INTERFACE CONTROL SPECIFICATION

FOR

ASTRONAUT/LRRR (300)

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Approved for The Bendix Corporation

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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).