Bendix

Aerospace Systems Division

Interface Control Specification for Astronaut/ALSEP E	NO. IC 314134	REV. NO.
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R. MILEY
BxA/MSC

Interface Control Specification

for

Astronaut/ALSEP E

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1.0 SCOPE

1.1 Scope

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

1.2 Purpose

This specification establishes the requirements for the interface between the Apollo Lunar Surface Experiment Package (ALSEP) E Model and the astronaut while on the lunar surface. The purpose of this document is to present the crew engineering design criteria, principles and practices required to achieve mission success through the integration of the astronaut into the ALSEP system and to achieve effectiveness, simplicity, efficiency and safety of system operation so as to:

(a) Achieve satisfactory operator performance.
(b) Reduce skill requirements and training time.
(c) Increase the reliability of personnel-equipment combinations
(d) Foster design standarization within the system.

This specification does not alter requirements for system development participation of crew engineering specialists to interpret and implement these practices where necessary and to provide solutions to crew engineering problems which may arise and which are not specifically covered herein.

1.3 Associated Equipment

The ALSEP E Model, 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 ALSEP on the lunar surface. ALSEP 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. Unless otherwise stated, the applicable issue of each document shall be that issue in effect on 1 August 1970. 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 1965

DRAWINGS

Bendix

2338102	Assembly, Universal Handling Tool
2338093	Radioisotope Thermoelectric Generator (RTG)
2348602	Lunar Ejector and Meteorites Experiment (LEAM)
2345431	Sunshield Assy, Heat Flow Experiment (HFE)

2323571	Heat Flow Experiment (HFE)
2348601 2347803	Lunar Seismic Profiling Experiment (LSPE)
2348603	Lunar Mass Spectrometer Experiment (LMS)
2348600	Lunar Surface Gravimeter Experiment (LSG)
2334552	Graphite LM Fuel Cask (GLFC)

SPECIFICATIONS

Bendix

IC314119	Electrical Power (RTG)
IC314130	Lunar Ejector and Meteorites Experiment (LEAM)
IC314131	Lunar Seismic Profiling Experiment (LSPE)
IC314132	Lunar Mass Spectrometer Experiment (LMS)
IC314133	Lunar Surface Gravimeter Experiment (LSG)
IC314109	Heat Flow Experiment (HFE)

IC 314121 Graphite LM Fuel Cask (GLFC)

3.0 REQUIREMENTS

3.1 Performance

The performance requirements for the ALSEP/crew system interface are as follows:

3.1.1 ALSEP

ALSEP shall be capable of safe, rapid, easy and accurate extraction from the LM, RTG fueling, transportation to the deployment site, cable interconnection, experiments deployment, emplacement on the lunar surface, and central station and antenna orientation with respect to the lunar equator, the subearth point, and true lunar vertical.

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 ALSEP.

3.2 Astronaut Interface

The interface which exists between the astronaut and ALSEP occurs during the extravehicular activity on the lunar surface and is necessary for the successful deployment and operation of ALSEP.

Due consideration shall be applied in the design of ALSEP 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.

In applying human factors engineering criteria to the ALSEP 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 Simplicity of Design

The design of ALSEP shall be as simple as possible, consistent with functional requirements and the expected service conditions.

3.2.2 Fail Safe Design

A fail safe design shall be provided in those areas where failure can disable the system or cause a catastrophe through damage to the equipment, injury to the astronaut or inadvertent operation of critical equipment.

3.2.3 Astronaut Safety

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

3.2.3.1 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 ALSEP in those areas where the astronaut might reasonably be expected to be able to make contact with these edges, corners, protuberances, and surfaces.

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.

3.2.3.2 Protection from Thermal Hazards

Two potentially hazardous conditions should be precluded in the design of ALSEP 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 (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.

3.2.3.3 Protection from Explosive Hazards

No category "A" or "B" ordnance devices will be utilized in the design of the astronaut interface. Where actuators and initiators are utilized in the design of ALSEP they should comply with the following requirements:

(a) They shall be Apollo approved and standardized (ASI).

(b) They shall be incorporated into the system in accordance with the latest requirements for range safety.

(c) They will be protected by at least two non-storable commands from ground.

(d) Firing circuits shall be isolated in the ALSEP system and must contain protection from induction, stray voltage, and interference from other circuits in the system.

3.2.3.4 Protection from Electrical Hazards

At no time should ALSEP equipment design or operational tasks permit the astronaut to come in contact with hazardous voltages. As a design goal, no electrical connection tasks should be required of the astronaut unless absolutely necessary. Hardware design should prevent the possibility of the astronaut placing himself between the source and ground. Switches should be incorporated into connectors (if connectors are required) to permit the astronaut to complete the connection prior to activating the circuit. In addition, female connectors should be employed on the source side of a connection and should be recessed in an insulator surface in order to prevent inadvertent contact.

3.2.4 Tools and Work Aids

Integral and detachable tools and work aids shall permit the astronaut to deploy ALSEP from a standing position and shall adhere to the constraints imposed on the astronaut by the EMU.

3.2.4.1 Universal Handling Tool

The Universal Handling Tool (UHT - reference drawing 2338102) which shall be utilized for fastener release, removal, deployment, emplacement, leveling, alignment, manipulation, or adjustment of all ALSEP subpackages and components, shall be designed for utility and simplicity of operation. The UHT design shall provide a tool shaft which is 26.5 inches in length and has the capability of engagement near the head of the tool. The engagement action shall be controllable from the opposite end of the UHT by trigger action. A modified "T" handle grip shall be included in the design of the tool.

Non-slip grip tape shall be provided on the tool shaft to aid the astronaut in the handling of the tool.

Two Universal Handling Tools shall be provided, one for each astronaut.

3.2.4.2 Universal Handling Tool Interfaces

As required, fixed or rotatable interface sockets for the Universal Handling Tool shall be provided on ALSEP. The UHT sockets (ref. drawing 2345431) and UHT engagement markings (ref. drawing 2323571) shall be provided to permit engagement and use of the UHT. The subpackage UHT sockets shall be located on close proximity to the carry handle and shall be angled to permit engagement and disengagement while the subpackages are emplaced either horizontally or vertically. The UHT sockets on the subpallets, RTG cable reel, etc. shall be as close to the center of mass of the deployed configuration as is feasible, taking into account other design constraints, in order to maximize equipment maneuverability.

3.2.4.3 Carry Handles

As required, carry handles shall be provided on the subpackages and subpallets for removal of the subpackages and subpallets, for temporary emplacement on the lunar surface, for transport to the emplacement site and for supporting the subpackages and subpallets during employment. The handles shall be oriented horizontally in line with the direction of carry and as close to directly over the center of mass as possible to insure adequate package maneuverability.

The handle grip cross section shall be 0.65 x 1.25 inches (rectangular or elliptical) and 6.0 inches or more in inside length as a design goal, and a minimum two inch clearance shall be provided around the handle grip for finger ingress.

3.2.4.4 Leveling and Alignment

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" condition. The leveling and alignment devices (i.e., bubble levels and sun compasses) shall be designed to be easily readable from a height of six feet above the lunar surface, with a sun elevation angle between 7 and 45 degrees to the east.

The "in-tolerance" condition for subpackage #1 (Central Station) shall be alignment to within ± 5 degrees of the East-West line, using the partial sun compass, gnoman, and orientation arrow, and leveling to within ± 5 degrees, using the circular bubble level provided on the top of the subpackage.

There is no requirement for leveling or alignment of subpackage #2 (Radioisotope Thermoelectric Generator - RTG).

3.2.4.5 Pull Rings

Pull rings shall be made from strips of plastic or metal wire that will not damage the EMU, shall have an 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. Pull rings shall be international orange (Fed Std 595 #22246) in color.

3.2.4.6 Tie-Down

Tie-down mechanisms such as Boyd bolts or pull pins shall be designed to provide simple release and removal by the standing astronaut.

The standing astronaut shall employ the UHT to release the Boyd bolts. To facilitate fastener release the Boyd bolts shall be enclosed by fastener guides and fastener guide caps. The Boyd bolts shall be releasable by a maximum of 75° of rotation and a release force of less than 10 pounds applied to the handle of the UHT.

The standing astronaut shall either manually release and remove the pull pins or employ the handle of the UHT to release and remove the pull pins. The associated pull ring shall have an inside diameter of no less than 2 inches and the pull pin shall have a pull-to-release force of less than 5 pounds.

3.2.4.7 Subpackages Unloading

The two ALSEP subpackages shall be capable of being removed from LM by one astronaut. Mechanical decoupling of ALSEP from LM shall be accomplished through a linkage which is activated through lanyards by the astronaut. Unloading of both subpackages shall be accomplished automatically by the use of the LM-provided booms, or manually by first decoupling the subpackages from the booms. For the latter purpose, suitable handles shall be provided on each unit for use by the astronaut in lowering it to the lunar surface.

3.2.4.8 Subpackages Back Support

The design of the subpackages shall include back supports which shall be capable of supporting the subpackages in a vertical position on lunar slopes up to 15 degrees.

3.2.4.9 Subpallets

The subpallet assemblies on subpackage #2 shall provide easy and quick removal of the astronaut tools, components and experiments away from the RTG in order to protect the crew and equipment from the heat and high temperature levels of the generator.

The standing astronaut shall manually release and remove the pull pins which fasten the subpallets to the subpackage #2 structure. The associated pull rings shall have a pull-to-release force of less than 5 pounds. After rotating subpackages #2 to the deployed position (horizontal), the standing astronaut shall employ the Universal Handling Tool to release the Boyd bolts which also fasten the subpallets to the subpackage #2 structure. To facilitate fastener release the Boyd bolts shall be enclosed by fastener guides and fastener guide caps.

A U-shaped handle which encloses an area that is 6 inches wide and 2 inches high and locks in position when deployed shall be provided to permit manual removal of the HFE subpallet from subpackage #2 by the standing astronaut. A fixed UHT carry socket shall be provided for use as a back-up in removing the HFE subpallet. A fixed carry socket shall also be provided on the LEAM subpallet to permit removal from subpackage #2 by the Universal Handling Tool.

3.2.4.10 Primary Carry Mode

Provisions shall be included for primary carry mode utilizing an interconnecting bar between the RTG and the Central Station packages. This design shall provide the astronaut with a simple, slip-fit, spring-activated socket, which secures the carry bar to the subpackages . The primary mode of carry bar release from the subpackages shall be a push-button with a pull pin/pull ring mechanism being used as back-up. The design shall provide the astronaut with a telescoping type of carry bar which will include an automatic locking mechanism when fully extended to its maximum length of 40 inches. Two "D" handles oriented horizontally in line with the direction of carry shall be included in the design of the carry bar.

3.2.4.11 Astromate Connectors

The standing astronaut shall manually release and remove the pull pins which fasten the astromate connectors and the cable reels to the subpallet structures. The associated pull rings shall have an inside diameter of no less than 2 inches and the pull pin shall have a pull-to-release force of less than 5 pounds.

Integral U-shaped handles with a cross-sectional gripping surface that is 1 inch wide and 0.5 inch high and encloses an area that is 3 inches wide and 2 inches high shall be provided to permit manual removal of the astromate connectors from ALSEP and simultaneously automatic release of the cable reels.

The standing astronaut shall manually mate the astromate connectors to the Central Station connectors by applying a push-to-engage force that shall not exceed 20 pounds.

Different keyway configurations and orientations and alignment marking locations shall be provided for the astromate connectors to preclude connectors mismate (interchanging).

Locking levers shall be provided on each astromate connector to actuate the "posilok" feature. The astronaut shall manually rotate the astromate connector locking levers 45° to the lock position.

3.2.4.12 Astronaut Switches

The design of the astronaut switches shall comply with requirements in Section 3.2.9 and the following additional requirements:

(a) The switches shall be designed for manual activation through the application of the UHT.

(b) The switches shall be angled to approximately 45 degrees to increase visibility and engagement for manual activation.

(c) The design of the switches shall only require 60 degrees of rotation and shall provide positive stops at the limits of rotation.

(d) The switches shall be labeled and provide a positive indication of switch position i.e. pointers.

3.2.4.13 Central Station Sunshield Deployment

After removing the experiments from subpackage #1 (Central Station) the astronaut shall proceed to release the Sunshield Boyd bolts around the perimeter, the ALSEP antenna Boyd bolts and the inner Boyd bolts. As the sunshield is raised, the side and rear thermal curtains shall be designed to be automatically deployed and positioned except for the Velcro tabs at the corners which the astronaut shall manually secure.

The design of the sunshield shall include telescoping, spring extenders at each corner of the subpackage so that when the sunshield is released the extenders will self-deploy.

3.2.5 Task Design

Task design shall include consideration of PLSS/OPS purge rate and traverse time/distance ratios. Tasks shall be designed to present familiar operational conditions (i.e., sterotype) 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 simplified due to the mobility and fatigue constraints imposed by the pressurized EMU. Distance measurement on the lunar surface for the deployment of ALSEP shall be accomplished by the astronaut pacing off the distance.

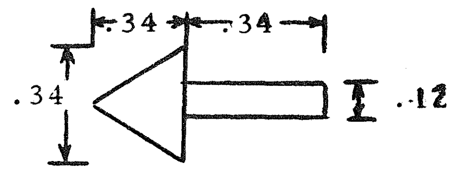
3.2.6 Visual Requirements

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.

3.2.6.1 Design Recommendations for Visual Tasks

The following factors should be considered:

(a) Numerals and letters should be sized as large as other constraints permit. However, character height for all applications other than the antenna aiming mechanism should be no less than 0.34 inch. The width-to-height ratio of the character should be at least two to three. The stroke width of the character should be about one-sixth of the character height. Character separation should be no less than the stroke width of the characters employed. Directional arrows should be configured with the following minimum dimensions:



(b) The design of numerals and letters should be without flourishes. Block numerals and letters are preferred. Openings and breaks should be readily apparent.

(c) Graduation mark height for alignment mechanisms, etc., but excluding the antenna aiming mechanism, should be no less than 0.34, 0.56, and 0.78 inch for minor, intermediate, and major indices, respectively. Graduation mark stroke width should be no less than 0.14 inch. Graduation mark separation should be no less than 0.28 inch. Again, index scales should be sized as large as other constraints permit to facilitate astronaut tasks and avoid errors. The number of graduations between numbered points should not exceed four.

(d) The following numerical progressions are preferred: 1, 2, 3, 4, 5; 5, 10, 15, 20, 25; or 10, 20, 30, 40, 50.

(e) Pointers and scale indices should be oriented so that the pointer is close to the index and yet does not cover numerals or graduation markings (i.e., 0.063 inch maximum). The pointer tip should be the same width as the graduation markings (i.e., 0.14 inch minimum). The pointer and scale index should be mounted nearly flush so that visual parallax is minimized. The pointer should be the same color as the numerals and indices.

(f) Color contrast, in order of preference, for the purpose of providing painted markings, etc., are as follows:

Black on diffused gold.

Black on white.

International orange on white.

White on black.

White on international orange.

Note: Decals shall have black characters on a diffused gold background.

(g) Hazardous areas should be color-coded red-on-white or solid red.

(h) Equipment design (i. e., through the use of highly reflective surfaces) and task selection (i. e., having the astronaut facing eastward toward the sun) which require the astronaut to place himself in such a position that the full intensity of the sun will fall within his range of vision should be avoided.

3.2.6.2 Labeling

Items of equipment that must be located, identified, read, or manipulated should be appropriately and clearly labeled to permit rapid and accurate human performance. No label will be required on equipment whose use is obvious to the user. The characteristics of the labeling to be used should be determined by such factors as:

(a) The accuracy of identification required.

(b) The time available for recognition or other responses.

(c) The distance at which the labels must be read.

(d) The illumination level and color characteristics of the illuminant.

(e) The criticality of the function labeled.

Labels, and information thereon, should be oriented horizontally so that they may be read quickly and easily from left to right. Vertical orientation should be used only when labels are not critical for personnel safety or performance and where space is limited. Labels should be placed on or very near the items which they identify so as to eliminate confusion with other items and labels. Labels should be located so as not to obscure any other information needed by the operator. Labels should be located in a consistent manner throughout the equipment and system.

Labels should primarily describe the functions of equipment items. Secondarily, the engineering characteristics or nomenclature may be described. Standard abbreviations should be selected. If a new abbreviation is required, its meaning should be obvious to the intended reader. Capital letters should be used. Periods should be omitted except when needed to preclude misinterpretation. The same abbreviation should be used for all tenses and for both singular and plural forms of a word. Trade names and other irrelevant information should not appear on labels or placards.

Labels should be as concise as possible, without distorting the intended meaning or information, and should be unambiguous. Redundancy should be minimized, lunar surface "cuff cards" for crew instructions may be assumed. Where the general function is obvious, only the specific function should be identified. Words should be chosen on the basis of operator familiarity whenever possible, provided the words express exactly what is intended. Brevity should not be stressed if the results will be unfamiliar to operating personnel. For particular users (i. e., astronaut personnel), common technical terms may be used even though they may be unfamiliar to nonusers. Abstract symbols (i. e., squares and Greek letters) should be used only when they have a commonly accepted meaning to all intended readers. Common, meaningful symbols (i. e., % and +) may be used as necessary.

Labels and decals should be designed to read easily and accurately at the anticipated operational reading distances, and illumination levels, taking into consideration the following factors:

(a) Contrast between the lettering and its immediate background.

(b) Height, width, stroke width, spacing, and style of letters and numerals.

(c) Method of application (i. e., etching, painting, or silk screen).

(d) Relative legibility of alternative words.

Labels should not be covered or obscured by other units in the equipment assembly. Labels should be sharp, have high contrast, and be mounted so as to minimize wear or obscurement by dirt. Labels should be prepared in capital letters, except that extended copy (i. e., instructions) should be in lower-case letters.

3.2.6.3 Glare

All ALSEP 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. 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).

3.2.6.4 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 and the saturation, and brightness levels for the colors to be used in the marking of the experiment. If required, ALSEP shall have arrow decals or arrow(s) stencilled upon the exterior, indicating proper deployment orientation. ALSEP shall have equipment-peculiar precautions, operating instructions, and engagement markings printed on decals, stencilled or painted on the equipment. The precautions and the instructions shall be readable in the deployed mode and the precautions and engagement markings (and, if possible, the instructions) shall be readable in the stowed mode. The crew shall approve all decals and decal placement. The engagement markings shall be international orange.

3.2.6.5 Visual Displays

Visual displays should be utilized to provide the astronaut with a clear indication of equipment or system conditions commensurate with the operational philosophy of the system under design.

(a) The information displayed to an astronaut should be limited to that which is necessary for him to perform specific actions or make decisions required of him and should be displayed only to the degree of specificity and precision required for a specific astronaut action or decision. Information should be presented to the astronaut in a directly usable form. (Requirements for transposing, computing, interpolating, or mental translation into other units should be avoided). Redundancy in the display of information to an astronaut should be avoided unless it is required to achieve specified reliability.

(b) Displays should be so designed that failure of the display or display circuit will be immediately apparent to the astronaut. Failure of the display circuit should not cause a failure in the equipment associated with the display.

(c) Displays should be located and designed so that they may be read to the degree of accuracy required by the astronaut in the normal operating position.

(d) Display faces should be perpendicular to the astronaut's normal line of sight whenever feasible and should not be less than 45° from the line of sight. Parallax should be minimized. Displays should be constructed, arranged and mounted to minimize the reflectance of the ambient illumination from the glass or plastic display cover.

(e) The viewing distance to displays located close to their associated controls is limited by reach distance and should not exceed 28 inches. Otherwise, there is no maximum limit other than that imposed by space limitations provided that the display is properly designed.

3.2.7 Mobility Requirements

Consideration shall be given in design of tasks and equipment to the following requirements:

(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 minimized or eliminated.

(c) No task shall be designed to include bending forward more than 25 degrees unrestrainted or 45 degrees restrained.

(d) Equipment design will not require the astronaut to assume a kneeling or prone position on the lunar surface.

(e) All equipment shall be designed so that when it is employed in the carry mode the astronaut's feet are not obscured from his vision.

(f) Where latching or unlatching is a requirement, careful attention shall be paid to provide the optimum latch motion. If design constraints dictate that a twisting motion is necessary, it shall be in the direction of easiest wrist joint movement (abduction).

(g) 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.

(h) 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.

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

3.2.8 <u>Force Requirements</u>

ALSEP Components should be designed so that they are operable with a minimum amount of energy expenditure by the astronaut and so that they will not cause the astronaut to lose his balance or in any other way endanger himself. Controls and actuation devices should never require more force for operation than the astronaut can provide.

(a) In no case should an astronaut be called upon to exert more than 20 pounds of force in any given direction. If design requirements necessitate the application of more than 20 pounds of force, a lever arm or geared assist device must be provided.

(b) Care must be taken in the design of astronaut-operated devices that the force required to be applied by the astronaut not exceed the force required to move the equipment being operated. A case in point would be the provision of a 5 pound pull-to-release pip pin to secure a part of a 24 pound earth weight subsystem. When the astronaut exerts 5 pounds of pull force on the 4 pound lunar weight subsystem (1/6 earth weight), the astronaut will inadvertently lift the subsystem rather than release the fastener.

(c) 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 20 pound static load and dynamic loads as high as 60 lbf under lunar surface gravity conditions and in extreme circumstances.

(d) 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.

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

(f) 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.

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

(h) 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.

3.2.9 Control Design

Controls shall comply with the following requirements:

(a) Stops should be provided at the beginning and end of the range of control positions if the switch is not required to be operated beyond the end positions or specified limits.

(b) All controls which have sequential relations, which have to do with a particular function or operation, or which are operated together, should be grouped together along with their associated displays.

(c) Knobs should be used when little force is required, and when precise adjustments of a continuous variable are required. A moving knob and index with a fixed scale is preferred over a moving knob and scale with a fixed index for most tasks. If positions of non-multirevolution controls must be distinguished, a pointer or marker should be available on the knob. Knob size is relatively unimportant, provided the resistance is low and the knob can be easily grasped and manipulated. When space is extremely limited, knobs should approximate the minimum values and should have resistance as low as possible without permitting the setting to be changed by merely touching the control.

(d) Rotary selector switches should be used when ready visual identification of control position is of primary importance and speed of control operation is not critical.

(e) Detent controls should be selected whenever the operational mode requires control operation in discrete steps.

(f) The switch resistance should be elastic, building up, then decreasing, as each position is approached, so that the control snaps into position without stopping between adjacent positions.

(g) Controls should be designed and located so that they are not susceptible to being moved accidentally. Particular attention should be given to critical controls whose inadvertent operation might cause damage to equipment, injury to personnel, or degradation of system functions. Any method of protecting a control from inadvertent operation should not preclude its being operated within the time required.

For situations in which controls must be protected from accidental activation, one or more of the following methods, as applicable should be used:

(a) Locate and orient the controls so that the operator is not likely to strike or move them accidentally in the normal sequence of control movements.

(b) Recess, shield, or otherwise, surround the controls by physical barriers.

(c) Cover or guard the controls. (If the control must be used frequently the cover or guard should be designed so that it may be locked in the uncovered position).

(d) Provide the controls with interlocks so that extra movement (e. g., a side movement out of a detent position or a pull-to-engage clutch) or the prior operation of a related or locking control is required.

(e) Provide the controls with resistance (i. e., viscous or coulomb friction, spring-loading, or inertia) so that definite or sustained effort is required for actuation.

(f) Provide the controls with a lock to prevent the control from passing through a position without delay when strict sequential activation is necessary (i. e., the control moved only to the next position, then delayed).

(g) Design the controls for operation by rotary action.

3.2.10 Antenna Design

The antenna assembly shall contain the capability for leveling and alignment independent of the data subsystem and the following:

(a) The antenna aiming mechanism shall be located high enough to allow the astronaut to perform the aiming task from a standing position.

(b) All aiming mechanism controls shall be located to be easily accessible to the astronaut and within his line-of-sight during aiming. They shall be designed to accommodate the dexterity constraints imposed by the thermal gloves.

(c) Latitude and longitude indices shall be painted black on a white background.

(d) The antenna aiming mechanism shall be pre-aligned in longitude and latitude to the landing site coordinates. The principal tasks for the astronaut shall be leveling and sun compass alignment.

(e) The antenna shall be designed to include a permanently mounted mast in order to simplify and minimize all required assembly tasks and eliminate a potential single point failure.

3.2.11 Fueling and Deploying the RTG

Fueling of the RTG shall be sequentially accomplished as the final tasks prior to leaving the descent stage stowage compartment area. Specific tasks shall be developed and specific design considerations incorporated into the dome removal and fuel handling tools which provide maximum protection for the astronaut at all times during the cask and fuel transfer operations. In addition, positive isolation from RTG heat shall be provided as a means of minimizing heat transfer to the EMU under conditions resulting in the RTG reaching the maximum temperature level prior to deployment. The preferred deployment mode specifies transporting the RTG while it is heating up, but unusual conditions may require RTG transporting at up to maximum temperature. The RTG deployment tasks shall be designed to include an emergency mode of operation to be followed in case the task is interrupted prior to completion.

3.2.11.1 Fuel Cask

The fuel cask shall be located in an area remote from the descent stage stowage compartment. The cask design shall include a permanent thermal barrier (shield) extending at least 180 degrees around the diameter and the full length of the cask. The cask shall also include a device called a "bird cage" to protect the astronaut from inadvertent contact with the heated fuel cask. The cage shall permit tilting of the cask and unrestricted access for removal of the cask dome and fuel capsule.

3.2.11.2 Cask Mounting

A means shall be provided in the design of the cask mounting which will allow the cask to be positioned in a manner which will facilitate safe and easy removal of the fuel cell.

3.2.11.3 Dome Removal Tool

The dome removal tool design shall provide a tool shaft which is approximately 24 inches in length and has the capability of engagement to the top of the fuel cask dome. The engagement action shall be controllable from the opposite end of the tool. An off-center "T" handle grip shall be included in the design of the tool. The DRT will incorporate an automatic fuel cask dome engagement mechanism. After removing the fuel cask dome with the dome removal tool, the dome/tool assembly will be discarded.

3.2.11.4 Fuel Handling Tool

The fuel handling tool design shall provide a tool shaft which is approximately 24 inches in length. At one end of the shaft, a four-inch handle grip shall be mounted, axially; the capsule gripping head shall be attached to the other end of the shaft. The gripping pressure shall be controlled by rotating the handle which in turn shall activate the fingers of the gripping head of the tool, which shall be designed to fit the sockets in the fuel capsule end plate. The tool shall be designed so it cannot be inadvertently released from the fuel capsule. A handle guard which shall be approximately half way down the shaft shall be included in the tool design in order to protect the astronaut from coming in contact with the fuel capsule.

3.2.11.5 RTG Tasks

Tasks concerned with the RTG deployment and emplacement shall be designed to take full advantage of the RTG warm-up period to avoid thermal overloading and reduce contact hazards.

3.2.11.6 Cable Storage and Deployment

A cable reel shall be provided for storing and easily deploying the RTG interconnecting cable. The astronaut task of removing the RTG cable reel from ALSEP shall permit automatic cable deployment concurrent with RTG cable reel carry to the Central Station. The automatic deployment of the RTG cable shall not require more than a five pound pull force.

3.2.11.7 Cable Length

The total length of the interconnecting cable shall be sufficient to permit the astronaut to emplace the Subpackage at the desired deployment distance. The interconnecting cable should have enough slack to allow for thermal expansion and contraction of the cable, as well as uneven terrain.

3.2.11.8 Connector Receptacle Location

The receptacle for the RTG data subsystem electrical interconnection shall be located in such a manner as to allow completion of the interconnect when the data subsystem package is resting on its back with the handle up. To facilitate the RTG shorting plug mating to the connector, guide pins shall be added to aid the alignment of the shorting plug for connection.

3.2.11.9 RTG Shorting Plug

The RTG shorting plug design shall comply with the following requirements:

(a) A "T" handle shall be provided in the design of the Shorting Plug in order to facilitate handling and engagement.

(b) The ammeter shall be angled to 45 degrees to increase visibility in either a horizontal or vertical position.

(c) A rotary switch which has the capability of being activated manually or with the UHT shall be included in the shorting plug design.

(d) A visual engage/disengage indicator shall be located to be within the astronaut's line-of-sight during mating of the RTG shorting plug to the Central Station connector.