Bendix

Aerospace
Systems Division

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R. MILEY
BxA/MSC

AL 900133

PERFORMANCE AND DESIGN REQUIREMENTS

FOR

LUNAR SURFACE GRAVIMETER EXPERIMENT SUBSYSTEM

FOR

APOLLO LUNAR SURFACE EXPERIMENTS PACKAGE SYSTEM

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Contract No. NAS 9-5829

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1.0 SCOPE

1.1 Scope. - This document specifies the performance and design requirements for the Lunar Surface Gravimeter Experiment subsystem (herein after referred to as the LSG) of the Apollo Lunar Surface Experiment Package (ALSEP). The objectives of this experiment are:

a. To utilize the moon as an antenna to search for gravitational radiation from cosmic sources, by search for the lowest frequency free oscillations.

b. To measure the lunar deformation associated with tidal forces in order to obtain information on the internal structure of the moon.

c. To provide vertical axis seismic activity information up to frequencies of 16 cycles per second.

d. To measure the ratio of lunar g to earth g.

The LSG consists of three major assemblies: (1) sensor package assembly, (2) electronics assemblies and (3) structural/thermal assembly.

1.2 Associated equipment. - The LSG shall be capable of operating in conjunction with the following equipment (which is not part of this specification) in accordance with the requirements set forth within this specification; (a) ALSEP Structure/Thermal Subsystem, (b) ALSEP Data Subsystem, (c) ALSEP Power Subsystem, (d) ALSEP GSE and (e) LSG GSE.

The LSG is designed to operate on the Lunar Surface in conjunction with the ALSEP Central Station. The Central Station is defined as the data subsystem including supporting structure and thermal control, and the power conditioning unit including supporting structure and thermal control.

2.0 APPLICABLE DOCUMENTS

The following documents, of the issue shown, form a part of this specification to the extent specified herein. In the event of a conflict the requirements of this specification shall be considered the superseding requirement.

STANDARDS AND SPECIFICATIONS

Military

MIL-STD-130	Identification Marking of U.S. Military Property
MIL-STD-721B	Definition of Effectiveness Terms for Reliability, Maintainability, Human Factors and Safety
MIL-W-6858C	Welding Resistance: Aluminum, Mangesium, Non-hardening Steels or Alloys, Nickel or Alloys, Heat Resistance Alloys, Spot and Seam
MIL-STD-810B (USAF)	Military Standard Environmental Test Methods for Aerospace and Ground Equipment
MIL-STD-889	Definition of Dissimilar Metals
MIL-E-5272C(1)	Environmental Testing, Aeronautical and Associated Equipment, General Specification for
MIL-STD-143A	Specification and Standards, Order of Precedence for the Selection of

NASA

NHB 5300.4 (3A)	Requirements for Soldered Electrical Connections
NHB 8040.2	Apollo Configuration Management Manual

Grumman Aircraft Corporation (GAC)

LED-520-1F	Design Criteria and Environment for the LM
LSP 390-8A	Connectors, Miniature Circular, Electrical Power Subsystem Design Control Specifications

Other Documents

NASA

DS-1	System Accessibility for Maintenance
DS-3	Electrical Connectors - Keying
DS-5	Transistors - Selection of Types
DS-7	System Checkout Provisions
DS-12	Single Point Failures
DS-22	Flammability of Wire Bundles
PS-6	Ultrasonic Cleaning Electrical and Electronic Assemblies
PS-8	Application of Previous Qual Tests
PS-10	Protective Covers or Caps for Receptacles and Plugs - Electrical
PS-11	Direct Procurement of Parts

Bendix Aerospace Systems Division

SS-100000	Technical Specification for Apollo Lunar Surface Experiments Package System.
ARD 501	Performance/Design and Product Configuration Specification for the Gravimeter Sensor Component of the LSG
AL 770000	ALSEP EMI Specification
AL 902131	Performance/Design and Product Configuration Specification for Mechanical and Thermal Components of the LSG
IC 314133	Interface Control Specification for the Lunar Surface Gravimeter Experiment
AL 902132	Performance/Design and Product Configuration Requirements Specification for Electrical Components of the LSG
ATM-241 Rev. E	Acceptable Parts List for ALSEP
ATM-242, Rev. E	Approved Materials for ALSEP Equipment
Exhibit A Array E Contract NAS9-5829	Statement of Work for ALSEP option 5 Lunar Surface Gravimeter Experiment
AL 902133	Performance/Design and Product Configuration Specification for the LSG Experiment Test Set
Exhibit B Schedule III Contract NAS 9-5829	Technical Specification Array E

DRAWINGS

Bendix

2338102	Universal Handling Tool
CA 2773	Bolt, Positive Locking
2335931	Guide, Fastener
2334675	Cap, Guide, Fastener
2345869	Bubble Level Specification Drawing
2348600	ICD - LSG Experiment

(Copies of specifications, standards, drawings, bulletins and publications required by suppliers in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

3.0 REQUIREMENTS

3.1 Performance

3.1.1 Mission Capabilities. - The LSG shall be capable of being transported to the moon (stowed in the ALSEP) and deployed on the lunar surface by one astronaut with a minimum expenditure of energy and maximum safety. The LSG shall be capable of operating for a period of two years after deployment and must include provision for activation through earth command.

3.1.1.1.1 Installation of LSG into ALSEP. - Final installation of the LSG into ALSEP shall take place at the Contractor's facility prior to delivery of ALSEP to KSC. After ALSEP has been delivered to KSC no repairs will be made to the LSG experiment except replacing the complete subsystem.

3.1.1.2 Installation of ALSEP into LM. - ALSEP shall be installed into LM nominally 100 days but not less than 45 days before launch.

3.1.1.3 Translunar Flight - The LSG shall be inoperative during translunar flight. There shall be no necessity for checkout or servicing of the LSG during this phase of the mission.

3.1.1.4 Lunar Surface Operation

3.1.1.4.1 Deployment - Deployment of the LSG shall be in accordance with the human factors requirements of paragraph 3.1.3.6 and 3.3.13. The system design shall be such that under normal conditions the entire ALSEP can be deployed by two astronauts in 120 minutes or by one astronaut in 180 minutes after removal from LM.

3.1.1.4.2 Activation - Activation of the LSG experiment shall be by Earth command after the completion of ALSEP deployment.

3.1.2 Operational Characteristics - The LSG shall have the following operational characteristics when in operation on the lunar surface.

3.1.2.1 Sensor Assembly Description and Characteristics - The sensor shall be a Short Range, Model D (Lunar), LaCoste and Romberg gravity meter as defined in ARD 501. This is a very sensitive mass-spring system incorporating a differential capacitor that senses the position of the suspended mass and provides an electrostatic force input to this mass.

3.1.2.2 Electronics Assembly Description and Characteristics - The electronics shall operate as defined in AL 902132. The LSG electronics accepts the signal provided by the sensor, amplifies and conditions the signal, and feeds it back as a correction to the sensor. Three voltages are measured. One is proportional to the instantaneous servo error voltage. This is the seismic output. The second voltage is the servo voltage required to restore the mass to its equilibrium position. This measures the lunar tide. The third voltage is the amplified output of a high pass tidal frequency cut off filter. When Fourier analyzed this can provide information on the lunar free oscillations in search for gravitational radiation.

Outputs are provided in three band pass ranges:

a. Tidal: dc to 1 cycle/minute

b. Free oscillation: 2 cycles/minute to 1 cycle/20 minutes

c. Seismic: 0.05Hz to 16 Hz

Thirty-six data words are sampled in the normal electrostatic servo mode as follows:

	Samples per Frame,	Bits per Sample	Bits per Frame
Seismic	31	10	310
Tide	1	10	10
Free Mode	1	10	10
Temperature	1	10	10
Command Reg. Status	1	10	10
Experiment Operate Status	1	10	10

These data are sampled and fed in digital form to the ALSEP Central Station each data frame. The seismic, tide and free mode samples provide scientific data and the temperature sample is used to monitor sensor temperature for long term drift correction. The status word provides information regarding the various relays as an indication of gravimeter operating status. The command register status word provides status of the command register.

On special command the screw servo encoders are sampled as shown below:

	Samples per Frame	Bits per Sample	Bits per Frame
Coarse Encoder (MSB)	9	9	90
Coarse Encoder (LSB)	9	10	90
Fine Encoder (MSB)	9	9	90
Fine Encoder	9	10	90

The screw servo mode provides encoder readout. Since the shaft encoders are 19 bit encoders, the first data word provides the 9 most significant bits of the coarse encoder, the second work gives the 10 least significant bits of the coarse encoder, the third word provides the 9 most significant bits of the fine encoder, and the fourth word gives the 10 least significant bits of the fine encoder. This information is repeated nine times during a frame. The additional bit available for both coarse and fine encoder is not used.

In addition, ten analog signals are routed over the analog lines to the Central Station each ninety frames to provide engineering data. These analog signals also serve as backup for prime science data.

3.1.2.3 Thermal Control - Thermal control shall be in accordance with AL 902131 and the following:

3.1.2.3.1 Operation. - The sensor shall be designed to be calibrated on Earth at its spring inversion temperature of $50 \pm 2^{\circ}C$. The specific temperature shall be determined for each instrument. The control of the sensor operating temperature shall be better than $0.001^{\circ}C$ for short term (up to 30 minutes) stability. The thermal design of the instrument shall provide for less than $0.1^{\circ}C$/month long term drift when operated on the lunar surface with a design goal of less than $0.01^{\circ}C$/month.

The correct operating temperature will be determined on the lunar surface following deployment by using the instrument as a thermometer and by adjusting the operating temperature through sixty-four, fifty-millidegree steps providing at least 26 steps on either side of the inversion temperature determined by LaCoste and Rombers.

3.1.2.3.2 Internal Heat Production. - The thermal control system shall be designed to dissipate up to 2.1 watts of steady state electronics power plus 0.4 watts of heater power during lunar noon and shall also be designed to maintain the required internal temperature with a maximum steady state power of 8.2 watts (electronics package, heater box heater and instrument housing heater) of internal heat input during lunar night. During the lunar night condition heat leak through the multilayer insulation assembly and support system shall not exceed 1.0 watt when the internal surface of the assembly is maintained at $125^{\circ}F$ and the external surface of the assembly is maintained at $-300 \pm 20^{\circ}F$ in a steady state condition. These conditions shall be met regardless of the operating temperature ($50 \pm 3.3^{\circ}C$).

3.1.2.3.3 Thermal Considerations. - The thermal design shall provide for all lunar surface temperatures for LSG operations as specified in LED 520-1. The design shall be based on the following variables:

a. Leveling tolerance ($\pm 3^{\circ}$)

b. Seasonal sun variation ($\pm 1.51^{\circ}$)

c. Sun tilt angle setting mechanical tolerance (0.5°)

d. Alignment to lunar equator tolerance ($\pm 3^{\circ}$)

e. Total included sun angle (0.5°)

3.1.2.3.4 Thermal Barrier. - Each wire which interfaces with the thermal barrier of the LSG experiment shall contain a manganin insert which exhibits the same thermal resistance equivalent to or less than an 8.0 inch section of a 24 AWG standard manganin wire in order to minimize thermal losses. This low thermal resistance wire equivalent exhibits an electrical resistance of 0.44 to 0.6 ohms per insert at 20°C. Provision will be made for connecting the manganin wires on both sides of the thermal interface. Heat leak through this assembled cable shall not exceed 0.1 watt during lunar day or night conditions.

3.1.2.4 Sensitivity. - The LSG shall have the sensitivity to measure deviations in lunar surface acceleration of one part in 10^{10} or better. The output sensitivity shall be up to the limits set by the thermal fluctuations of the sensor, as a design goal. As a design goal, the instrument shall measure the ratio of lunar g to earth g with a precision of 1 in 10^5. The noise performance shall be equal to or exceed the performance measured on the engineering model electronics developed by the University of Maryland.

3.1.2.5 Accuracy and Precision. - The accuracy of the LSG in measuring lunar tide amplitudes shall be 0.1 percent or better. The resolution for individual measurements shall be limited solely by the quantization errors of analogue to digital conversion.

3.1.3 Operability

3.1.3.1 Reliability. - As a design goal the LSG, excluding the LSG gravimeter sensor, shall have 0.90 probability of surviving launch, translunar flight, and lunar surface operation (including deployment) in the environment specified in paragraph 3.1.3.4 herein. This probability goal is predicted on an operating life of 2 years. The design shall provide maximum resistance to single point catastrophic failures.

3.1.3.2 Maintainability. - Component arrangements, accessibility for maintenance and interchangeability features shall be incorporated into the design to provide for efficient pre-flight maintenance as defined in MIL-STD-721. The requirements of DS-1 and DS-7 shall apply.

3.1.3.3 Useful Life - The LSG shall be capable of performing as specified herein during all phases of lunar day and night for a period of two years, after a maximum storage period of 3 years. (The design goal for overall experiment life shall be 5 years).

3.1.3.4 Environment Requirements. - The experiment subsystem shall be capable of performance as specified herein after being subjected to the most severe environmental conditions shown in IC 314133 or any logical combination of these environments applied simultaneously. The most severe environmental values shown in IC314133 are minimum design requirements. Testing shall be in accordance with specification MIL-E-5272 and standard MIL-STD-810, as applicable.

3.1.3.4.1 Lunar Surface Environment - The surface environment shall be as defined by document LED 520-1 except that shock while stowed in ALSEP shall not exceed a 20g/11 msec sawtooth shape acceleration pulse as defined in IC 314133.

3.1.3.4.2 Mission Environment Phase - The mission environment phases shall be in accordance with IC 314133.

3.1.3.5 Ground Handling and Transportability - Full design recognition shall be given to the durability requirements of the experiment subsystem during the pre-flight preparation. However, special packaging and transportation methods shall be used to minimize design penalties.

3.1.3.6 Human Factors. - The LSG shall be designed to be simply, efficiently, and safely deployed by one suited astronaut. The astronaut interfaces are defined in IC 314133

3.1.3.6.1 Deployment Time - The total time required for the astronaut to deploy the LSG shall not exceed 5.0 minutes.

3.1.3.6.2 Alignment and Leveling - Provisions for leveling and alignment shall be simple and easy to utilize and shall provide a rapid method of achieving and identifying an "in-tolerance" leveling of the LSG to within $\pm$ 3° of true lunar vertical. The tilted sunshade design shall perform as a tilted gnomon and compass to permit alignment within ±3° to the suns shadow. The tilted gnomom design shall be capable of operation when deployed ±25° latitude and ± 65° longitude.

3.1.3.6.3 Emplacement. - The experiment shall be placed approximately 25 feet from ALSEP with the tilted sunshade pointed toward the equator.

3.1.3.6.3.1 Site Selection. - The deployment site selection by the astronaut shall be approximately horizontal (the astronaut shall avoid setting the experiment down on the slopes of craters or outcroppings) and relatively smooth (the astronaut shall avoid setting the experiment atop rubble). In addition, the astronaut shall select a site which allows for stable leveling within the $\pm 3^{\circ}$ tolerance that is consistent with leg and foot design criteria as specified in paragraph 3.1.3.6.3.2 herein.

3.1.3.6.3.2 Deployment Surface. - The LSG shall be deployed on the lunar surface on a slope which does not exceed 5 degrees. A lunar soil bearing strength of 1 to 2 psi per inch depth is assumed for foot and leg design.

3.1.3.7 Safety. - Safety requirements shall comply with the limitations of the suited astronaut and the following:

3.1.3.7.1 Personnel Safety. - The safety of the crew while unloading, transporting and deploying the equipment on the lunar surface and of personnel while handling the equipment on earth shall be a prime consideration in the LSG design. This shall include avoidance in the equipment design of abrasive surfaces and sharp edges, corners and protuberances. Inherent protection of personnel from inadvertent contact with high temperature surfaces, explosive hazards and hazardous electrical points shall be provided. The requirements of DS-22 shall apply.

3.1.3.7.2 Equipment Safety. - Where practical, the various components shall be hermatically sealed or of explosive proof construction.

3.1.3.7.3 Hazard Proofing. - The design of the LSG subsystem shall minimize the hazard of fire, explosion and toxicity to the crew, launch area personnel and facilities. The hazards to be avoided include accumulation of leakage of combustible gases, spark or ignition sources (including static electric discharge) and toxicity due to inhalation or spillage of volatile or poisonous expendables.

3.1.3.7.4 Fail Safe. - Part or component failures shall not propagate sequentially. The requirements of DS-12 shall apply.

3.2 Interface Requirements. - The interface requirements are defined in IC 314133.

3.3 Design and Construction. - To fulfill the performance requirements the experiment shall be configured into a single package containing the sensor, the electronics package and the appropriate housing and thermal protection equipment. The sole electrical connection with ALSEP shall be via a flat conductor, ribbon cable.

3.3.1 General Design Features

3.3.1.1 Size and Form Factor. - The size and form factor of the LSG shall be constrained by the requirements of ICD 2348600.

3.3.1.2 Weight. - The weight of the experiment shall be maintained at a minimum and shall not exceed 25 pounds.

3.3.1.3 Center of Gravity. - The center of gravity shall be as shown on ICD 2348600.

3.3.1.4 Power. - The total power required by the experiment shall be maintained at a minimum and shall conform to IC 314133.

3.3.2 Selection of Specifications and Standards. - Requirements for selection of specifications and standards shall be in accordance with specification SS-100000.

3.3.3 Materials, Parts and Processes. - To the extent feasible, parts, materials and processes shall be the same as those which were chosen and qualified for use in previous ALSEP Arrays. Bendix documents ATM-241 and ATM-242 shall be used for selection and derating of parts and materials. All parts, materials and processes shall be compatible with the intended use, the environment requirements specified in 3.1.3.4 herein and shall be selected to meet the operating and storage life requirements set forth in paragraphs 3.1.3.3 and 3.3.11, herein.

3.3.3.1 Materials. - Bendix document ATM-242 shall be used to select materials in accordance with ALSEP program requirements. All materials not selected from ATM-242 shall be subject to Nonstandard Parts and Material Request approval procedures prescribed in ATM-242, with the exception of materials used by LaCoste and Romberg in their sensor. Materials used in the fabrication or processing of flight type ALSEP hardware shall be of the highest quality compatible with design requirements specified herein. The following types of materials shall not be used without prior written approval of NASA:

a. Flammable materials

b. Toxic materials

c. Unstable materials

d. Plastic - (Only epoxy resin-based compounds, teflon, mylar and those specified in ATM-242 shall be used.)

e. Dissimilar metals in direct contact which tend toward active electrolytic or galvanic corrosion.

3.3.3.2 Standard Processes. - Standard processes used during equipment fabrication shall conform or be equivalent to applicable government standards. The order of precedence for selection of specifications and standards shall conform to standard MIL-STD-143. The contractor may submit in-house fabrication specifications for NASA approval.

3.3.3.2.1 Soldering. - NASA Publication NHB 5300-4(3A) shall apply for hand soldering of all electrical connections.

3.3.3.2.2 Welding. - Resistance welding (spot and seam) shall conform to specification MIL-W-6858.

3.3.3.2.3 Ultrasonic Cleaning. - The requirements of PS-6 shall apply.

3.3.3.3 Standard Parts. - Electrical, Electronic and Electromechanical parts shall be selected based on the order of preference and application criteria set forth in Bendix document ATM-241. Mechanical standard parts shall be selected from NASA Standard parts, Air Force-Navy (AN), Military Standards (MS) or joint Air Force-Navy (JAN), as applicable.

3.3.3.3.1 Electrical Connectors. - Where applicable, electrical connectors shall conform to Document LSP 390-8. Documents DS-3 and PS-10 shall apply.

3.3.3.3.2 Parts Procurement. - The requirements of PS-8 and PS-11 shall apply.

3.3.3.3.3 Transistors. - The requirements of DS-5 shall apply.

3.3.4 Standardization. - Maximum economic standardization of parts and components shall be provided. Where identical or similar functions are performed in more than one application, effort shall be made to use only one item design for all applications.

3.3.5 Moisture and Fungus Resistance. - Materials which are not nutrients for fungus shall be used whenever possible. The use of materials which are nutrients for fungus shall not be prohibited in hermetically sealed assemblies and in other accepted and qualified uses such as paper capacitors and impregnated transformers.

If it is necessary to use fungus nutrient materials in other than such qualified applications, these materials shall be treated with a process which will render the resulting exposed surface fungus resistance.

3.3.6 Corrosion of Metal Parts. - Metals shall be of corrosion-resistant type or suitably treated to resist corrosive conditions likely to be met in storage or normal service. Unless suitably protected against electrolytic corrosion, dissimilar metals, as defined in Standard MIL-STD-889 shall not be used in direct physical contact.

3.3.7 Interchangeability. - Items of equipment with the same part numbers shall be physically and functionally interchangeable as defined in MIL-STD-721.

3.3.8 Workmanship. - Workmanship requirements for the experiment shall comply with the requirements of Specification SS-100000.

3.3.9 Electromagnetic Interference (EMI). - The design and construction of the experiment shall be in accordance with the EMI requirements defined in the specification, IC 314133. EMI specification AL 770000 shall apply.

3.3.10 Identification and Marking. - The experiment shall be marked for identification in accordance with Standard MIL-STD-130.

3.3.11 Storage. - The experiment shall have a shelf life of 3 years. Shelf life is defined as a storage period in a controlled environment of 50°F to 80°F and a relative humidity of no more than 50% following acceptance and prior to installation on the LM for flight.

3.3.12 Sensor Package Charge and Seal. - The sensor package shall be charged with 10 $\pm$ 1 torr of dry nitrogen (5-10% helium will be added for leak detection). After charging, the sensor package shall be sealed such that the pressure drop shall not exceed 1 torr per six month period of lunar operation. The design goal shall be 1 torr drop in two years. The helium leak rate, when tested in an atmosphere of less than 0.1 torr, shall be less than 10^{-8} std cc He/sec.

3.3.13 Human Engineering Design Requirements - Hardware external to the LSG, in both the stowed and deployed configuration, shall be designed so that it does not pose any hazard to the suited astronaut, nor does it in any way constitute a potential source of mission degradation by compromising the astronaut's performance.

3.3.13.1 Tie-Down - The Boyd bolts (ref. drawing CA2773), fastener guides (ref. drawing 2335931) and fastener guide caps (ref. drawing 2334675) required for LSG tie-down to the ALSEP structure shall provide simple and quick release and removal by the standing astronaut.

3.3.13.2 UHT. - The Universal Handling Tool (UHT) (ref. drawing 2338102) shall be employed to release the Boyd bolts which fasten the LSG to the ALSEP pallet. A UHT socket shall be provided on the LSG to permit experiment removal by the standing astronaut. UHT engagement markings shall be placed adjacent to the UHT socket as shown on drawing ICD 2348600. The UHT shall be capable of insertion into the socket in such a manner as not to interfere with the deployment of the sunshade.

3.3.13.3 Deployment

3.3.13.3.1 Cable Deployment - The cable reel shall automatically release as the LSG is removed from the ALSEP Pallet. Stowage criteria shall be as defined in ICD 2348600.

3.3.13.3.2 Sunshade. - The sunshade shall be capable of being deployed and locked automatically by one continuous pull of an integral handle. An indication of sunshade tilt angle shall be provided covering the range of 0 to 25°. Numbered major index marks shall be located every 5° to correspond to degrees of latitude, and unnumbered minor index marks shall be located every 1° between major index marks. There is no requirement that consecutive markings be linearly spaced.

3.3.13.3.3 Alignment and Leveling.- Solid lines perpendicular to the hinge joining the upper and lower sunshades shall extend 1 3/4 inches below the hinge on the inside of each lower sunshade. Two lines shall be located on each lower sunshade to represent a $\pm 3^\circ$ misalignment with the suns shadow as cast from the opposite upper sun shade. Each line shall be marked "3°". A 3° bubble shall be provided per reference drawing 2345869 and shall be located on the same side of the LSG as the UHT Socket.

3.3.13.3.4 Gimbal Release. - The gimbal caging release mechanism shall be actuated by pulling a pull ring that shall have an inside diameter of 2.0 inches. A minimum force of 2 pounds shall be required.

3.3.13.3.5 Stability. - The LSG shall be statically stable on a 15° slope with the sunshade deployed and fully tilted.

3.3.13.4 Surfaces: Physical Contact. - Sharp edges, corners, protuberances, burrs and abrasive surfaces shall be eliminated from the exterior of the experiment. The radius of external surface edges, corners and protuberances shall be a minimum of 0.030 inches. Where material thickness does not permit this radiusing, the use of beading is preferred, but the use of telfon tape shall be considered. Exposure to hinging surfaces and other moving parts that might pinch or cut the Extravehicular Mobility Unit (EMU) shall be precluded through the use of guards, detents or friction hinges. Experiment external surfaces shall not exceed $\pm 250^\circ$F during deployment.

3.3.13.5 Surfaces: Visual Aspects. - All experiment 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 which has low reflective properties. Corners, edges, adjustments and control surfaces shall be marked and colored in such a manner as to enhance the contrast quality of those surfaces to the extent this does not affect thermal design or raise external surface temperatures to the point at which degradation of the astronaut's Extravehicular Mobility Unit (EMU) can occur. White matte thermal control paint is the preferred means of thermal control from an astronaut visual standpoint. Gold, aluminized mylar or kapton are the second best materials from an astronauts viewpoint. Second surface mirrors should be avoided entirely or covered while the astronaut is working on the experiment.

3.3.13.6 Visual Tasks. - Visual tasks shall be designed to the optimum viewing angle of the astronaut in the EMU. This angle encompasses a cone of vision circumscribed by 15 degrees left and right, 0 degrees up, and 30 degrees down from the horizontal line of sight. All visual tasks shall be designed for performance within the constraints of the extravehicular protective visor and sun visor. All tasks shall be designed to make full use of the astronaut's shadow, EMU and equipment reflectivity and full sunlight, as required, to obtain the optimum visual advantage. All carry tasks shall be designed to permit the astronaut to view his feet, footing and line of traverse. Sun angle during deployment operations will be between 7 degrees and 45 degrees above the lunar horizon.

3.3.13.7 Similarity of Operations. - Astronaut tasks shall be standardized in order to reduce the probability of "reversal errors" under the stress created by the mission environment, fatigue or other psycho-physiological factors and in order to simplify astronaut training.

4.0 QUALITY ASSURANCE PROVISIONS

The following paragraphs specify the technique by which compliance with the requirements of section 3.0 shall be verified. See paragraph 6.3 herein for the basis of the quality program.

4.1 Inspection. - The following requirements of section 3.0 shall be verified by inspection:

Requirement	Paragraph of Section 3.0 of This Specification
Safety	3.1.3.7
Subsystem Interface Requirements	3.2 (As Applicable)
Size and Form Factors	3.3.1.1
Workmanship	3.3.8
Identification and Marking	3.3.10

4.2 Analysis. - The following requirements of Section 3.0 of this specification shall be verified in whole or in part by review of analytical data and design disclosure documentation.

Requirement	Paragraph
Reliability	3.1.3.1
Useful Life	3.1.3.3
Storage	3.3.11
Materials, Parts and Processes	3.3.3
Standard Parts	3.3.3.3
Moisture and Fungus Resistance	3.3.5
Corrosion of Metal Parts	3.3.6

4.3 Demonstration. - The following requirements of Section 3.0 of this specification shall be verified by demonstration:

Requirement	Paragraph
Lunar Surface Operations and Human Factors	3.1.3.6

4.4 Test - Testing of the LSG shall be performed using the LSG Experiment test set as defined in AL 902133.

4.4.1 Acceptance Test - The following requirements of Section 3.0 of this specification shall be verified by test:

Requirement	Paragraph
Mass Properties	3.3.1.2 and 3.3.1.3
Environment	3.1.3.4
Electromagnetic Interference	3.3.9
Performance	3.1 (As Applicable)
Pressure	3.3.12

4.4.2 Qualification Test - The LSG shall be qualified in accordance with the requirements set forth in Schedule III Exhibit B Paragraph 7.0 of contract NAS 9-5829.

5.0 PREPARATION FOR DELIVERY

5.1 Packaging and Shipping - Packaging and shipping of equipment shall be in accordance with the applicable portions of Exhibit B to Schedule III of the ALSEP contract.

6.0 NOTES

6.1 Specification preparation - This specification was prepared in accordance with the format and content requirements of Exhibit I to document NHB 8040.2.