

LASER RANGING
RETRO-REFLECTOR
(LRRR)

FAMILIARIZATION MANUAL
(REVISION A)

PREPARED FOR
LUNAR SURFACE PROJECT OFFICE
MANNED SPACECRAFT CENTER

THE BENDIX CORPORATION
AEROSPACE SYSTEMS DIVISION

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PREFACE

The Laser Ranging Retro-Reflector (LRRR) will be used to continue long-term laser ranging measurements of Earth-Moon distances in keeping with the objectives of the lunar laser ranging experiment. At the time of this publication, the Apollo 11 LRRR has been in use for a period of almost two years, and the Apollo 14 LRRR has been in use for a period of three months in obtaining these measurements.

The purpose of this LRRR Familiarization Manual is to familiarize the reader with the scientific objectives of the lunar laser ranging experiment, the LRRR equipment make-up, deployment, and operation. This manual describes the experiment in Section I, the equipment in Section II, and LRRR operations in Section III.

The information contained in this manual includes formalized data released and available prior to the publication date: 1 May 1971.

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SECTION 1

INTRODUCTION

1-1. LASER RANGING RETRO-REFLECTOR

The Laser Ranging Retro-Reflector (LRRR) is designed to be transported to the moon aboard the Apollo Lunar Module, and be deployed on the surface of the moon by an Apollo crewman. It will establish a fiducial point consisting of an array of retro-reflectors to facilitate laser ranging for precise measurement of Earth-Moon distances. This data will be used to derive information on the geophysical dynamics of the Earth-Moon relationship.

1-2. LUNAR LASER RANGING EXPERIMENT

The lunar laser ranging experiment is the responsibility of the Lunar Ranging Experiment (LURE) Group which consists of the members listed in Table 1-1.

1-3. EXPERIMENT OBJECTIVES

The primary scientific objectives of an extended sequence of lunar-ranging measurements is to obtain data for more accurate determination of:

- a. The physics of the Earth
 - 1. Large-scale crustal motions
 - 2. Motion of the north pole
 - 3. Rotation rate and fluctuation
- b. The physics of the Moon
 - 1. The motion of the Moon in its orbit
 - 2. Physical librations
 - 3. Mass distribution
 - 4. Size and shape
- c. Gravitation and relativity.

Table 1-1. Membership, Lunar Ranging Experiment Group

Member	Affiliation
C. O. Alley, Coordinator	University of Maryland
P. L. Bender	National Bureau of Standards, University of Colorado
D. G. Currie	University of Maryland
R. H. Dicke	Princeton University
J. E. Faller*	Weslayan University
W. M. Kaula	University of California, Los Angeles
G. J. F. MacDonald	University of California, Santa Barbara
J. D. Mulholland	Jet Propulsion Laboratory
H. H. Plotkin	Goddard Space Flight Center
D. T. Wilkinson	Princeton University

*Principal investigator, with responsibility for the LRRR package.

1-4. EXPERIMENT DESCRIPTION

Accurately timed pulses of light from a ruby laser are directed through a telescope which is aimed at the LRRR deployed on the Moon. The laser light striking the LRRR is reflected back on a path parallel to the incident beam. The reflected light is collected by the telescope and detected by special receiving equipment. The time required for a pulse of light to reach the LRRR and be returned is used to establish the Earth-Moon distance at that time.

The telescope decreases the divergence of the laser beam by an amount equal to the ratio of the telescope aperture size to the diameter of the laser beam. A telescope aperture of 100 inches is needed to reduce the divergence of a laser beam so that its spot on the Moon is a little more than one mile in diameter. Further reduction is prevented by the turbulence of the Earth's atmosphere.

The laser beam reflected by one of the retro-reflectors in the array on the Moon is almost ten miles in diameter when it reaches the Earth.

Laser pulse durations of a few nano-seconds are used for lunar ranging. The light, traveling at 186,000 miles per second, requires about 2.5 seconds to make the 480,000-mile round trip. Returning photons collected by the telescope are directed into a photo-multiplier detector. A set of counters is activated sequentially to count any pulses produced by the detector. The counting sequence is centered on the expected time of arrival based on range predictions for each laser shot. The timer corresponding to the LRRR distance-time will record the greatest number of return pulses because the LRRR will reflect more of the laser beam than the total surrounding lunar surface illuminated by the beam.

The accuracy of the range measurements depends on thorough calibration of all electronic delays. When the entire system is calibrated, and the effects of the atmospheric delay are calculated and subtracted from the travel-time, an overall uncertainty of ± 6 inches in one-way range is achievable with the present equipment.

1-5. Retro-Reflector Array. The lunar laser ranging experiment requires the deployment of three retro-reflector arrays on the lunar surface as illustrated in Figure 1-1 to effectively isolate and measure the motions and librations of the moon.

The 100-reflector Apollo 11 LRRR and Apollo 14 LRRR arrays have been deployed at well-separated sites near the lunar equator. Laser ranging to these arrays is providing high quality data concerning motions and librations of the moon in longitude.

Deployment of the 300-reflector Apollo 15 LRRR array at the Hadley Rille site will allow direct measurement by laser ranging of all the rational motions associated with the physical librations of the moon.

The 300-reflector array has an optical efficiency nearly four times that of the 100-reflector arrays. The larger returns which will be obtained from this array will provide a greater frequency of returns, and will provide the basis for significantly higher accuracy of measurements by permitting the use of subnanosecond laser pulses. The larger return will allow laser ranging through telescopes of smaller aperture, enabling participation by a larger number of ground stations.

1-6. Ground Station Operation. Range measurements to the retro-reflector arrays are being performed during nearly all phases of the moon at the McDonald Observatory. The present ranging program consists of three ranging periods on most nights when weather permits, except for a period of five days at the time of the new moon. The ranging periods consist of several runs of about 50 shots each, and are performed three or four hours before, during, and three or four hours after the time of meridian transit on the moon.

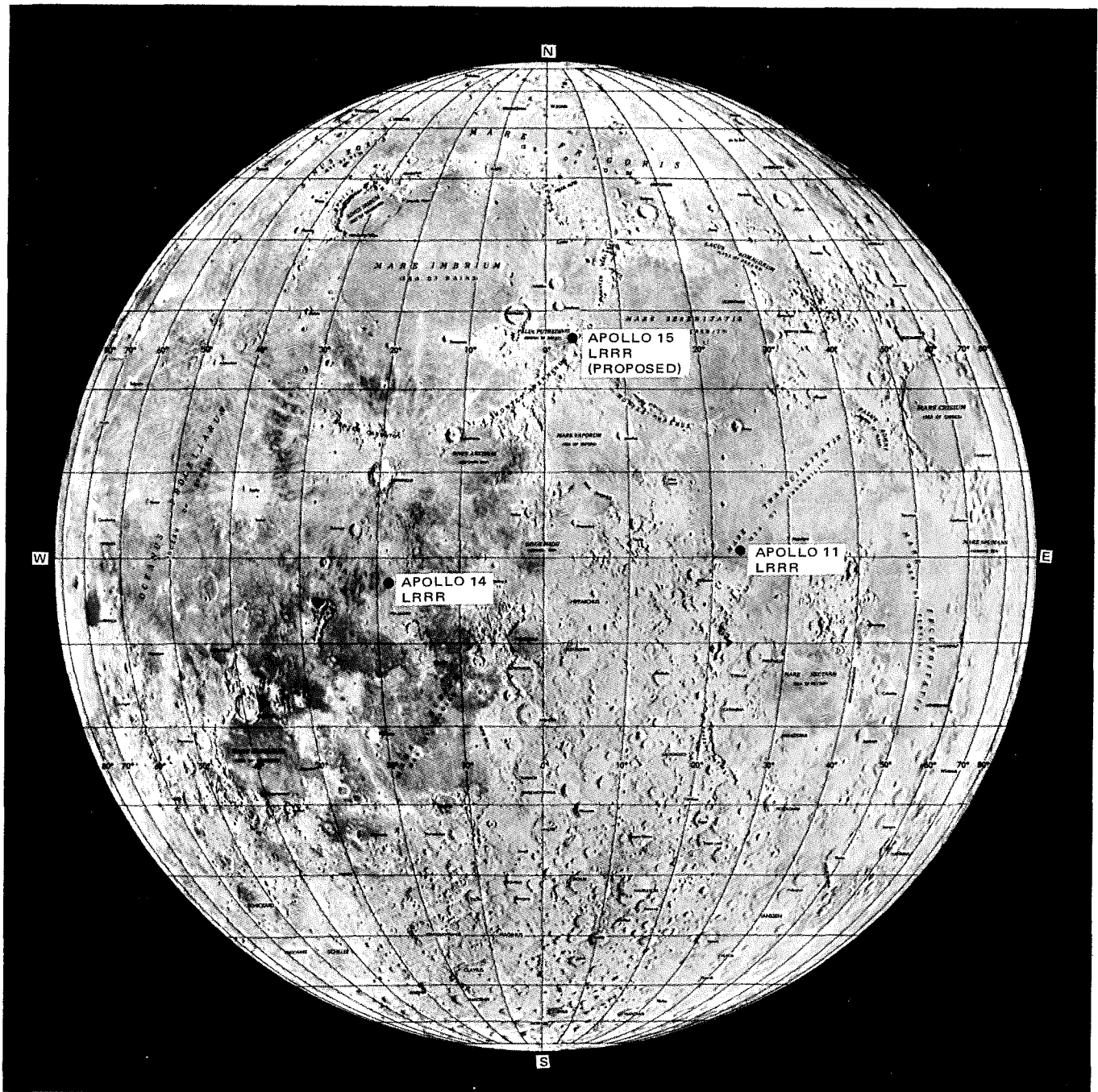


Figure 1-1. LRRR Locations on Moon

The ruby laser system used at present can provide three-joule pulses at a repetition rate of three seconds. The total pulse length between the ten percent intensity points is four nanoseconds. The rms variation in the observed transit time due to laser pulse length and photomultiplier jitter is two nanoseconds, which is equivalent to thirty centimeters in one-way distance. Improvement to less than one nanosecond is expected with refinements in the calibration procedures.

Recent developments in lasers, timing techniques, and in the knowledge of atmospheric corrections indicate that an accuracy of better than three centimeters can be achieved in lunar laser ranging.

Full utilization of the retro-reflector arrays entails an observing program which lasts decades and which employs a number of ground stations around the world in order to accurately measure wobble and rotation variations of the earth and differential tectonic drifts.

Laser ranging return signals from the Apollo 11 LRRR array have been obtained by the Lick Observatory at Mount Hamilton, California, the AFCRL Lunar Laser Observatory near Tucson, Arizona, and the Pic du Midi Observatory in France. Reports suggest that the ranging group in Japan has also had some initial success.

1-7. APOLLO 11 LRRR EXPERIMENT RESULTS

The Apollo 11 LRRR was deployed on the lunar surface in the southwestern part of Mare Tranquillitatis on July 21, 1969. It was aligned with the sun and leveled with precision sufficient to provide overall pointing of the array to within one degree of the center of the Earth's libration pattern. (See Figure 1-2.)

Reflected signals from the LRRR were first acquired with the 120-inch telescope of the Lick Observatory at Mount Hamilton, California on 1 August, 1969. The timing precision of the signals established the Earth-Moon distance with an accuracy of ± 25 feet. Initial acquisition with the 107-inch telescope of the McDonald Observatory at Mount Locke, Texas was on 20 August 1969. The timing-range accuracy of these signals was ± 8 feet.

These, and subsequent observations demonstrated that the LRRR did not suffer major degradation from debris generated during lift-off of the LM. Continued observations at the McDonald Observatory have demonstrated the successful performance of the LRRR at several sun illumination angles, as well as during and after lunar night.

The significance of the lunar laser ranging experiment for geophysical measurements was evident by the first series of lunar ranging observations. The data contained an apparent drift from the predicted time of return. This was the result of approximately 1,800 feet difference between the site of the Lick Observatory telescope and the coordinates of the site specified in the American Ephemeris and Nautical Almanac, which was used in generating the prediction ephemeris.

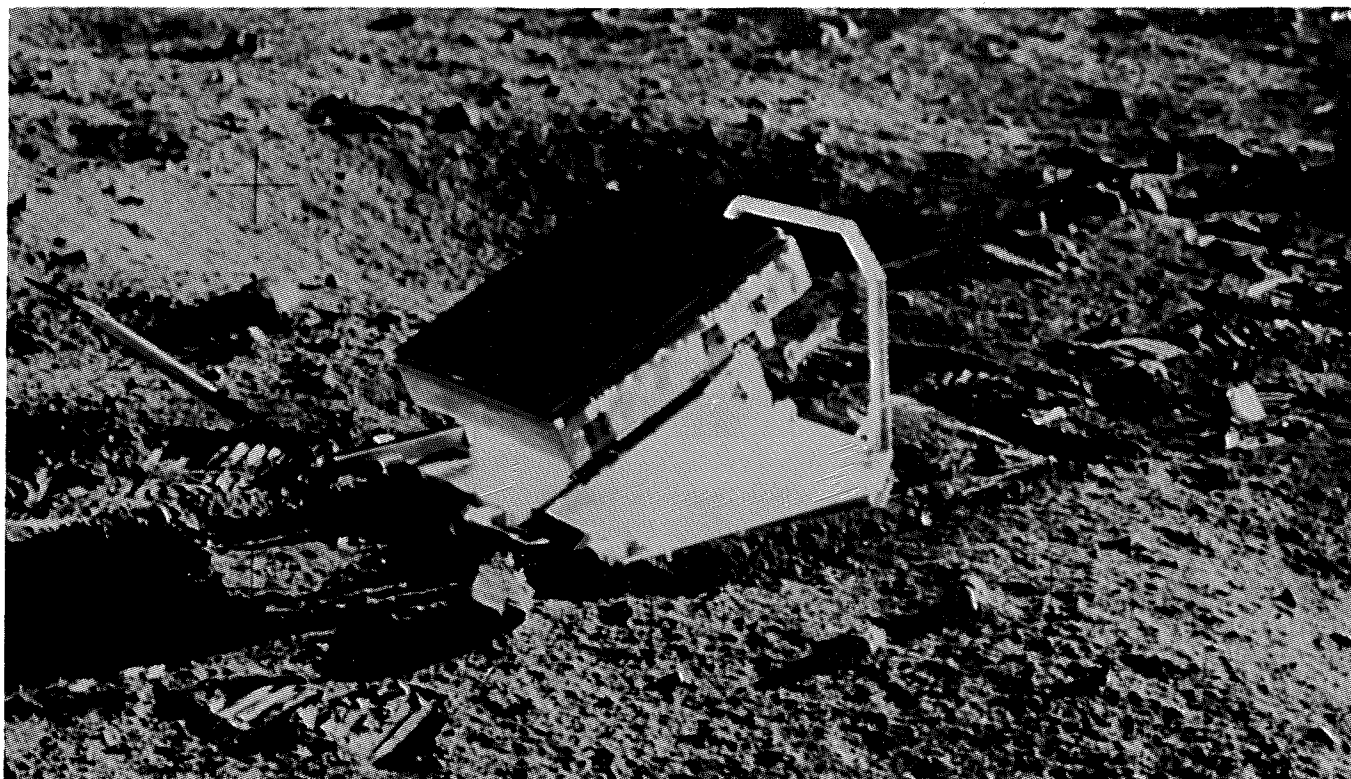


Figure 1-2. Apollo 11 LRRR Deployed on Lunar Surface

1-8. APOLLO 14 LRRR EXPERIMENT RESULTS

The Apollo 14 LRRR was deployed on the lunar surface in the vicinity of Fra Mauro on February 5, 1971. It was aligned with the sun and leveled with the lunar horizontal to provide overall pointing of the array toward the center of the Earth's libration pattern. (See Figure 1-3.)

Successful range measurements to the Apollo 14 LRRR were first made with the 107-inch telescope of the McDonald Observatory at Mount Locke, Texas on February 5, the same day it was deployed.

Laser ranging to the LRRR subsequent to LM liftoff indicated that no serious degradation of the reflectors resulted from the ascent engine burn. The returned signal strengths are comparable with the levels obtained from the Apollo 11 LRRR.

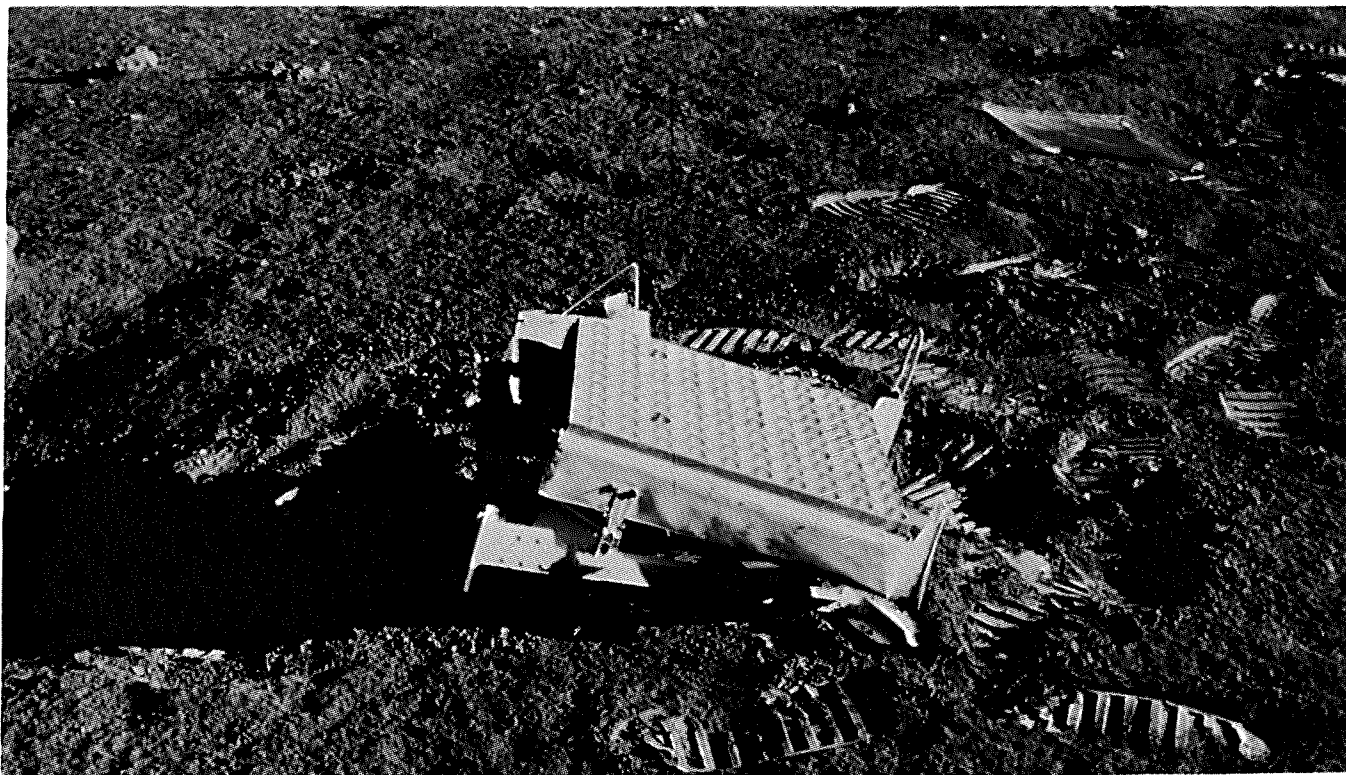


Figure 1-3. Apollo 14 LRRV Deployed on Lunar Surface

SECTION II

DESCRIPTION

2-1. APOLLO 14 LRRR DESCRIPTION

The LRRR for Apollo 14 was transported to the Moon in a compartment in the Quad I area of the lunar module (LM) descent stage. (See Figure 2-1.) After landing in the vicinity of Fra Mauro, a crewman extracted the LRRR from the LM and deployed it on the lunar surface so that it is pointed toward the center of the Earth's libration pattern. The LRRR will operate in conjunction with earth-based laser transmitting and receiving equipment over an extended period of time (10 years) to obtain Earth-Moon distance measurement.

The results of distance measurements to this Apollo 14 LRRR are being used along with measurements to the Apollo 11 LRRR to increase the effectiveness of the lunar laser ranging experiment.

2-2. APOLLO 14 LRRR PHYSICAL DESCRIPTION

The LRRR for Apollo 14 (Figure 2-2) is comprised of a retro-reflector array assembly mounted on a structure assembly. A leveling leg assembly was extended in deployment to support the LRRR at an elevation angle of approximately 18 degrees to the lunar surface. (See Figure 2-3.) A sun compass provides for a azimuthal alignment with respect to the sun, and a bubble level provides for alignment with the lunar horizontal. The LRRR leading particulars are listed in Table 2-1.

Table 2-1. Apollo 14 LRRR Leading Particulars

Characteristic	Value
Size (inches)	
Height (stowed)	11.75
Width	25.13
Length	25.50
Weight (pounds)	45.0
Number of retro-reflectors	100
Retro-reflector size	
Diameter (inches)	1.5

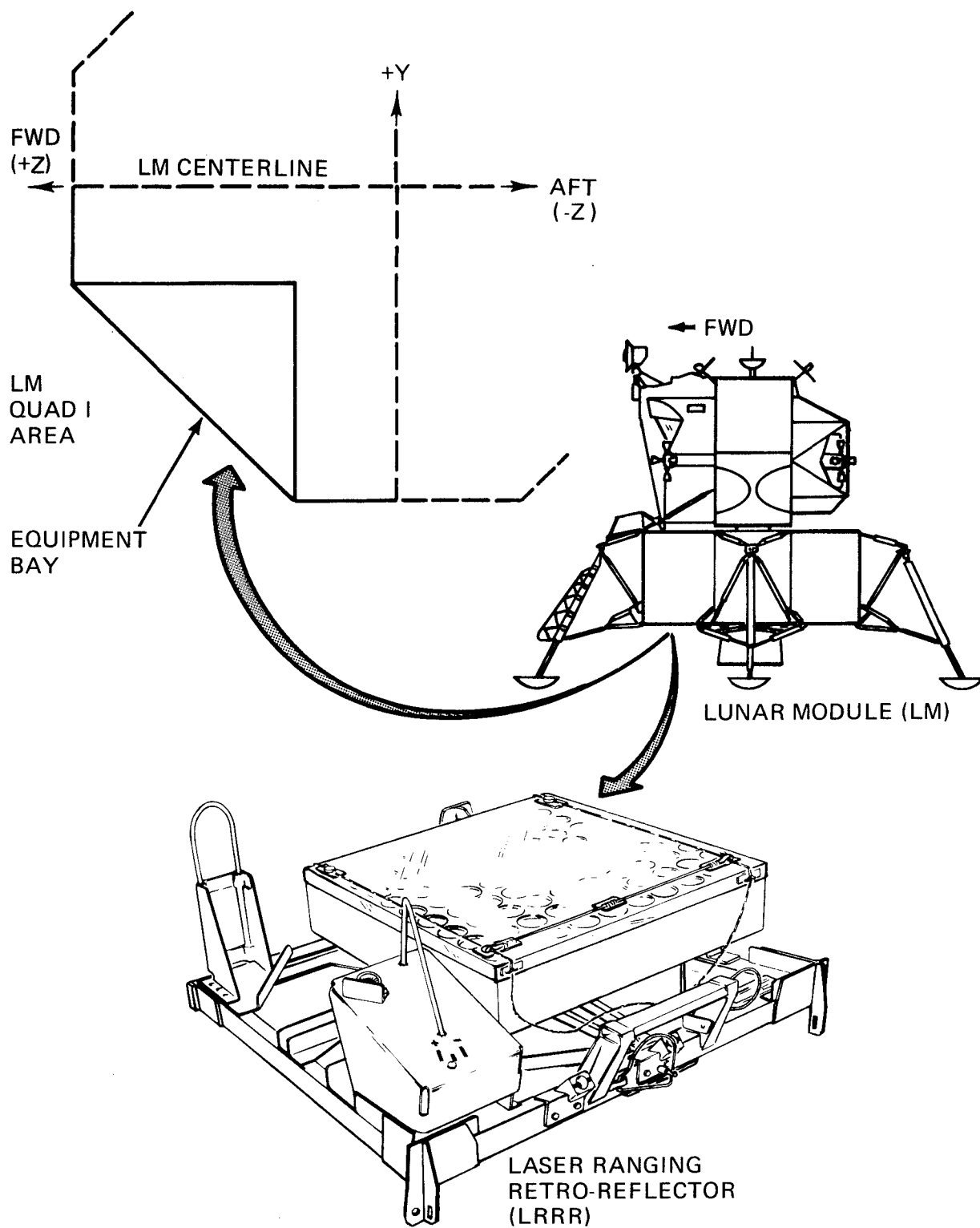


Figure 2-1. Apollo 14 LRRR/LM Interface

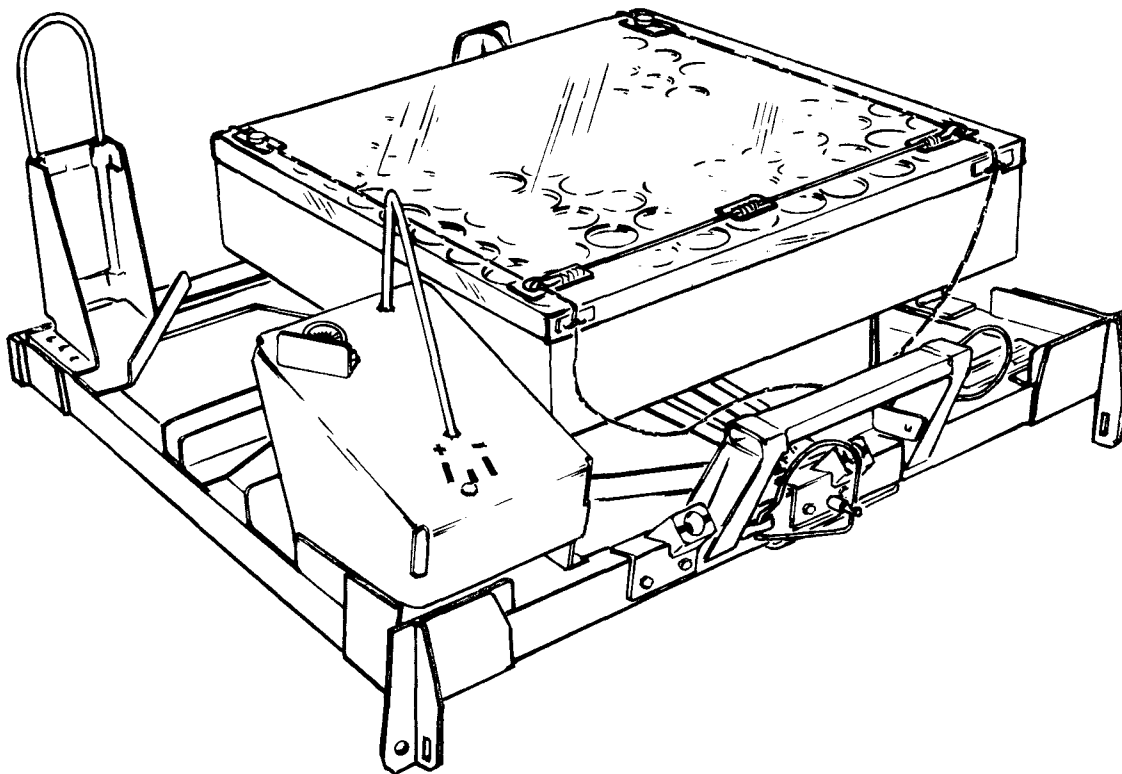


Figure 2-2. Apollo 14 LRRV, Stowed Configuration

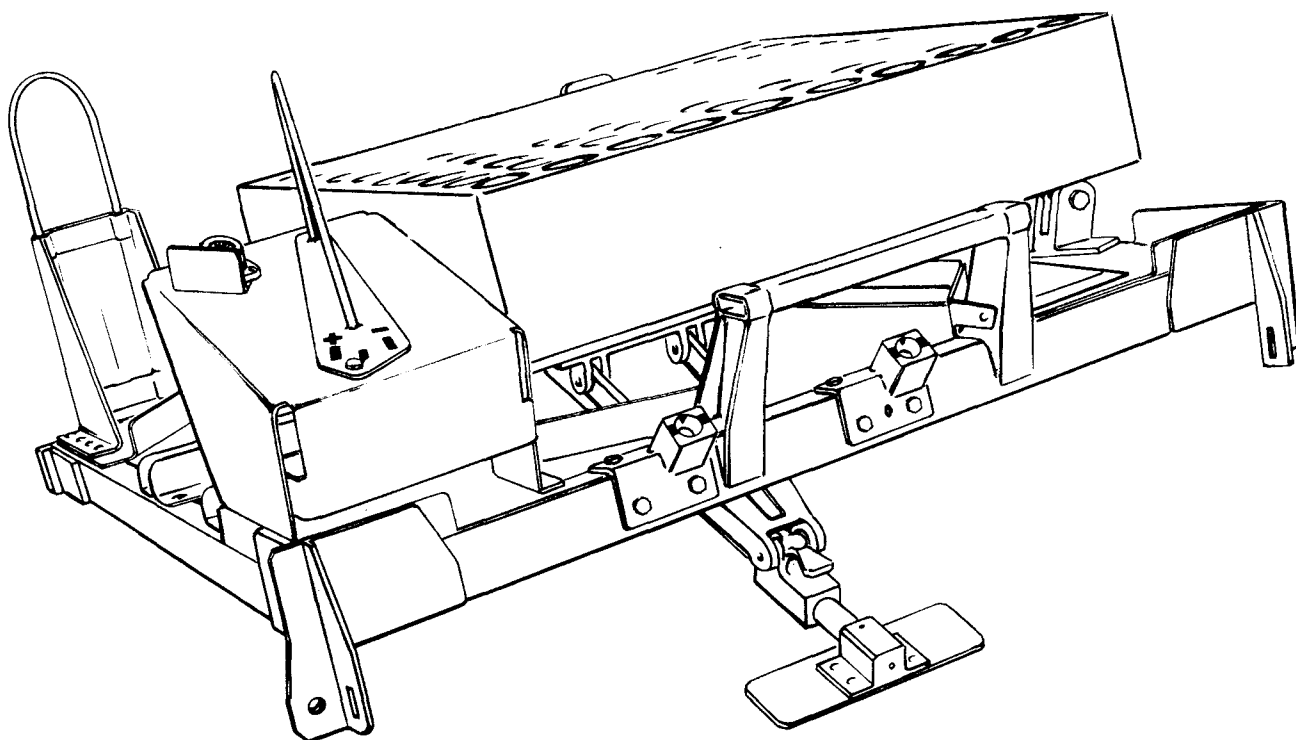


Figure 2-3. Apollo 14 LRRV, Deployed Configuration

2-3. Structure Assembly. The structure assembly is an aluminum framework which provides structural support for the LRRR assembly. A white thermal coating on the structure surfaces provides a low temperature-gradient between the structure and the retro-reflector array. The structure provides interface points for handling the LRRR, and for attachment to the Grumman Aircraft Corporation (GAC) flight pallet for installation in the LM.

The leveling leg is retained in the stowed position by a quick-release pin. Removal of the pin allows the leg to be extended and latched in the deployment position.

The sun compass assembly has index marks which are used to indicate azimuthal orientation of the LRRR by the shadow cast by the gnomon. The index marks are established for the Fra Mauro landing site and a specific deployment time period.

2-4. Retro-Reflector Array Assembly. The retro-reflector array assembly consists of a panel structure incorporating 100 retro-reflectors mounted in individual cylindrical cavities. A thermal insulation assembly, the highly reflective top surface of the panel, and the design characteristics of the cavities provide the desired thermal control for the retro-reflectors to maintain minimum temperature gradient within the reflectors. A transparent polyester cover assembly protects the array from dust during storage, transportation, handling, and flight. The cover is removed by the astronaut during lunar deployment.

The panel structure is machined from a solid aluminum block to satisfy the structural, weight, and thermal requirements. Precise alignment and dimensioning of the cavities provides proper positioning of each retro-reflector.

The sides and bottom of the panel structure are insulated by a multilayer insulation assembly attached to the panel with velcro tape. The insulation assembly consists of three double-aluminized polyester radiation shields separated by three double-layer spacers of polyester netting, and a protective outer cover of dacron sailcloth. A thermal shroud for ascent heating protection is applied over the insulation assembly. It consists of an inner layer of Beta cloth netting, a layer of double-aluminized Kapton, a layer of Beta cloth netting, and an outer cover of Beta cloth.

The retro-reflectors are high precision, fused quartz optical corners. The reflective characteristics of these retro-reflectors is such that a beam of light incident upon the reflector is reflected on a path parallel to the incident radiation. One hundred retro-reflectors are mounted in individual cavities in the panel structure. Each retro-reflector is aligned in its cavity to within $\pm 2^\circ$ of angular deviation relative to the array pointing direction. Thermal protection is provided the retro-reflector by the design of the cavity and components as shown in Figure 2-4. The use of teflon for the upper and lower mounting rings, and the precise clearances provided by the aluminum retaining ring allows for variations in temperature over a range of 40°K to 400°K , and provides thermal isolation of the individual retro-reflectors.

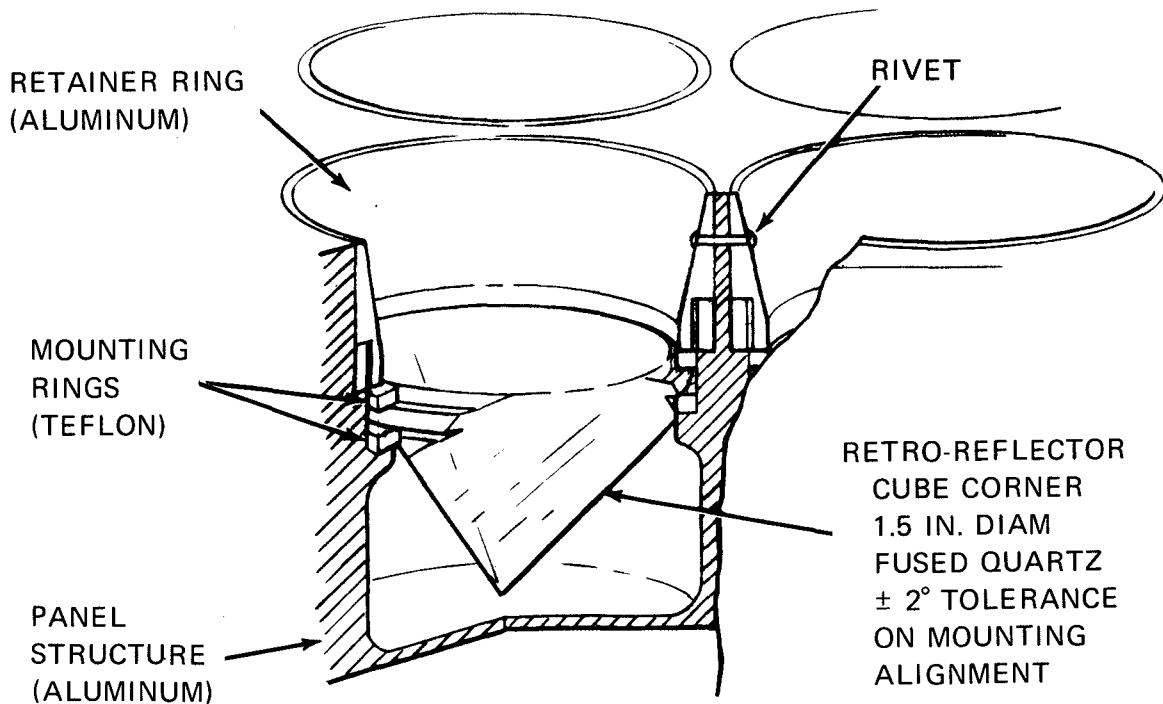


Figure 2-4. Retro-Reflector Mounting

2-5. APOLLO 15 LRRR DESCRIPTION

The LRRR for Apollo 15 will be transported to the Moon on the Quad III area of the lunar module (LM) descent stage. (See Figure 2-5.) After landing in the vicinity of Hadley Rille, a crewman will detach the LRRR from the LM and deploy it on the lunar surface so that it is pointed toward the center of the Earth's libration pattern. The LRRR will be used in conjunction with earth-based laser transmitting and receiving equipment in the same manner as the Apollo 11 LRRR and the Apollo 14 LRRR to obtain Earth-Moon distance measurements.

2-6. APOLLO 15 LRRR PHYSICAL DESCRIPTION

The LRRR for Apollo 15 (Figure 2-6) is comprised of a hinged, two-panel retro-reflector array assembly mounted on a deployment leg assembly. The deployment leg will be extended in deployment to support the retro-reflector array at an elevation angle of approximately 26 degrees to the lunar surface. (See Figure 2-7.) A sun compass assembly provides for azimuthal alignment with respect to the sun, and a bubble level provides for alignment with the lunar horizontal. The LRRR leading particulars are listed in Table 2-2.

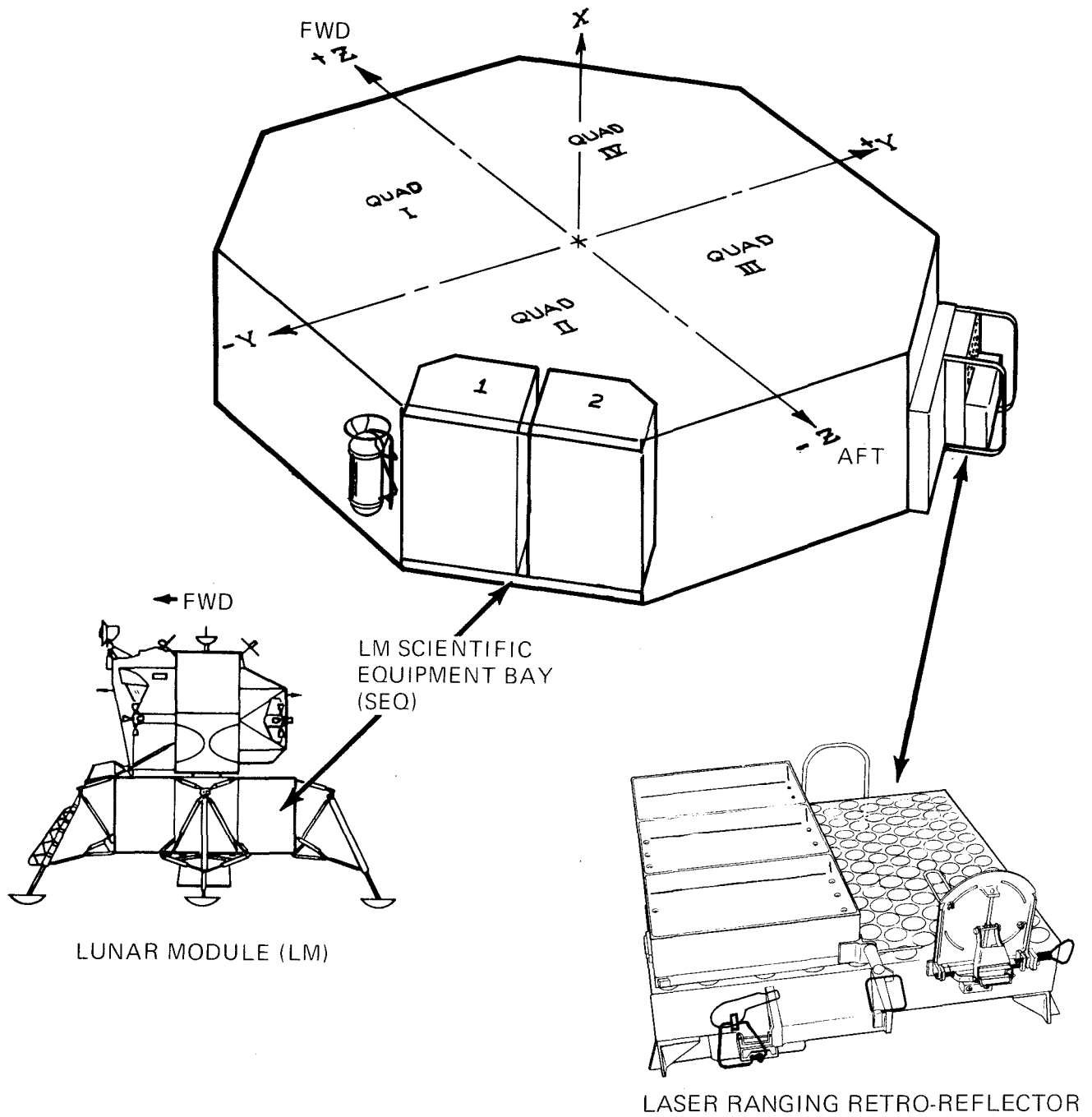


Figure 2-5. Apollo 15 LRRR/LM Interface

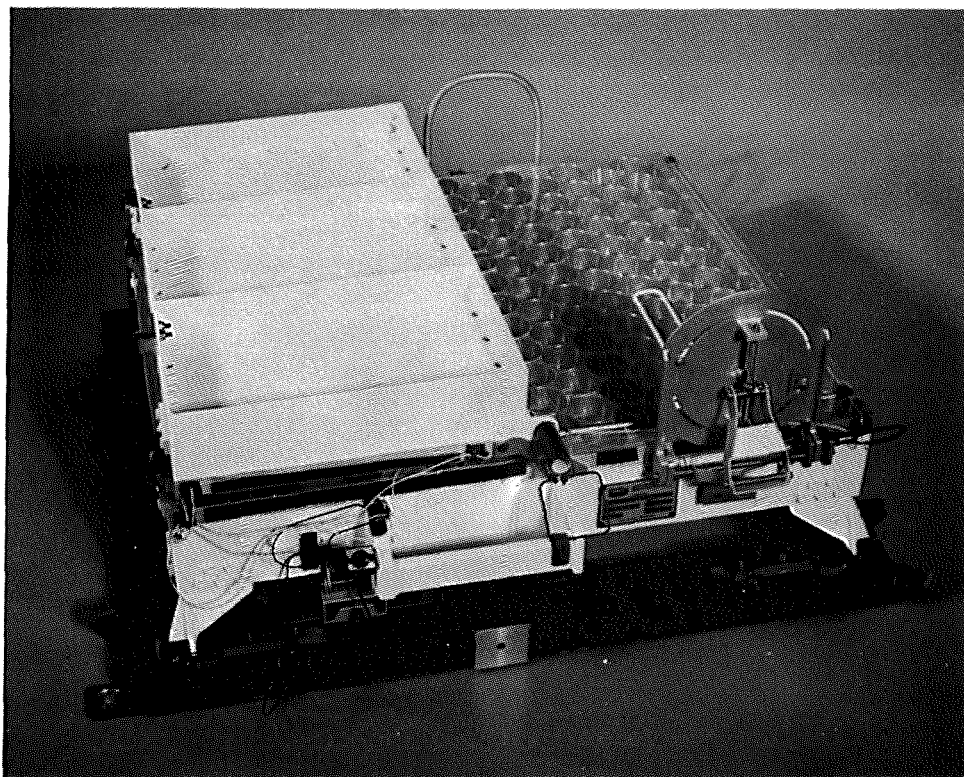


Figure 2-6. Apollo 15 LRRR, Stowed Configuration

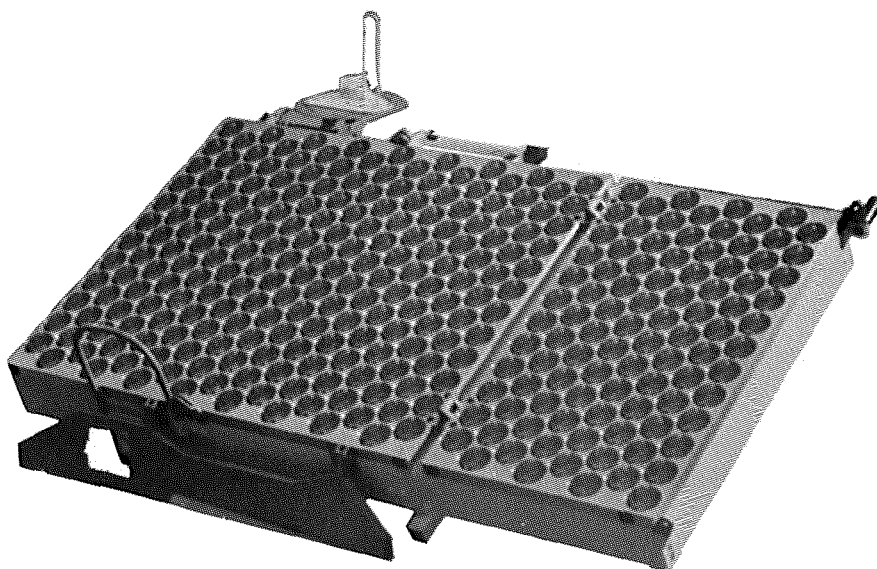


Figure 2-7. Apollo 15 LRRR, Deployed Configuration

Table 2-2. Apollo 15 LRRR Leading Particulars

Characteristic	Value
Size (inches)	
Height	11.75
Width (stowed)	27.375
(deployed)	41.375
Length	25.50
Weight (pounds)	79.83
Number of retro-reflectors	
Array A	204
Array B	96
Total	300
Retro-reflector size	
Diameter (inches)	1.5

2-7. Retro-Reflector Array. The retro-reflector array is comprised of a 204-reflector Array A and a 96-reflector Array B. Array B is hinged to Array A so that it can be inverted over Array A in the stowed configuration as shown in Figure 2-6, and deployed parallel with Array A as shown in Figure 2-7. Array A is hinged to the rear support bracket of the deployment leg assembly so that it can be raised to the desired deployment angle.

The arrays are structurally identical except for mounting 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 highly 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 is coated with white thermal paint.

The retro-reflectors and the method of mounting is identical to that used for the Apollo 14 LRRR. Refer to paragraph 2-4 for descriptive information.

2-8. Deployment Leg Assembly. The deployment leg assembly is comprised of a rear support bracket, leg and foot assembly, and a slide brace assembly. The leg assembly is retained in the stowed position by a quick-release pin. It is extended in deployment to support the array assembly at the desired deployment angle. The slide brace is adjustable to accomodate a range of deployment angles.

2-9. 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 is attached to the Array A panel assembly. It is retained in a vertical attitude by a quick-release pin in the stowed configuration. 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 accomodate a range of deployment attitudes. The surface plate assembly is adjustable in azimuth to accomodate a range of deployment locations.

SECTION III

OPERATIONS

3-1. INTRODUCTION

This section describes the operations required to enable the LRRR to accomplish its objectives of lunar distance measurement. Operations subsequent to NASA acceptance of the LRRR by DD-250 sign-off at Bendix will be described. This includes packaging and transportation, KSC operations and lunar surface operations.

Preservation, packaging and transportation requirements and operations are provided in procedure 2347051.

3-2. APOLLO 14 LRRR OPERATIONS

3-3. KSC OPERATIONS

KSC operations include those activities from receiving inspection of the LRRR through installation in the LM. These activities include receiving inspection, transportation, handling, and installation as shown in Figure 3-1.

Receiving inspection of the LRRR is performed at the ALEP Launch Preparation Site (ALPS).

The LRRR is removed from the shipping container and the handling ground support equipment (GSE) is installed. The LRRR, in the GSE, is transported from the ALPS to the launch umbilical tower (LUT) on the launch pad. It is elevated to the LUT 260 level holding area, carried across swing arm 7, and handed through the instrument unit (IU) door into the spacecraft/LM adapter (SLA) section of the launch vehicle. The LRRR is then hoisted to the XA 525 level where it is removed from the GSE. The LRRR is then attached to the Grumman Aircraft Corporation (GAC) flight pallet, and installed in the LM bay.

3-4. GROUND SUPPORT EQUIPMENT

The ground support equipment required to support Apollo 14 LRRR operations is listed in Table 3-1 and illustrated in Figures 3-2, 3-3, and 3-4.

3-5. LUNAR SURFACE OPERATIONS

Lunar environmental conditions impose constraints on hardware deployment by the astronaut. LRRR deployment procedures will be performed at a time when the sun angle from the lunar horizon is 7 to 22 degrees. At a sun angle of 7 degrees, the lunar surface temperature is approximately -50 to -60 degrees F. At a sun angle of 22 degrees, the lunar temperature is +80 to +100 degrees F. LRRR design allows deployment at a maximum sun angle of 45 degrees and a relative lunar surface temperature of approximately +165 degrees F.

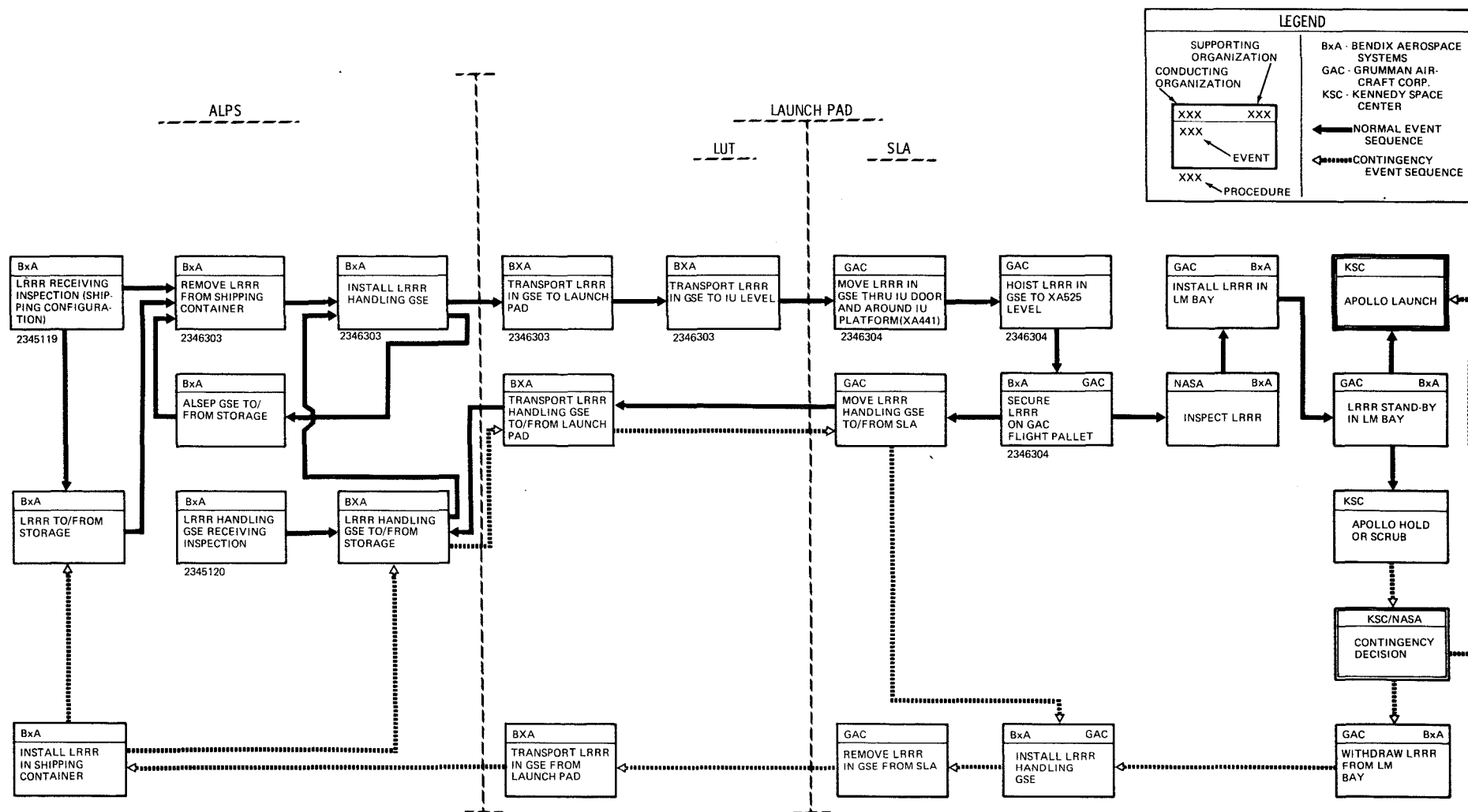


Figure 3-1. Apollo 14 LRRR KSC Operations Sequence

Table 3-1. Apollo 14 LRRR Ground Support Equipment

Nomenclature	Function	Part Number
Holding fixture, subpackage No. 2	Attaches to base of LRRR for shipping and handling operations. Mounts to handling cart for movement (ALPS).	2335338
Handling device, subpackage No. 2	Provides tie points for LRRR handling during transfer to LRRR handling fixture (ALPS).	2335313
Handling cart	Provides mounting tie down for LRRR on holding fixture during handling (ALPS).	2332899
Hoisting device	Attaches to holding fixture or handling device for LRRR hoisting operations (ALPS).	2335310
Handling fixture, LRRR	Attaches to LRRR for transportation and handling operations (ALPS/SLA).	2340562
Protective cover, LRRR	Provides environmental protection for LRRR during transportation and handling operations (ALPS/SLA).	2340583
Carrying handle, handling fixture	Attaches to LRRR handling fixture for transportation and handling operations (ALPS/SLA).	2340559
Sling assembly	Attaches to handling fixture for hoisting LRRR in horizontal attitude (ALPS/SLA).	2340585
Sling assembly	Attaches to handling fixture carrying handle for hoisting LRRR in vertical attitude (ALPS/SLA).	2340586
Shipping container, LRRR assembly	Provides physical protection and controlled environment for shipment of LRRR to KSC.	2340599
Hoisting device, monorail	Provides means of hoisting LRRR in GSE to XA 525 level in SLA.	(GAC)

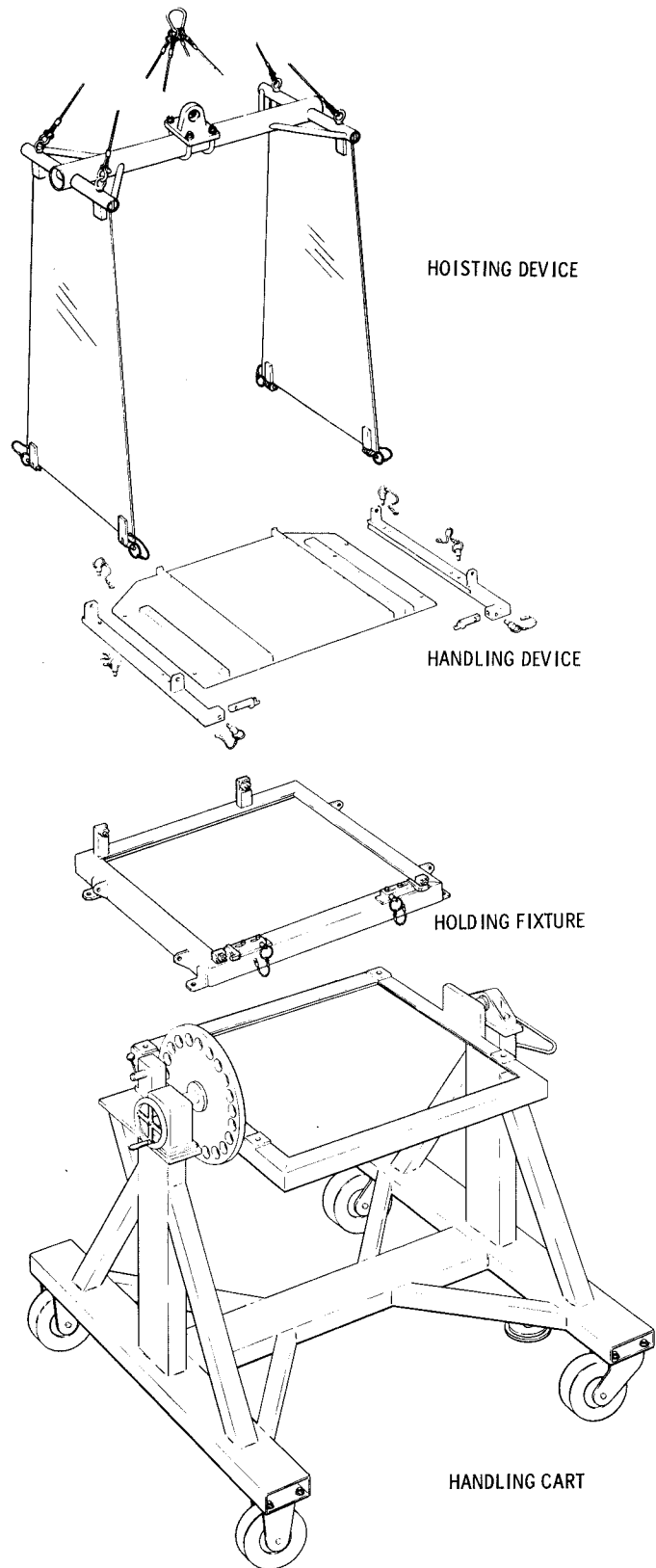


Figure 3-2. Handling GSE (ALPS)

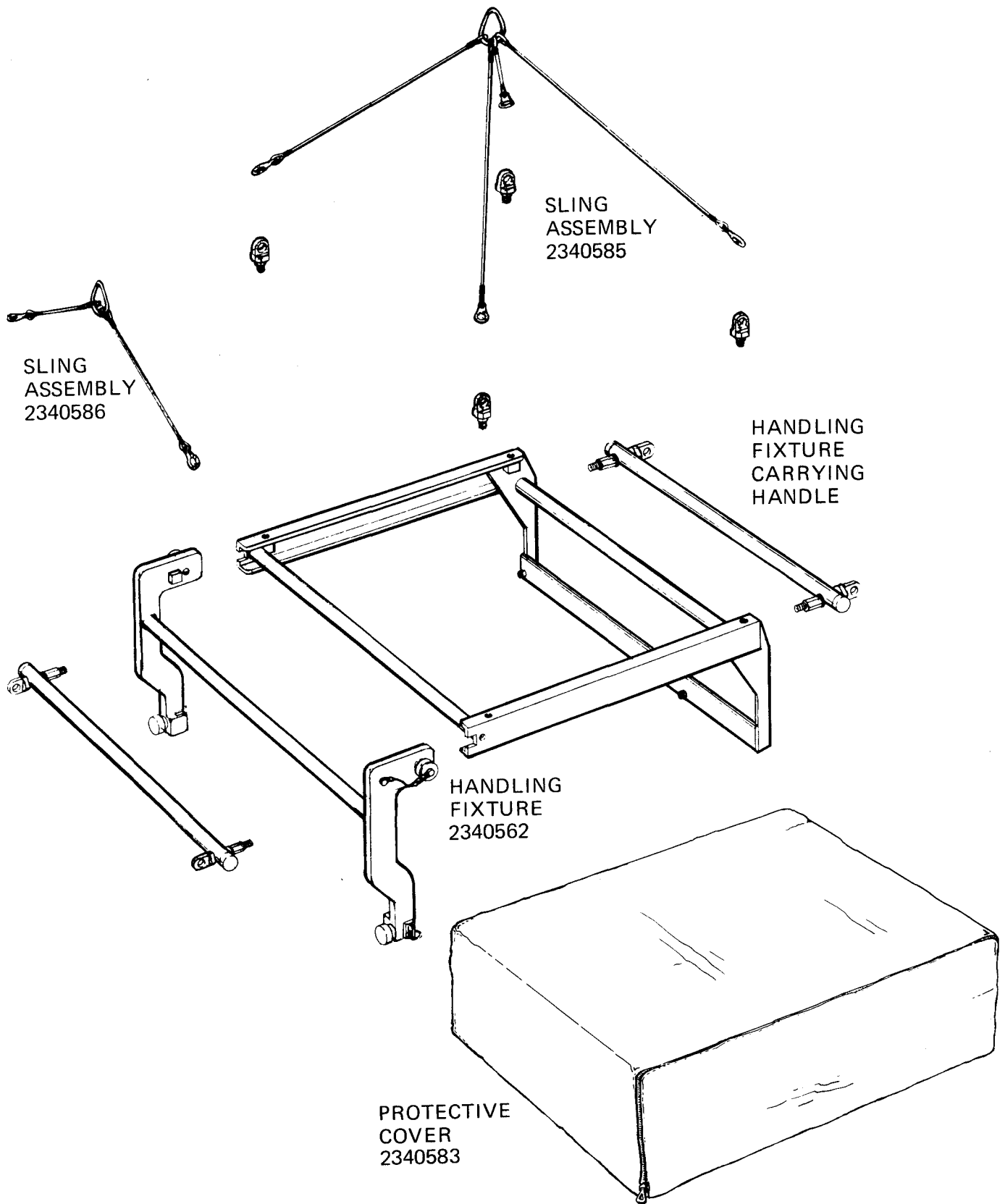


Figure 3-3. Apollo 14 LRRR Handling GSE (ALPS/SLA)

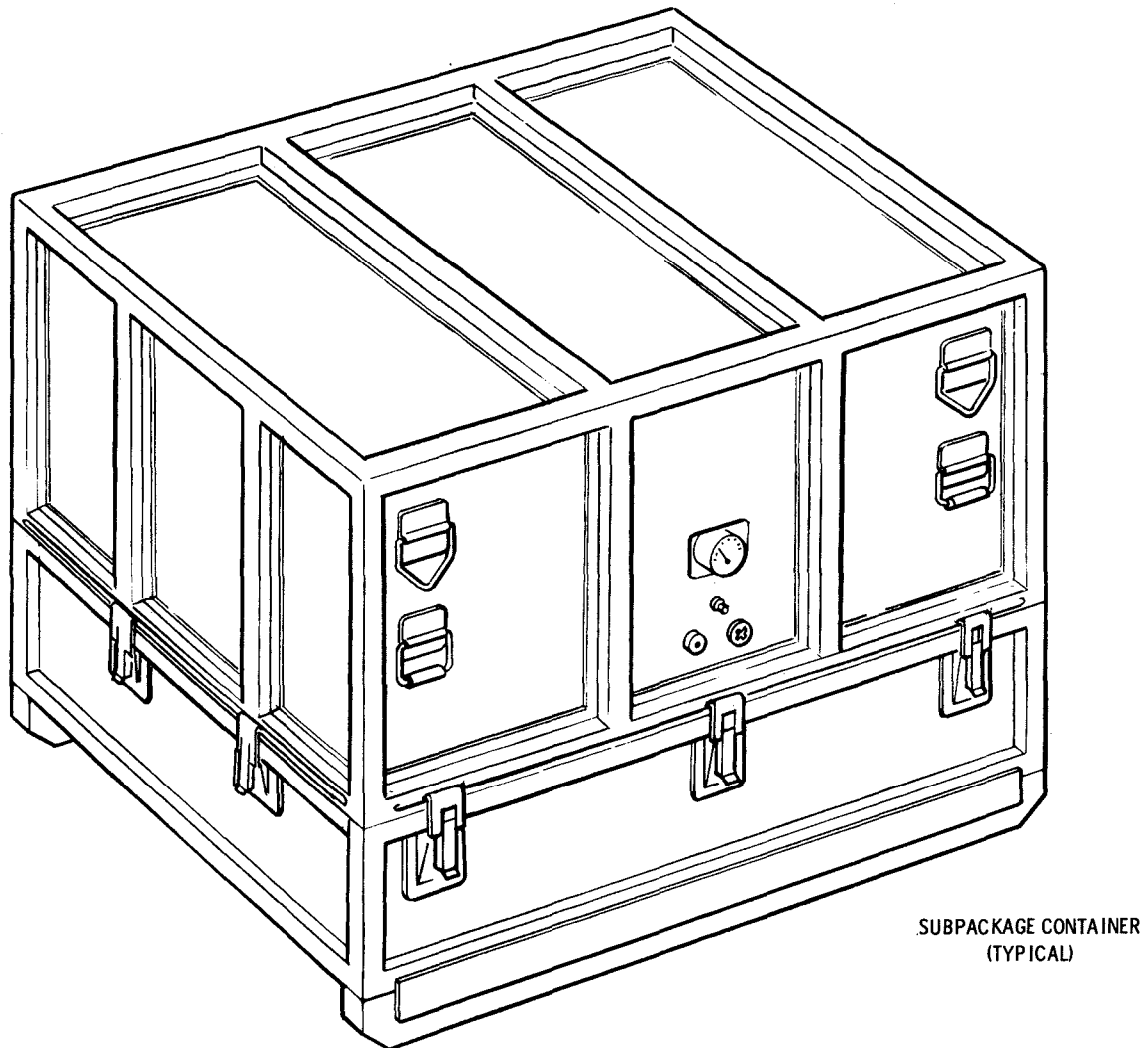


Figure 3-4. Shipping Container

The LRRR deployment area is chosen to minimize degrading conditions such as heat, dust, and debris which could be brought about by the LM, ASEP, or other lunar equipment. The LRRR was deployed within the deployment area specified for the Apollo 14 Fra Mauro landing site, 300 or more feet out from the LM in the +Y direction.

Deployment of the LRRR is one of many tasks required of the astronauts during their stay on the lunar surface, and may be combined with other tasks. Only those tasks related to LRRR deployment will be considered here.

The astronaut activities in performing the deployment sequence are as follows:

- a. Walk to the Quad I area of the LM.
- b. Remove and discard the thermal cover from the LM compartment.
- c. Release the LRRR/flight pallet assembly from the compartment tie-down.
- d. Pull the LRRR/flight pallet assembly from the LM compartment, and set it on the lunar surface.
- e. Separate the LRRR from the flight pallet and discard pallet.
- f. Carry the LRRR to the deployment area 300 feet from the LM + Y landing leg, and choose a suitable deployment site. (See Figure 3-5).
- g. Release and extend leveling leg to the locked position. (See Figure 3-6)
- h. Orient the LRRR Array eastward, and set it on lunar surface on its rear supports.
- i. Engage the universal handling tool (UHT) in tool socket.
- j. Remove and discard cover assembly. (See Figure 3-7.)
- k. Rotate the LRRR to the deployment attitude, supported by the leveling leg at an elevation angle of approximately 18 degrees to the lunar surface.
- l. Position the LRRR, using the UHT, to align the sun compass index mark with the gnomon shadow, and center the bubble level. (See Figure 3-8.)
- m. Disengage the UHT from the LRRR.
- n. Check the LRRR alignment and leveling, and report to MSFN.

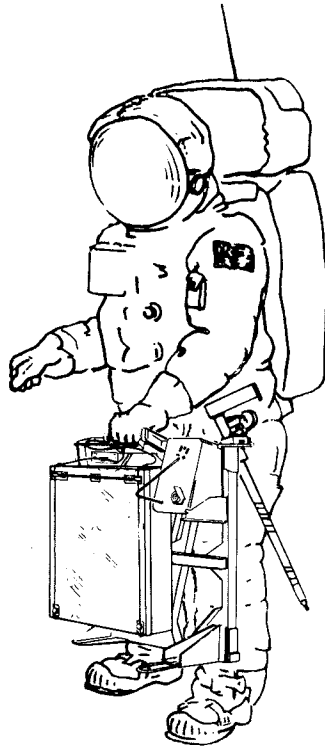


Figure 3-5. Astronaut Carrying Apollo 14 LRRR



Figure 3-6. Astronaut Extending Leveling Leg (Apollo 14 LRRR)

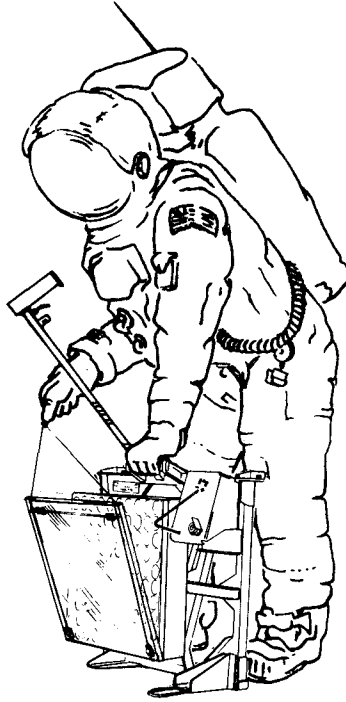


Figure 3-7. Astronaut Removing Dust Cover (Apollo 14 LRRR)

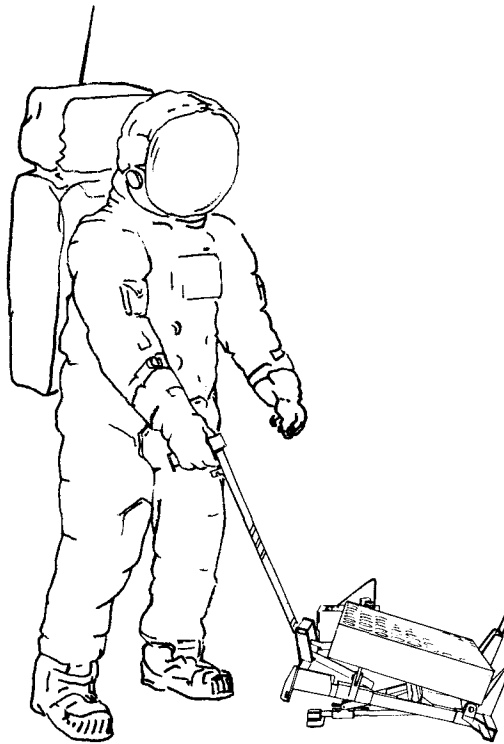


Figure 3-8. Astronaut Aligning and Leveling the Apollo 14 LRRR

3-6. APOLLO 15 LRRR OPERATIONS

3-7. KSC OPERATIONS

KSC operations include those activities from receiving inspection of the LRRR through installation in the LM. These activities include receiving inspection, transportation, handling, and installation as shown in Figure 3-9.

Receiving inspection of the LRRR will be performed at the ALSEP Launch Preparation Site (ALPS).

The LRRR will be removed from the shipping container and the handling ground support equipment (GSE) will be installed. The LRRR, in the GSE, will be transported from the ALPS to the launch unbilical tower (LUT) on the launch pad. It will be elevated to the LUT 260 level holding area, carried across swing arm 7, and handed through the instrument unit (IU) door into the spacecraft/LM adapter (SLA) section of the launch vehicle. The LRRR is then hoisted to the XA 525 level where it will be removed from the GSE. The LRRR is then attached to the Grumman Aircraft Corporation (GAC) flight pallet, and installed on the LM.

3-8. GROUND SUPPORT EQUIPMENT

The ground support equipment required to support Apollo 15 LRRR operations is listed in Table 3-2 and illustrated in Figures 3-2, 3-4, 3-10, and 3-11.

3-9. LUNAR SURFACE OPERATIONS

Lunar environmental conditions impose constraints on hardware deployment by the astronaut. LRRR deployment procedures will be performed at a time when the sun angle from the lunar horizon is 7 to 22 degrees. At a sun angle of 7 degrees, the lunar surface temperature is approximately -50 to -60 degrees F. At a sun angle of 22 degrees, the lunar temperature is +80 to +100 degrees F. LRRR design allows deployment at a maximum sun angle of 45 degrees and a relative lunar surface temperature of approximately +165 degrees F.

The LRRR deployment area is chosen to minimize degrading conditions such as heat, dust, and debris which could be brought about by the LM, ALSEP, or other lunar equipment. The LRRR will be deployed within the deployment area specified for the lunar landing site. The area proposed for the Apollo 15 Hadley Rille landing site is 300 or more feet out from the LM in the +Z direction, 25 feet minimum west of the ALSEP central station.

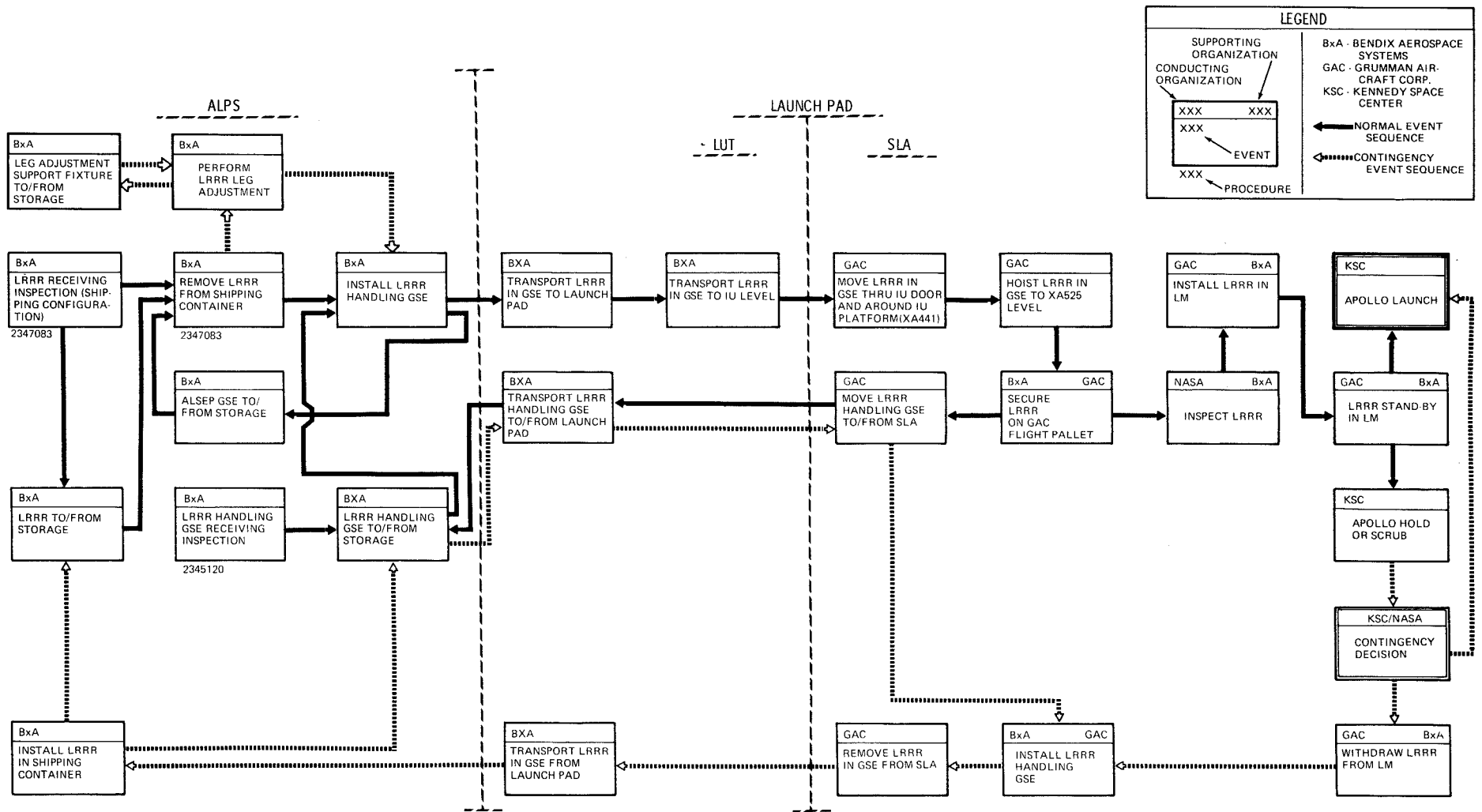


Figure 3-9. Apollo 15 LRRR KSC Operations Sequence

Table 3-2. Apollo 15 LRRR Ground Support Equipment

Nomenclature	Function	Part Number
Holding fixture, subpackage No. 2	Attaches to base of LRRR for shipping and handling operations. Mounts to handling cart for movement (ALPS).	2335338
Handling device, subpackage No. 2	Provides tie points for LRRR handling during transfer to LRRR handling fixture (ALPS).	2335313
Handling cart	Provides mounting tie down for LRRR on holding fixture during handling (ALPS).	2332899
Hoisting device	Attaches to holding fixture or handling device for LRRR hoisting operations (ALPS).	2335310
Handling fixture, LRRR	Attaches to LRRR for transportation and handling operations (ALPS/SLA).	2346988
Protective cover, LRRR	Provides environmental protection for LRRR during transportation and handling operations (ALPS/SLA).	2340583
Sling assembly	Attaches to handling fixture for hoisting LRRR in horizontal attitude (ALPS/SLA).	2340585
Sling assembly	Attaches to handling fixture carrying handle for hoisting LRRR in vertical attitude (ALPS/SLA).	2340586
Shipping container, LRRR assembly	Provides physical protection and controlled environment for shipment of LRRR to KSC.	2340599
Support fixture, leg adjustment, LRRR	Provides support for LRRR during leg adjustment operations (ALPS)	2347379
Hoisting device, monorail	Provides means of hoisting LRRR in GSE to XA 525 level in SLA.	(GAC)

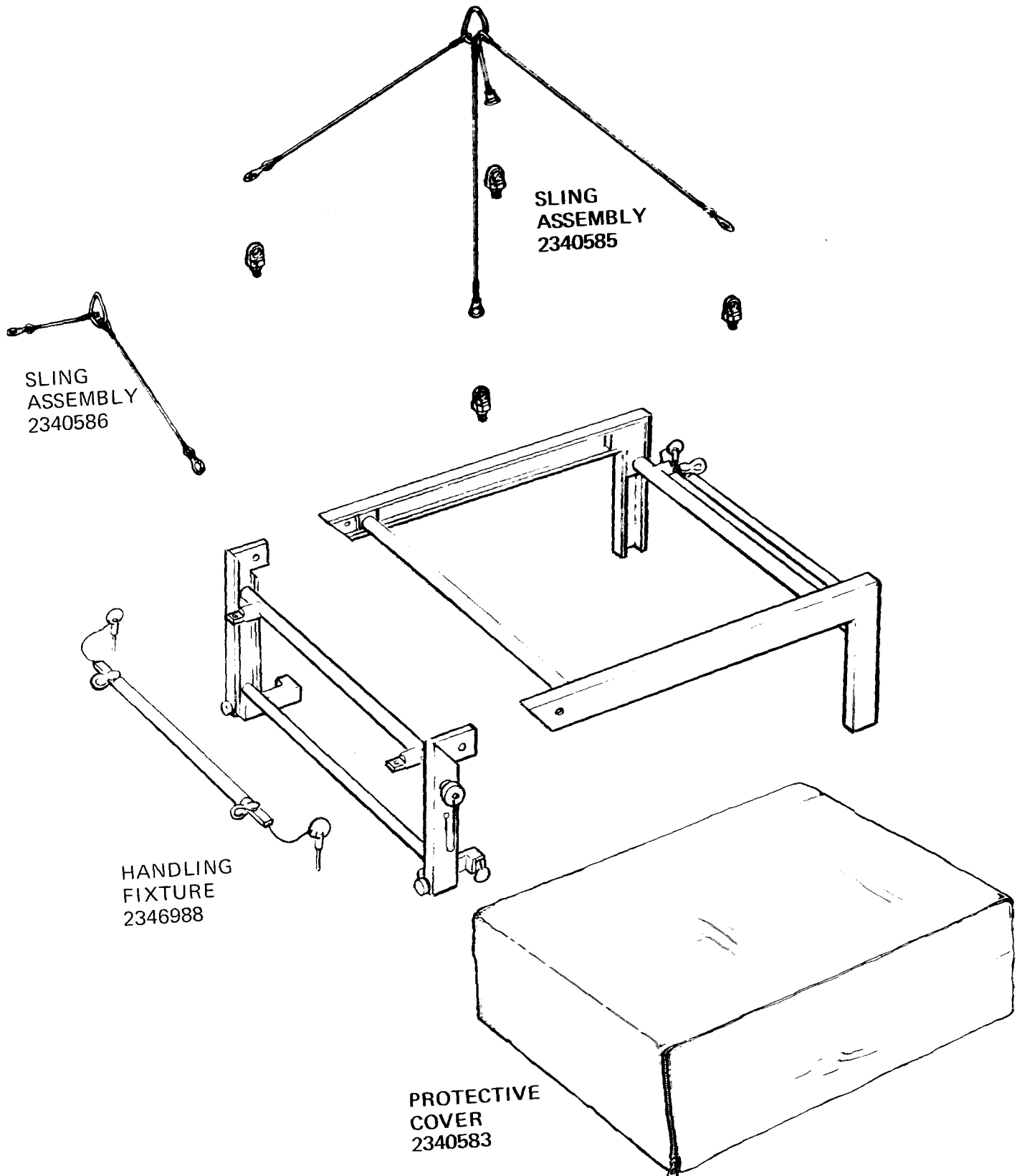


Figure 3-10. Apollo 15 LRRR Handling GSE
(ALPS/SLA)

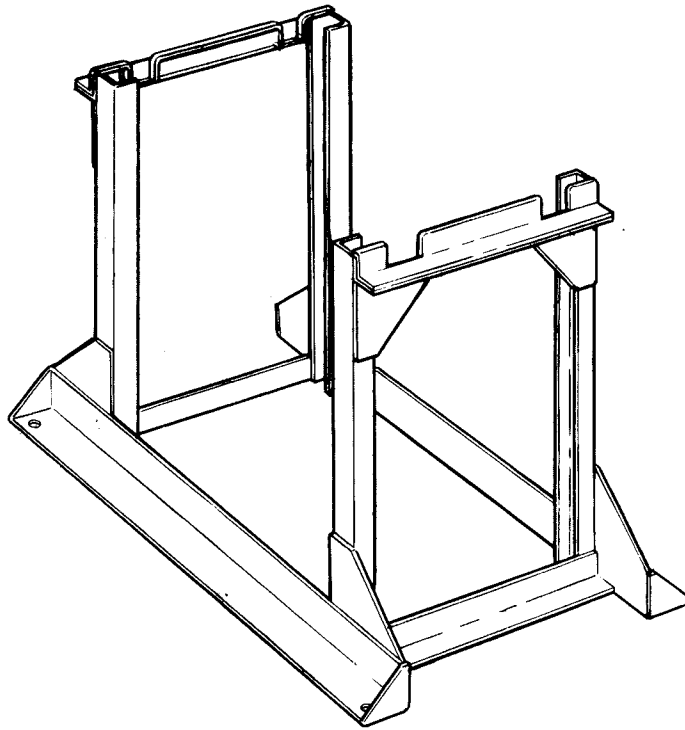


Figure 3-11. Apollo 15 LRRR Leg Adjustment Support Fixture (SLA)

Deployment of the LRRR is one of many tasks required of the astronauts during their stay on the lunar surface, and may be combined with other tasks. Only those tasks related to LRRR deployment will be considered here.

The astronaut activities in performing the deployment sequence are as follows:

- a. Walk to the Quad III area of the LM.
- b. Release the LRRR/flight pallet assembly from the LM, and set it on the lunar surface.
- c. Separate the LRRR from the flight pallet and discard pallet.
- d. Carry the LRRR to the deployment area 300 feet from the LM +Z landing leg, and choose a suitable deployment site 25 feet west of ALEP central station. (See Figure 3-12.)
- e. Orient the LRRR Array south-westward, and set it on lunar surface on its rear supports.
- f. Engage the universal handling tool (UHT) in tool socket.
- g. Unstow and rotate Array B 180° to the deployed position and verify it locked. (See Figure 3-13)
- h. Unstow and extend deployment leg to the locked position. (See Figure 3-14.)
- i. Unstow and rotate sun compass assembly to the deployed position, and verify it locked. (See Figure 3-15.)
- j. Remove and discard dust cover assemblies. (See Figure 3-16)
- k. Rotate the LRRR to the deployment attitude, supported by the deployment leg at an elevation of approximately 26 degrees to the lunar surface.
- l. Position the LRRR, using the UHT, to align the sun compass index mark with the gnomon shadow, and center the bubble level. (See Figure 3-17.) The alignment and leveling devices are illustrated in Figure 3-18.
- m. Disengage the UHT from the LRRR.
- n. Check the LRRR alignment and leveling, and report to MSFN.

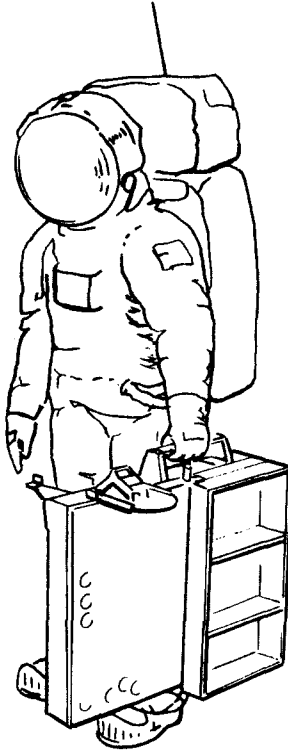


Figure 3-12. Astronaut Carrying Apollo 15 LRRR

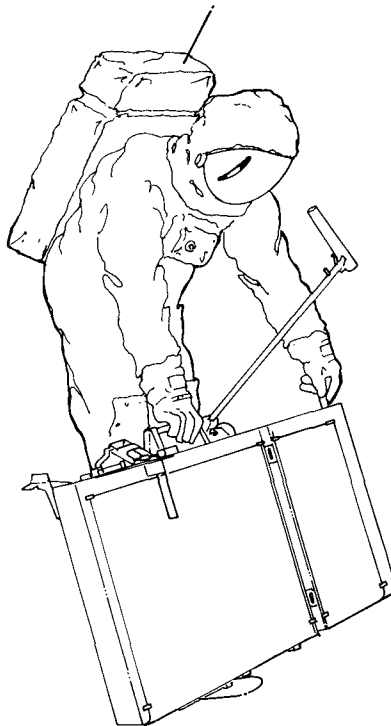


Figure 3-13. Astronaut Deploying Array Panel
(Apollo 15 LRRR)



Figure 3-14. Astronaut Extending Deployment Leg
(Apollo 15 LRRR)

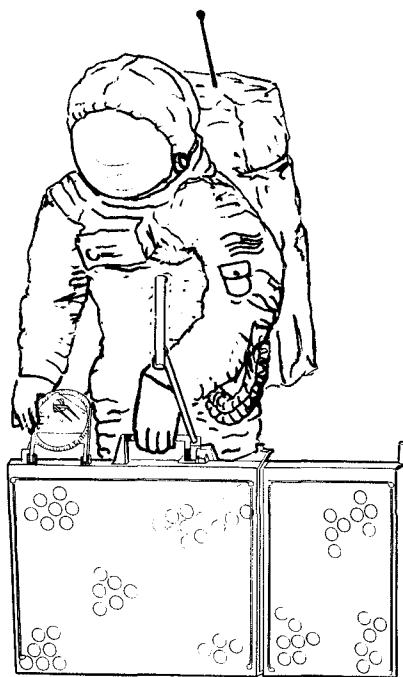


Figure 3-15. Astronaut Deploying Sun Compass
(Apollo 15 LRRR)

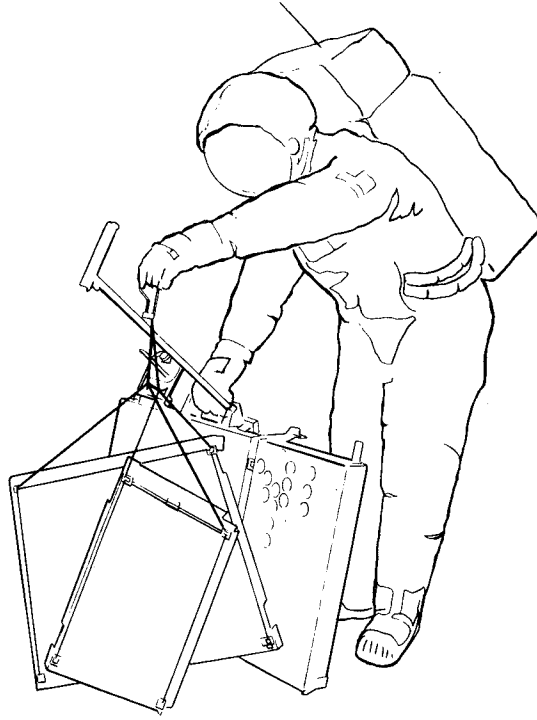


Figure 3-16. Astronaut Removing Dust Covers
(Apollo 15 LRRR)



Figure 3-17. Astronaut Aligning and Leveling
the Apollo 15 LRRR

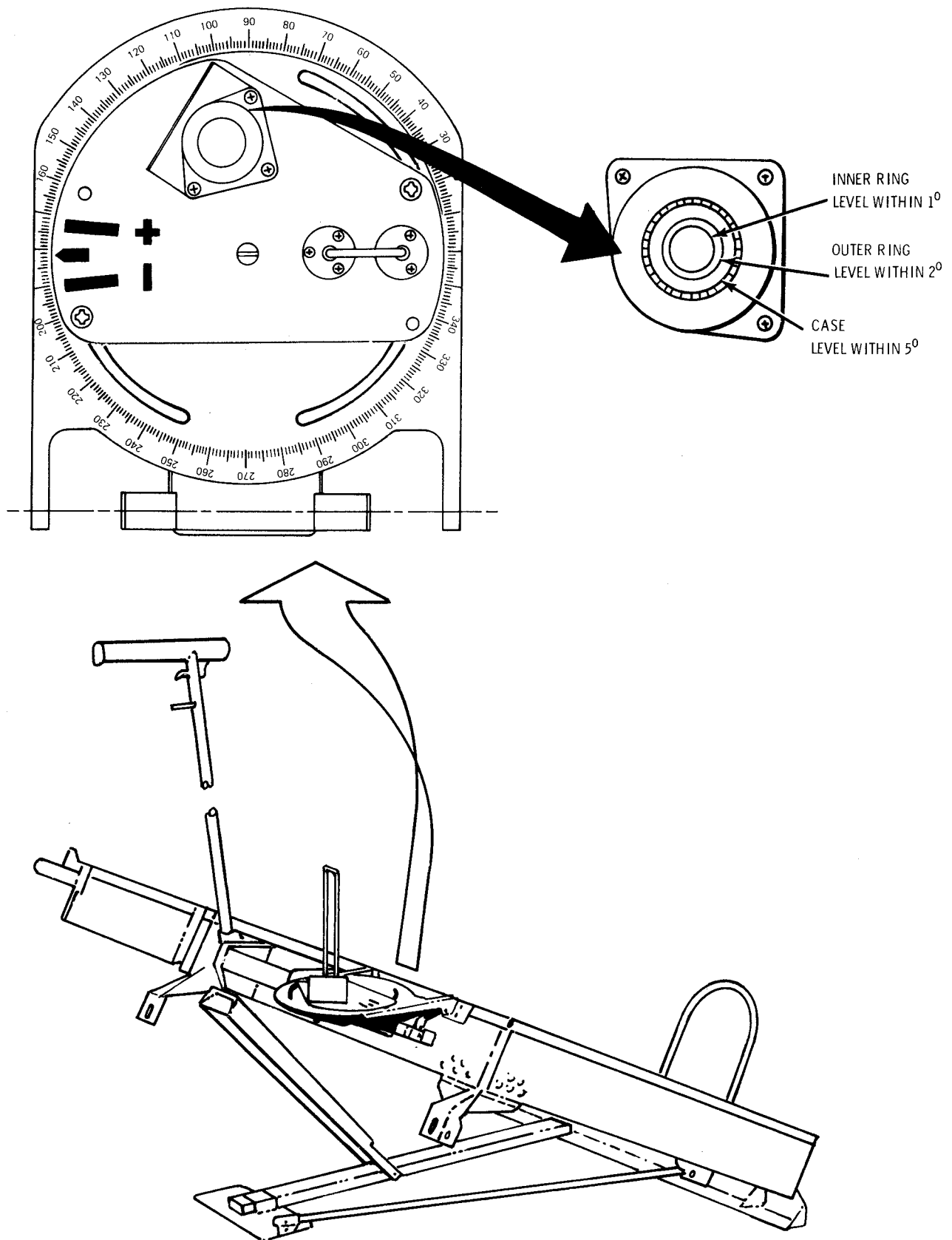


Figure 3-18. Apollo 15 LRRR Alignment and Leveling Devices