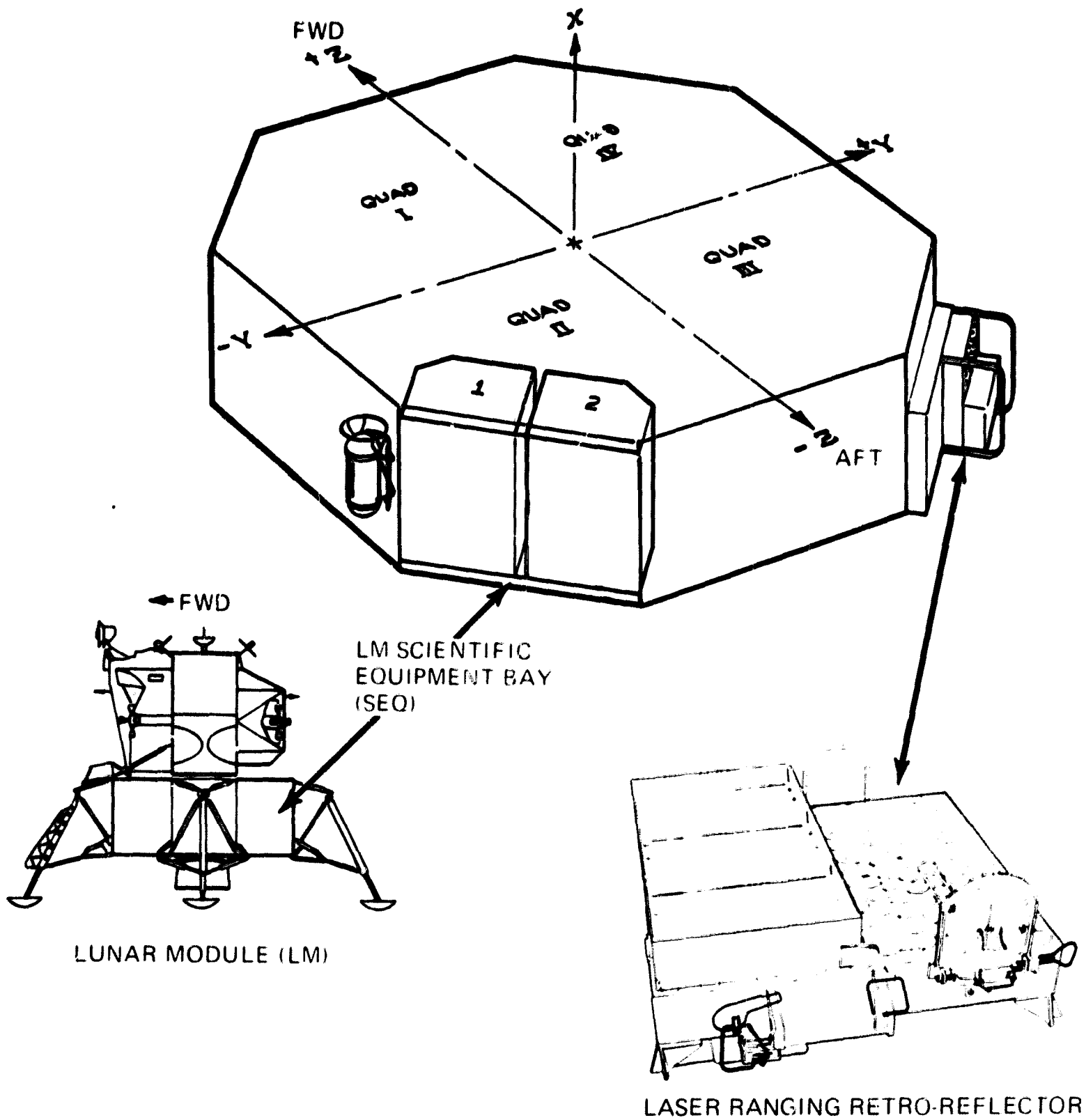


Figure 2-1 Apollo 15 LRRR/LM Interface

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3. A capability of withstanding the mechanical acceleration, vibration, and shock associated with the launch, boost, and lunar descent phases of lunar transit
4. That the design be such that one astronaut may remove the LRRR package from the LM, carry it to an assigned location, and deploy it as shown in Figures 2-2 and 2-3 so that data communication with earth will be possible from the prescribed Apollo landing site.
5. That the weight of LRRR (300) shall not exceed 97 lb.

2.2.2 LRRR Performance Requirements

During transportation to the lunar surface, the LRRR package is completely passive. The LRRR must remain completely passive in its operation, in the sense that it does not depend on any external source of energy to maintain its performance. It must provide an optical retro-reflective surface designed to withstand the stresses imposed by long term exposure to the lunar surface environment. Because of the particularly adverse effects of the temperature extremes and rates of change of temperature encountered on the lunar surface, special provisions were required to reduce the effect of this thermal environment on the optical properties of the retro-reflectors. The LRRR (300) differs from the previous LRRR packages in that it provides 300 optical retro-reflectors and thus three times the reflective capability of previous LRRR packages.

To obtain maximum information from the earth-moon ranging data, it is desirable to compare measurements made over a considerable length of time. It is hoped that the LRRR will constitute a useful ranging target for up to 10 years.

2.3 LRRR DESIGN DESCRIPTION

The LRRR (300) concept has taken form within the constraints of the mission, the existing LRRR retro-reflector mount design and the technical requirements stated above. The design, development, and testing experience gained with ALSEP and, especially, with the EASEP LRRR and the Apollo 14 LRRR has been extensively applied. Major segments of the hardware qualified for EASEP and the Apollo 14 LRRR have been incorporated into the LRRR (300). The design and construction of the LRRR (300) are described in considerable detail in the LRRR Familiarization Manual (ALSEP-MT-05, Revision A), and from which this section derives a brief design summary. The stowed LRRR (300) is shown in Figure 2-4. The LRRR, mounted on a Grumman Aerospace Corporation (GAC) flight pallet, will be removed from Quad III of the LM Descent Stage and lowered to the lunar surface by the astronaut. There is no ALSEP-type boom associated with this removal. The GAC flight pallet will then be removed from the LRRR and discarded.

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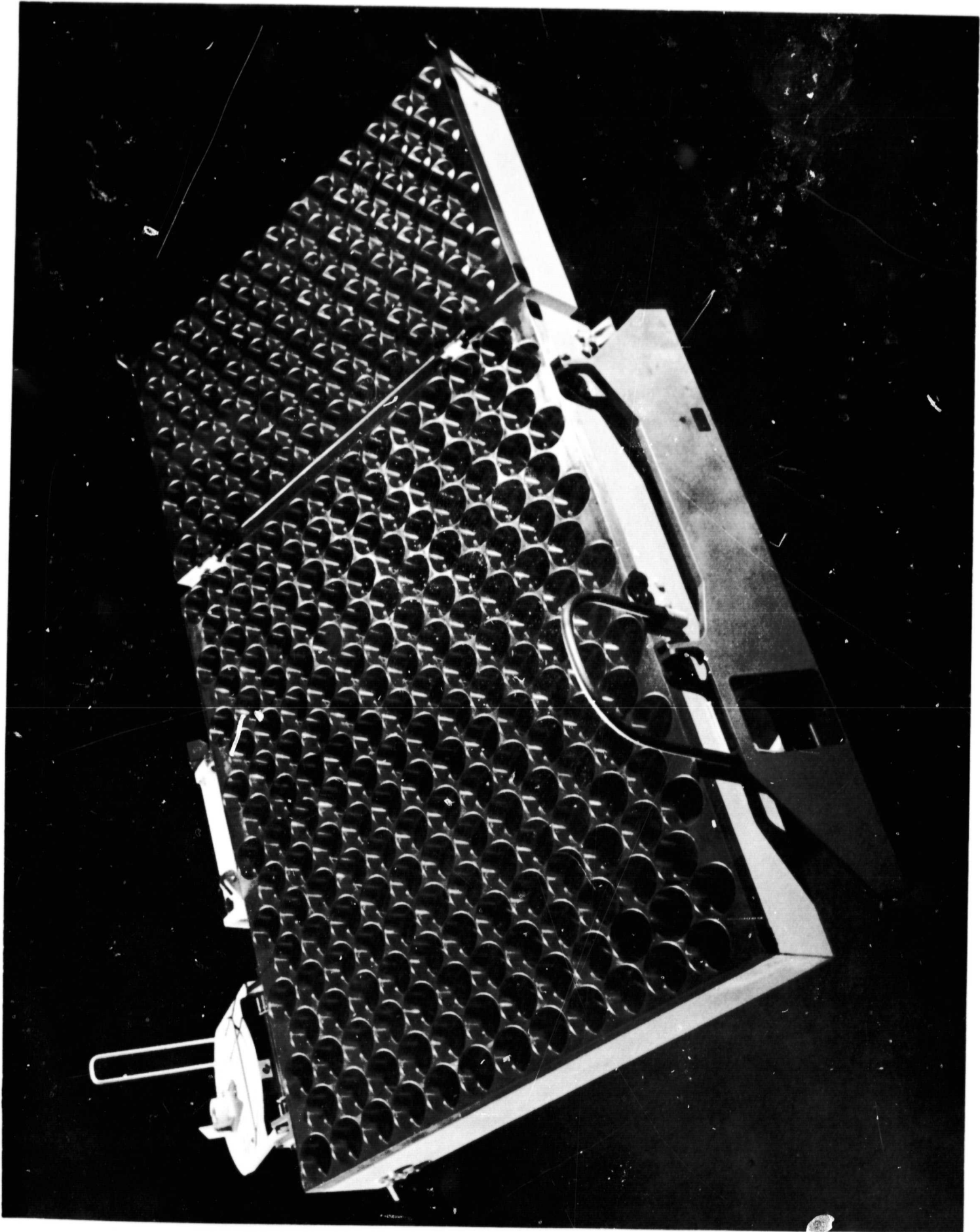


Figure 2-2 LRRR Deployed Configuration

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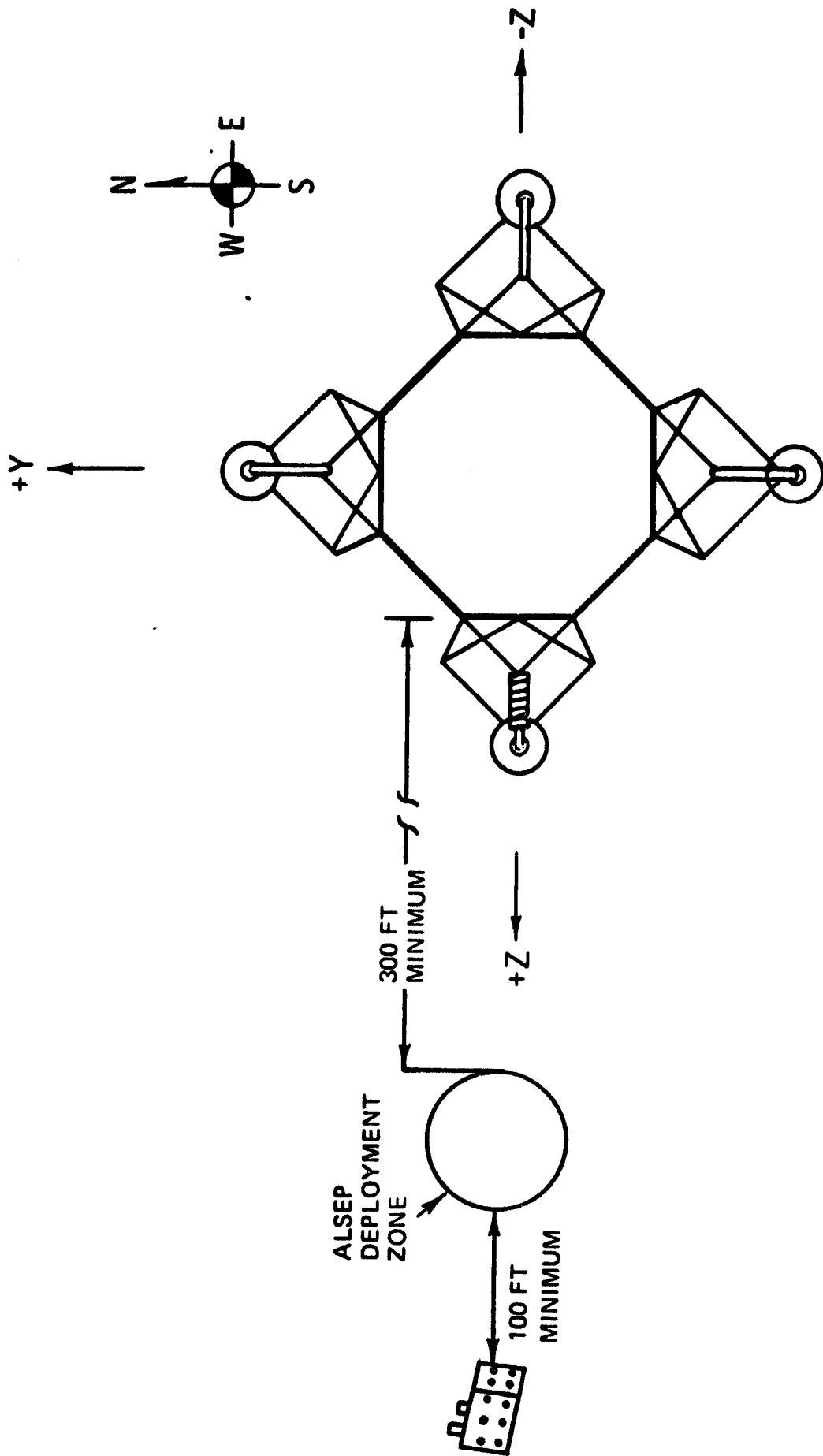


Figure 2-3 Planned LRRR Deployment Location

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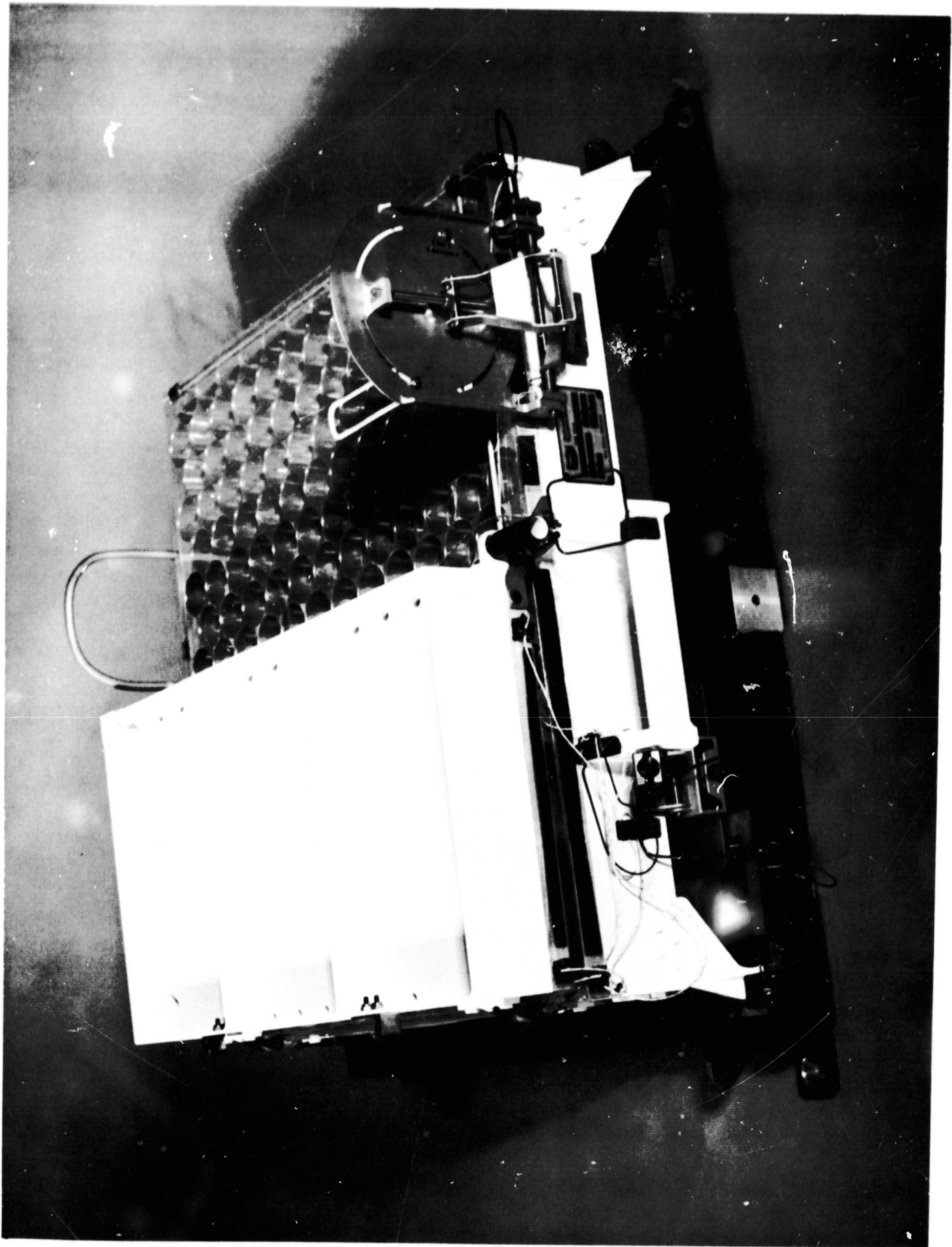


Figure 2-4 LRRR Stowed Configuration

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The rear support allows the LRRR to stand on end, for a time, during the course of deployment. With the LRRR up-ended, the astronaut has access to the carry handle and the UHT socket. He can release and deploy the small array panel and the sun compass assembly, release and lower the deployment leg to the proper position for the array tilt angle, remove the array protective covers and then set the LRRR down on the lunar surface for alignment and leveling by means of the ALSEP UHT. The deployment steps are depicted in Figure 2-5.

The LRRR will reflect laser radiation incident upon it on a path parallel to the incident beam. It will serve as a fiducial point on the surface of the moon to permit precise measurement by laser ranging of the distance from one or more sites on earth.

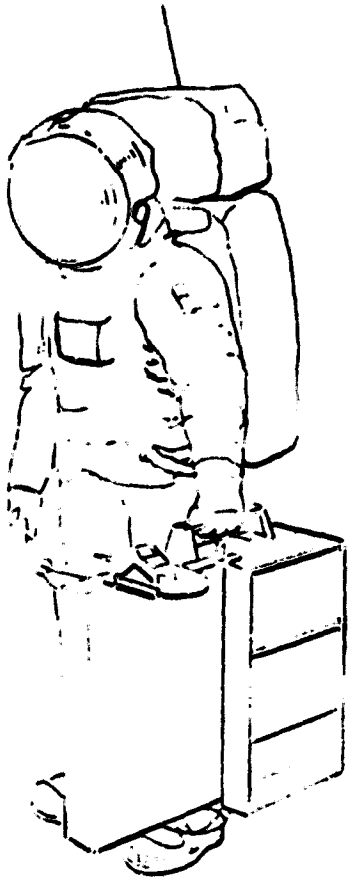
The LRRR is a passive device requiring no electrical power source or telemetry capability. As shown in Figures 2-2 and 2-4, its primary components are: (1) a large retro-reflector array, (2) a small retro-reflector array, (3) a deployment leg assembly, and (4) a sun compass assembly.

2.3.1 Retro-Reflector Arrays

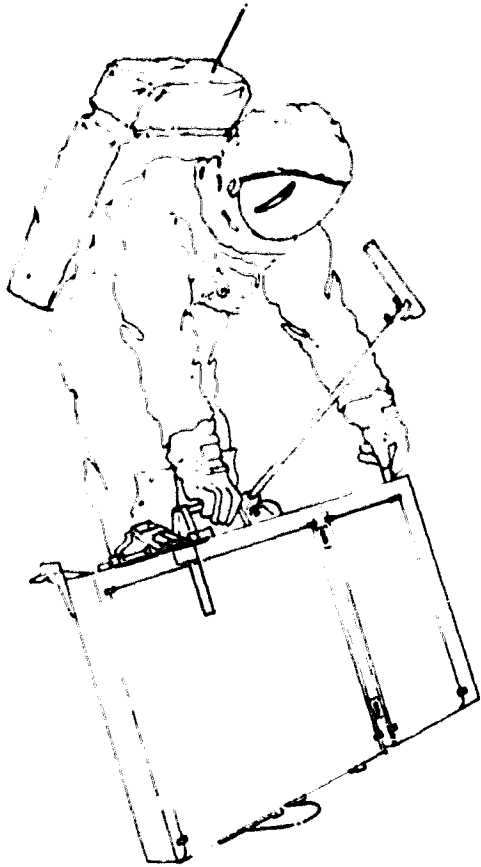
The LRRR includes two retro-reflector arrays; one having 204 retro-reflectors, the other having 96 retro-reflectors. The smaller array is hinged to the larger array so that it can be rotated above the larger into the stowed condition as shown in Figure 2-4. The larger array is hinged to the rear support bracket of the deployment leg assembly to permit it to be elevated to the desired array tilt angle.

The arrays are structurally identical except for support provisions and the number of reflectors. Each array consists of a panel structure incorporating retro-reflectors mounted in individual cavities. Thermal paint on the side and bottom surfaces of the panels, the reflective top surface of the panels, and the design characteristics of the cavities provide the desired thermal control for the retro-reflectors to maintain minimum temperature gradient within the reflectors. Transparent polyester cover assemblies protect the arrays from dust during storage, transportation, handling and flight. The covers are removed by the astronaut during lunar deployment.

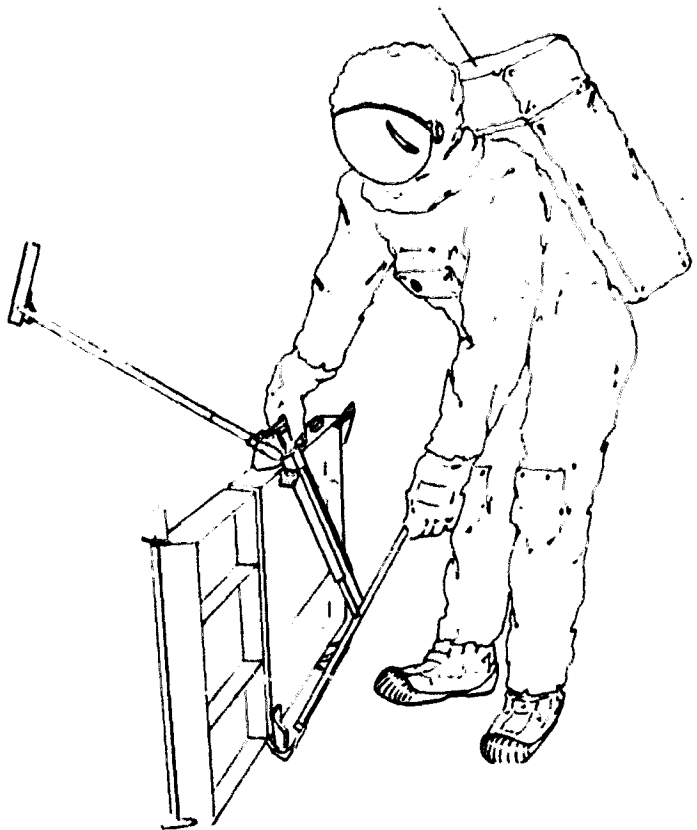
Each panel structure is machined from a solid aluminum block to satisfy the structural, weight, and thermal requirements. The cavities have been machined in a close-pack configuration to provide a high packing-density of retro-reflectors in the array. Precise alignment and dimensioning of the cavities provides proper positioning of each retro-reflector. The side and bottom surfaces of each panel are coated with white Z-93 thermal paint.



Astronaut Carrying
LRRR



Astronaut Deploying
Array Panel



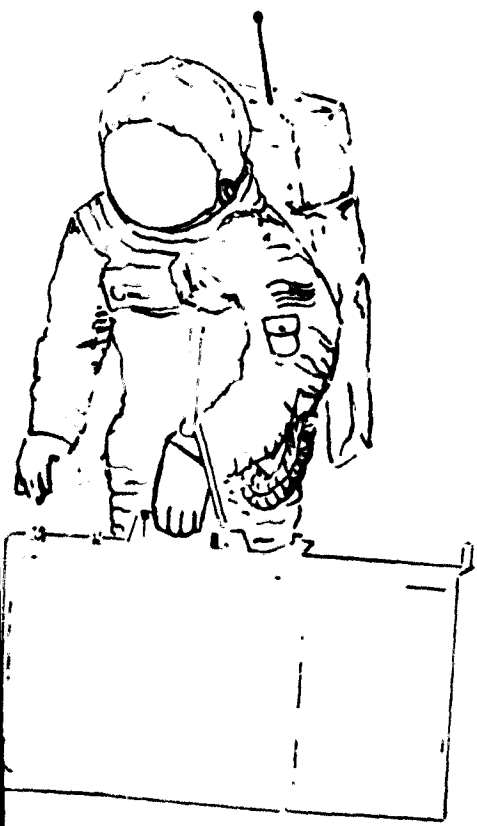
Astronaut Extending
Deployment Leg



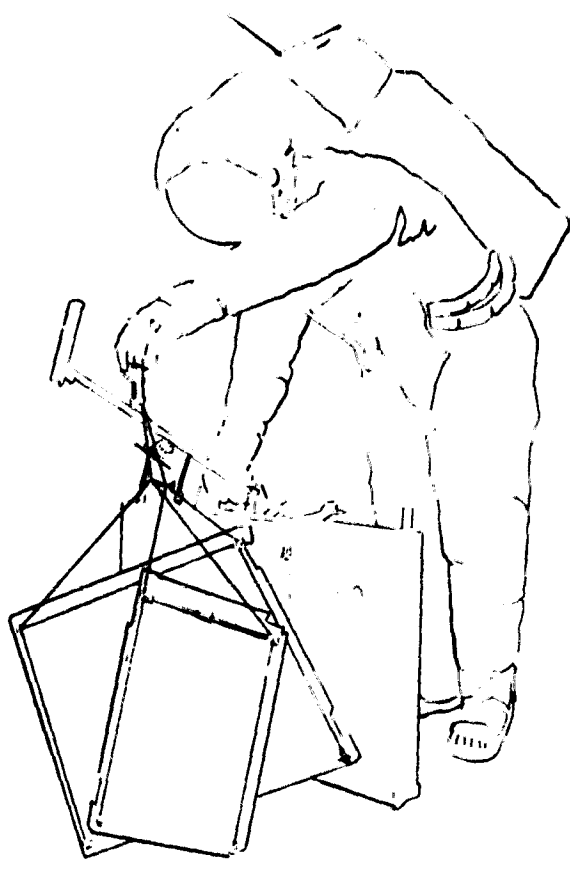
Astro
Sun

FOLDOUT FRAME

1



Astronaut Deploying
Sun Compass



Astronaut Removing
Dust Covers



Astronaut Aligning and Leveling
the LRRR

FOLDOUT FRAME

2

Figure 2-5 Lunar Surface Phase

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The large array assembly provides the tie points for securing the LRRR package on the GAC flight pallet in Quad III of the LM Descent Stage. Hinges and tie-points are also provided for mounting the small retro-reflector array on the large array.

The retro-reflectors and the method of mounting are identical to those used for the Apollo 14 LRRR. Retro-reflectors are high-precision, fused-silica optical retro-reflectors mounted in individual cavities in the panel structures. Each retro-reflector is aligned in its cavity to within $\pm 2^\circ$ of the average orientation for all the retro-reflectors. Thermal protection is provided each retro-reflector by characteristics inherent in the design of the cavity and the mounting components (see Figure 2-6). The use of teflon for the upper and lower mounting rings and the aluminum retaining ring, adjusted to a pre-determined clearance, provides the desired balance of thermal isolation of the retro-reflectors during variations in temperature over a range of 40°K to 400°K , and mechanical constraint of the retro-reflectors during severe flight environments.

The Apollo 14 and 15 LRRR array cavity design differs from the EASEP design only as follows: (1) the retainer ring has a 6° internal taper, where previously it was 1.5° ; (2) the retainer rings are riveted to the panel structure, where previously they were staked; (3) the panel structure cavities were modified to accommodate the new retainer ring design.

The objective of the LRRR is to reflect laser radiation beamed from earth. Maximum radiation will be reflected when the retro-reflector arrays are oriented as nearly normal to the incident radiation as possible.

The tilt angle of the deployed arrays is set by the deployment leg assembly (Figure 2-7). Before the arrays can be tilted, the quick release pin, which secures the deployment leg to the large array structure, must be removed by the astronaut. When the quick release pin has been removed, the deployment leg can be pivoted and locked to provide a tilt angle of approximately 26 degrees to the lunar surface.

The LRRR is oriented in azimuth and leveled on the lunar surface by inserting the ALSEP UHT into a handling socket mounted on the array carry handle. (Refer to Figure 2-7.) A trigger on the UHT is pulled by the astronaut to retract the ball-locks on the UHT, allowing the tool tip to be inserted into the socket. The astronaut, after releasing the trigger to lock the tool in the socket, then positions the LRRR on the lunar surface using the UHT as a handle. The proper positioning is achieved when the shadow cast by the gnomon is aligned with an appropriate index mark on the sun compass assembly. At the same time, the astronaut observes the bubble level mounted on the sun compass assembly to achieve proper leveling of the LRRR.

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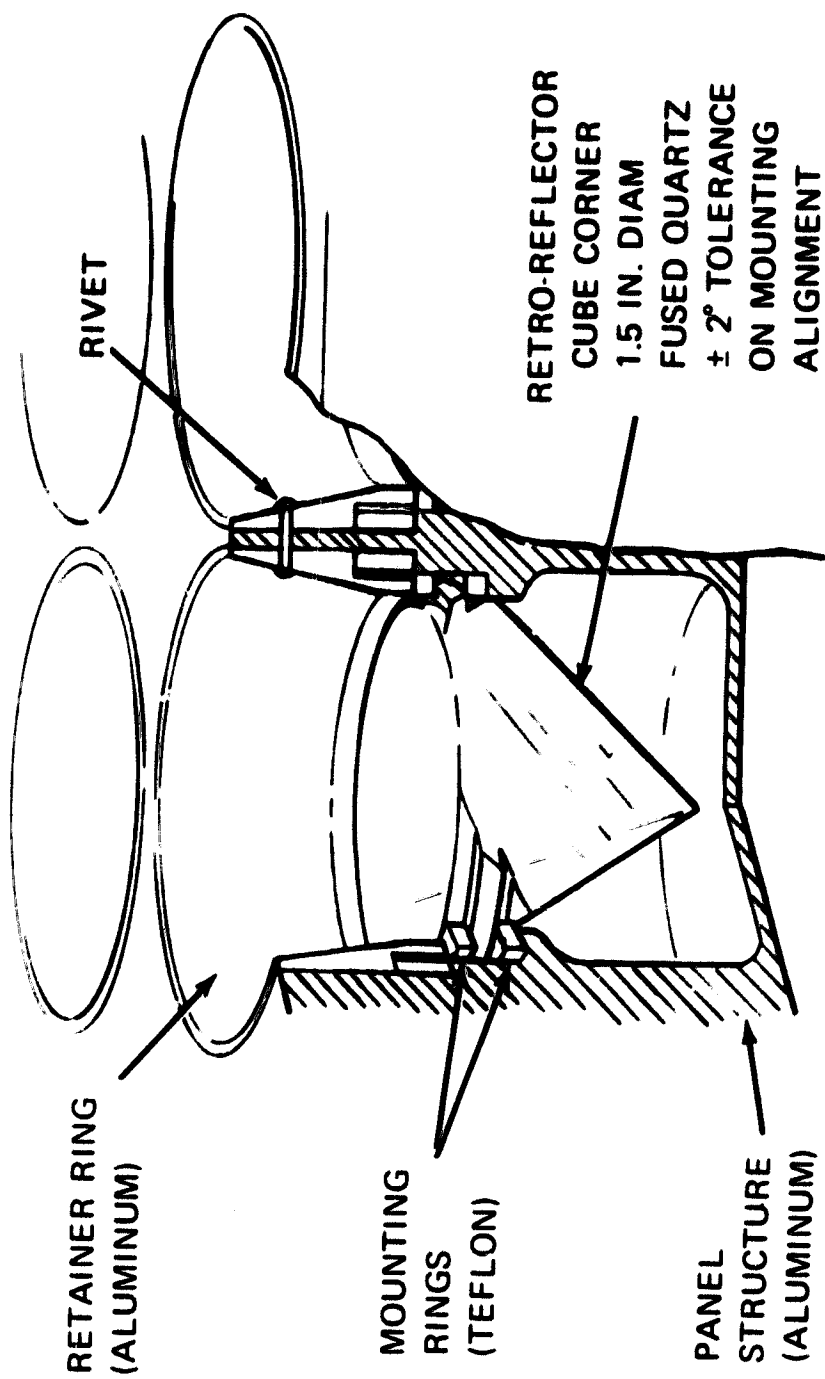


Figure 2-6 Retro-Reflector Mounting

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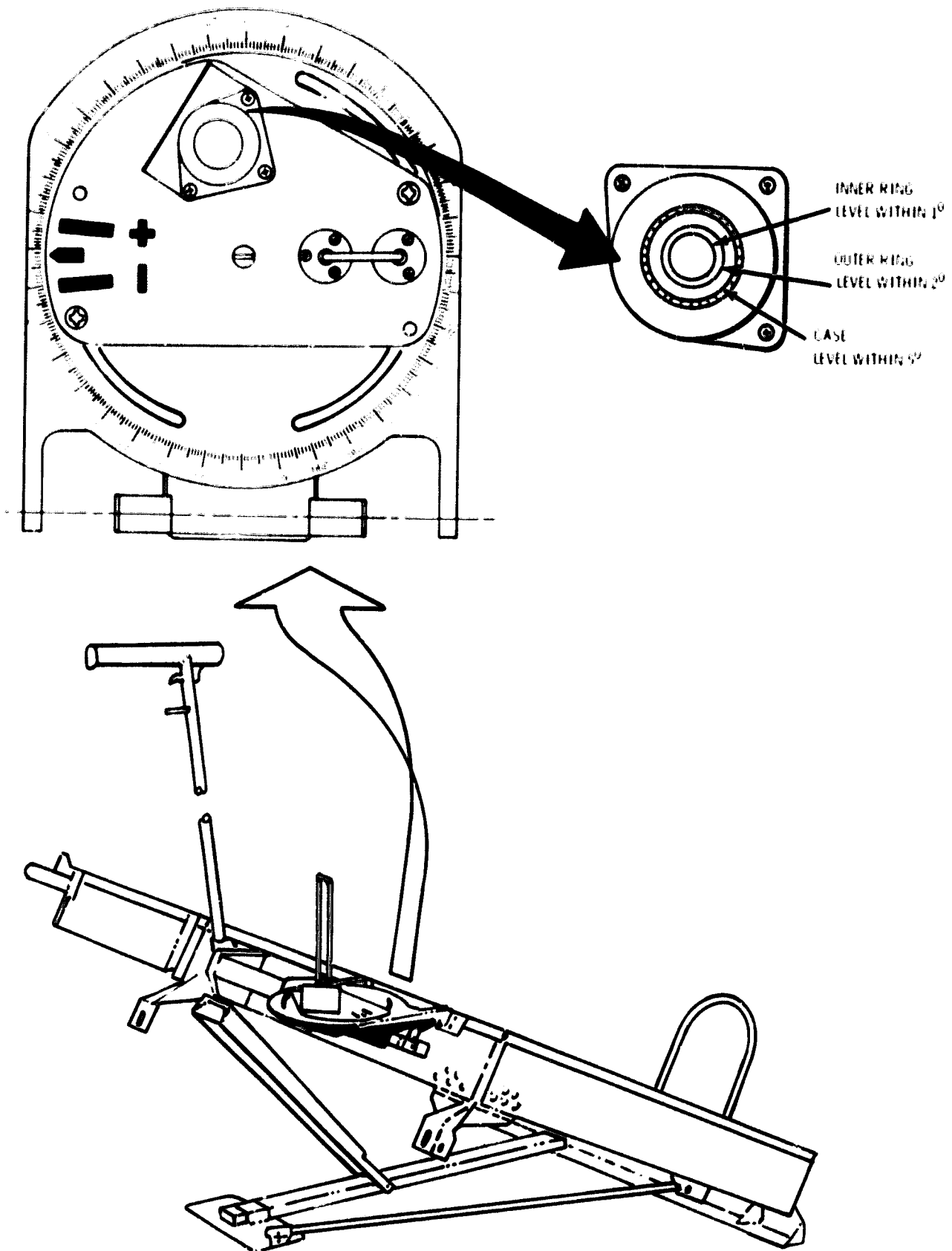


Figure 2-7 Apollo 15 LRRR Alignment and Leveling Devices

2.3.2 Deployment Leg Assembly

The deployment leg assembly is comprised of a rear support bracket, a leg and foot assembly, and a slide brace assembly. The deployment leg assembly is retained in the stowed position by a quick-release pin. It is lowered in deployment to support the arrays at the desired deployment angle. The slide brace and a locking device on the leg assembly are adjustable to accommodate a range of array tilt angles.

2.3.3 Sun Compass Assembly

The sun compass assembly is comprised of an adjustable bracket assembly, a base with compass markings, and a surface plate assembly with alignment index markings, gnomon, and bubble level. The sun compass assembly is attached to the large array assembly. It is retained in a vertical stowed attitude by a quick-release pin. When deployed, it is supported by the bracket assembly at an angle to the array such that it will be parallel to the lunar horizontal when the array is in the desired deployment attitude. The bracket assembly is adjustable to accommodate a range of array tilt angles. The surface plate assembly is adjustable in azimuth to accommodate a range of deployment locations and sun angles (i. e., EVA times).

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SECTION 3

DESIGN VERIFICATION

Concurrent with the fabrication and assembly of LRRR (300), a program of tests was established to demonstrate how the LRRR (300) equipment meets the performance and design requirements set forth in Section 2. This program considered the unique characteristics of the LRRR (300) Program, for example:

1. Use of pre-qualified hardware from the Apollo 14 LRRR, EASEP LRRR, and ALSEP Programs
2. A very short period of time in which to design, fabricate, and qualify the new hardware items.

The details of this test program were set forth in the LRRR Integrated Test Plan (ALSEP-TM-646). That document covers, in considerable detail, the scope and objectives of each test to be performed on each unit to demonstrate qualification and readiness for flight.

In addition to this program of testing, a number of inert models was constructed in support of other tests designed to demonstrate the concept and the compatibility with KSC and astronaut requirements. This section presents a summary of this total program of testing. Detailed information on the various tests may be obtained from the supporting documentation.

The design verification of the LRRR (300) is also substantiated by the design verification data previously provided for the Apollo 14 LRRR in the "Design Certification Review Report for the Apollo 14 Laser Ranging Retro-Reflector Experiment," BSR 3009 (15 September 1970) and for the EASEP LRRR in the "Design Certification Review Report for the Early Apollo Scientific Experiments Package," BSR 2699, Revision A (7 July 1969).

3.1 LRRR TEST PROGRAM

The LRRR test program consisted of three phases, each having a specific objective as follows:

1. Development test phase - to provide feedback of certain performance information during the design phase

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2. **Qualification test phase - to demonstrate compatibility of the performance with that stated in the system specification, and the capability of the system to withstand the effects of natural and induced environments**
3. **Acceptance test phase - to demonstrate that the flight unit's performance is within specification.**

The LRRR (300) qualification test model was manufactured in accordance with the same drawings, processes, and procedures as the flight model, except that the Qual model did not utilize the flight thermal coating and the retro-reflectors were not of flight optical quality. The thermal coating was not required since no thermal/vacuum tests were planned and the adherence of the thermal coating (Z-93) through all environmental conditions had previously been demonstrated.

3.1.1 LRRR Qualification Test Criteria

Qualification tests were performed at the system level and involved exposure of the LRRR qualification model to agreed levels of natural and induced environmental parameters. This exposure included various levels of the mechanical environmental parameters: shock and vibration. A visual inspection was performed after the mechanical environmental tests as was a mechanical functional deployment. A mass properties test was also performed.

3.1.2 LRRR Flight Acceptance Test Criteria

Flight acceptance tests, including vibration, tumble, and mechanical functional deployment, were performed on the LRRR flight model. In addition, a visual inspection was performed after the vibration tests. A mass properties test was also performed.

3.2 TEST DESCRIPTION

Throughout the process of development and fabrication of the LRRR, the quality of the concept, the performance, and the workmanship were demonstrated several times. The concept mockup and the Crew Training model have been used in demonstration and training sessions by the astronauts and by MSC and Bendix flight crew support personnel. A summary of these events up to delivery of the training model is given in Table 3-1.

During the initial design stages of the program, development tests were conducted at ADL using a single-corner cell, to establish the vibration capabilities of the retro-reflector and its mounting design. This information was used in the structural/dynamic analyses of the LRRR design to ensure that the design is adequate to maintain structural integrity of the retro-reflector and its mount, prior to being able to test a full-up assembly. In addition, acceptance tests were conducted

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TABLE 3-1

DEPLOYMENT DEMONSTRATIONS

Date	Nature of Test	Results
1 October 1970	Suited deployment of LRRR concept mockup (Bendix Crew Engineering Personnel)	Provided design inputs
5 October 1970	Shirt sleeve deployment of LRRR concept mockup (Olmstead/MSC-FCSD)	General design review by crew and acceptance of concept with specific design inputs
5 January 1971	Shirt sleeve deployment and acceptance of LRRR Crew Trainer Model (Bendix Crew Engineering Personnel)	Acceptance with minor discrepancies; corrected prior to shipment
7 January 1971	Shirt sleeve deployment and acceptance of LRRR Crew Trainer Model (Allen/MSC-Astro. Off., Roberts/MSC-FCSD)	Acceptance

on both large and small array panels for the ETM/Qual model and the Flight model. The panels were each subjected to acceptance level vibration environments and retro-reflector alignment was tested before and after the vibration tests.

A series of LRRR qualification tests was conducted using a model constructed specifically to demonstrate the capability of the flight model without degrading the actual flight hardware in the process. The Qual model has all of the components found on the Flight model except that the retro-reflectors are made from fused silica (quartz) of less than flight quality and have not been optically polished to the flight requirements. Mass properties and interface dimensional requirements are met, however. In addition, a simulated thermal coating was used as a finish on the Qual arrays, rather than the Z-93 thermal coating used on the Flight model, since no thermal/vacuum testing was required. It was manufactured in accordance with the same drawings, processes, and procedures used for the Flight model, except for the retro-reflectors and the thermal paint. The tests performed on this model are listed in Table 3-2.

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Finally, the LRRR Flight model (that model designated for lunar surface operation) underwent a series of tests to demonstrate its acceptability for the Apollo mission. The tests performed are also listed in Table 3-2.

TABLE 3-2

APOLLO 15 LRRR (300) TESTS

Tested Parameter	Qual Model	Flight Model
Mass Properties	X	X
Vibration - Acceptance Levels	X	X
Vibration - Design Limit Levels	X	
Mechanical Shock	X	
Tumble		X
Mechanical Function Deployment	X	X

3.3 CONDUCT OF TESTS

All tests were formally documented as described in the following subsections.

3.3.1 Data and Data Control

Qualification and acceptance tests were conducted in accordance with approved test procedures. These procedures were released and controlled through the configuration management system in the same manner as engineering drawings. Changes required approved Change Request Directives (CRDs) and Engineering Change Notices (ECNs). Floor changes were handled by variation to an individual procedure for a specific test or series of tests, and had approval of the Bendix Test, Quality, and Engineering representatives and the DCAS representative. At the conclusion of each test, the test conductor reviewed all as-run variations with the participants at a post-test meeting to establish what changes were to be incorporated in future procedure revisions.

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3.3.2 Data Verification and Approval

During tests, all out-of-tolerance indications caused; (1) halting of the test and (2) the preparation of a Discrepancy Report (DR) by the Quality Department representative. The DR number was recorded on the procedure variation sheet, and a decision subsequently was made and recorded to either continue the test, stop it, or troubleshoot. If troubleshooting was selected, a plan was specified on the DR and approved by Test, Quality, Engineering and DCAS representatives prior to proceeding. A reproducible copy was used as the master procedure and became the as-run record of the test. This as-run procedure and the DRs were reviewed at post-test meetings with representatives of Test, Engineering, Quality and DCAS. These meetings resulted in tentative approval of the test data, which were subsequently published in formal test reports and submitted to NASA/MSC for final approval.

3.4 TEST RESULTS

The LRRR successfully completed all component and system qualification and acceptance tests. During the post-test inspection of the Qualification Acceptance Level Vibration Test, a problem was encountered with the automatic deployment of the sun compass assembly. Design changes were implemented on both the Qualification and Flight models. The Qual Model was subsequently subjected to Design Limit vibration levels and the Flight model, to acceptance levels; the sun compass assembly on each model functioned as required. Other than this item, there were no other significant test discrepancies. The results of the Qualification and Flight acceptance test programs are described in Tables 3-3 to 3-12.

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TABLE 3-3

LRRR FLIGHT RETRO-REFLECTOR ARRAY ACCEPTANCE TEST

(Ref. : ADP for Array III)

Characteristics	Design Requirements	Test Results
Alignment of individual reflectors, after vibration	Each retro-reflector in the array shall be parallel to the resultant pointing direction of the array, within $\pm 2^\circ$	Large panel: 0.199° Small panel: 0.149°
Alignment of array and tilt axis, after vibration	The tilt axis shall be parallel to the resultant plane of the array retro-reflector front surfaces, within $\pm 0.25^\circ$	Large panel: 0.044° Small panel: 0.047°
Physical retention of retro-reflector during vibration	Large panel: Vibration levels specified in CEI Specification CP 100730. Small panel: Analytically confirmed vibration levels based on vibration levels specified in CEI Specification CP 100730 and amplified by the large panel structure.	No evidence of physical damage and no rotation of retainer rings
Reflector wave front deviation	The rms wave front deviation must be $\lambda/20$ or better	All reflectors are $\lambda/20$ or better in Flight Model. 69% of reflectors are $\lambda/24$ or better.

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TABLE 3-4

ACCEPTANCE LEVEL VIBRATION—LRRR QUAL

(Ref. : ATR-269)

TYPE OF TEST: Acceptance Vibration			
SUBSYSTEM: LRRR		HARDWARE: Qual Model	
Test Objective	Requirements	Results	Conclusions
To verify that no mechanical degradation would occur during and after normal flight vibration environment	Subject to earth launch and boost phase vibration (one sine, one sine dwell and one random test) in each of three axes per LRRR CEI Specification (CP 100730), Design and Performance Requirements	During post-test inspection, the sun compass assembly failed to deploy automatically.	Hinge shaft holes were enlarged by .0035 and dry lubricant was added to shaft finish. Automatic deployment was demonstrated after modifications were incorporated and after Design Limit Vibration Test.

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TABLE 3-5

DESIGN LIMIT VIBRATION—LRRR QUAL

(Ref. : ATR-270)

SUBSYSTEM: LRRR TYPE OF TEST: Design Limit Vibration HARDWARE: Qual Model			
Test Objective	Requirements	Results	Conclusions
To verify that no mechanical degradation would occur during or after the design limit vibration	Subject the package to one sine, one sine dwell and two random vibration tests in each of three axes per LRRR CEI Specification (CP 100730), Design and Performance Requirements	No evidence of physical damage	In compliance

TABLE 3-6

SHOCK—LRRR QUAL

(Ref. : ATR-271)

SUBSYSTEM: LRRR TYPE OF TEST: Shock HARDWARE: Qual Model			
Test Objective	Requirements	Results	Conclusions
To verify that the LRRR is capable of withstanding the shock induced by lunar landings	15 g for 11 milliseconds sawtooth pattern; three shocks in + X, ± Y, ± Z axes	No evidence of physical damage	In compliance

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TABLE 3-7

MASS PROPERTIES - LRRR QUAL

(Ref. : ATR-268)

SUBSYSTEM: LRRR		TYPE OF TEST: Mass and CG Determination	HARDWARE: Qual Model	
Test Objective	Requirements	Results	Conclusions	
To determine the total weight and center of gravity of LRRR. (CG to be determined relative to reference location)	Weight \leq 97 lb	Weight 78.83lb	In compliance	
	CG relative to reference axes X = 11.222 in. Y = 12.571 in. Z = 6.5 in.	CG relative to reference axes X = 11.068 in. Y = 11.638 in. Z = 5.595 in.		
	Within a sphere of 2.0-in. radius	Within a sphere of 1.309-in. radius	In compliance	

TABLE 3-8

MECHANICAL/FUNCTIONAL - LRRR QUAL

(Ref. : ATR-272)

SUBSYSTEM: LRRR		TYPE OF TEST: Mechanical/Functional	HARDWARE: Qual Model	
Test Objective	Requirements	Results	Conclusions	
To demonstrate LRRR deployment capability after exposure to launch and landing environments	Demonstrate operability of leveling leg, UHT socket, small array tie-down release and sun compass release and automatic deployment; deploy small array; remove pre-deployment cover.	All items functioned normally	Hardware in compliance with operational requirements	

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TABLE 3-9

ACCEPTANCE LEVEL VIBRATION—LRRR FLIGHT

(Ref. : ATR-276)

SUBSYSTEM: LRRR				TYPE OF TEST: Acceptance Vibration		HARDWARE: Flight Model	
Test Objective		Requirements		Results		Conclusions	
To verify that no mechanical degradation would occur during and after normal flight vibration environment		Subject to earth launch and boost phase vibrations (one sine, one sine dwell and one random test) in each of three axes per LRRR CEI Specification (CP100730), Design and Performance Requirements.		No evidence of physical damage		In compliance	

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TABLE 3-10

MASS PROPERTIES - LRRR FLIGHT

(Ref. : ATR-275)

SUBSYSTEM: LRRR		TYPE OF TEST: Mass and CG Determination		HARDWARE: Flight Model	
Test Objective	Requirements	Results	Conclusions		
To determine the total weight and center of gravity of LRRR (CG to be determined relative to reference location)	Weight \leq 97 lb	79.83 lb	In compliance		
	CG relative to references axes X = 11.222 in. Y = 12.571 in. Z = 6.5 in. Within a sphere of 2.0-in. radius	CG relative to reference axes X = 11.034 in. Y = 11.624 in. Z = 5.610 in. Within a sphere of 1.313-in. radius	In compliance		

TABLE 3-11

TUMBLE - LRRR FLIGHT

(Ref. : ATR-277)

SUBSYSTEM: LRRR		TYPE OF TEST: Tumble		HARDWARE: Flight	
Test Objective	Requirements	Results	Conclusions		
To assure operational integrity in a zero "g" environment	LRRR to be rotated about each of three major axes to show there are no loose parts or foreign matter	No loose parts or foreign matter observed	In compliance		

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TABLE 3-12
MECHANICAL/FUNCTIONAL - LRRR FLIGHT

(Ref. : ATR-278)

SUBSYSTEM: LRRR		TYPE OF TEST: Mechanical/Functional		HARDWARE: Flight Model	
Test Objective	Requirements	Results	Conclusions		
To demonstrate LRRR deployment capability after exposure to launch and landing environments	Demonstrate operability of leveling leg, UHT socket, small array tie-down release and sun compass release and automatic deployment; deploy small array; remove pre-deployment covers.	All items functioned normally	Hardware in compliance with operational requirements		